

# INTRODUCTION

# 1

U.S. agricultural policy has undergone significant changes since its introduction more than 100 years ago. Recently, many traditional agricultural price and income support programs have been eliminated along with many of the constraints they placed on producer decision-making. From one perspective, the scope of agricultural policy has contracted as traditional government programs have been eliminated. From another perspective, the scope of agricultural policy has expanded over the last quarter century as agricultural policy goals have expanded from ensuring adequate food supplies and agricultural price and income stability to include simultaneous achievement of multiple goals regarding the supply of food and fiber, social welfare, economic efficiency, environmental quality, and international competitiveness.

Just as agricultural policy has undergone significant changes, so has the setting for agricultural policy-making. The quantity and quality of information has increased exponentially, along with the speed with which it is available. These changes are primarily due to technological advances in analytical tools and communications infrastructure. As policy analysts and decision-makers adjust to new levels of sophistication in analytical capabilities, the evaluation of agricultural policies has grown more complex, and policy-makers demand quicker and more comprehensive evaluations of increasingly diverse policies and policy alternatives. Decision-makers and policy analysts expect increasingly complex, quantitative, and rapid estimation of a wide variety of specific policy impacts in a world of advanced technologies and a wealth of easily accessible data.

## **Role of the POLYSYS Modeling Framework**

In response to these changing demands for policy and impact analysis, the University of Tennessee's Agricultural Policy Analysis Center (APAC), along with United States Department of Agriculture's Economic Research Service and Oklahoma State University's Great Plains Agricultural Policy Center, developed the Policy Analysis System (POLYSYS) modeling framework. POLYSYS is a simulation modeling framework which provides policy analysts and researchers with an analytical "toolkit" for estimating a variety of impacts resulting from policy, economic, environmental or other changes. Based on a systems approach to modeling, POLYSYS operates as an umbrella framework, facilitating the interaction of agricultural supply, demand, and income modules. POLYSYS is capable of incorporating additional modules (e.g., modules relating to environment, community or industry impacts) as appropriate.

POLYSYS is designed to anchor its analyses to a baseline of projections for all model variables. Thus, POLYSYS estimates are measured as deviations from a baseline, allowing them to be easily interpreted and understood by decision-makers. Such a design, along with reliance on predetermined price-response parameters, allows POLYSYS to produce detailed and complex estimates quickly. Agricultural production response and resource use indicators are disaggregated to 305 regions with relatively homogeneous production characteristics. This disaggregation allows a detailed examination of interregional tradeoffs associated with a particular policy or other scenario.

POLYSYS is designed with a great deal of flexibility to allow analysts to tailor a simulation to specific needs. For example, POLYSYS has been used to estimate the impacts of ex ante and ex post changes in government price and income support programs and policies (Ray et al., 1995; De La Torre Ugarte, Ray, and Dicks, 1996; De La Torre Ugarte et al., 1995); movement toward more environmentally sustainable production practices (De La Torre et al., 1996a; 1996b); increased production flexibility (U.S. Geological Survey, 1994); changes in worldwide import and export expectations (Ray and Tiller, 1997); the introduction of new crops and alternative crop uses (Alexander, et al., 1993; Deyton and Sams, 1996; Gary, 1996); and unanticipated supply shifts resulting from events such as unusually adverse weather (Bhat, et al., 1994; Chembezi, et al., 1993; Chembezi, De La Torre Ugarte, and Ray, 1993). Further extending

POLYSYS's application flexibility, the modeler may choose: (1) the level of resolution of simulated model "shocks" – from one nationally applied change to multiple changes specific to each of 305 regions, (2) the time horizon for the simulation – from one to twenty-five or more years depending upon the number of years included in the baseline, and (3) the breadth of impact consideration – from the impacts on regional acreage allocations and returns and national prices and utilization, to inclusion of a variety of environmental performance indicators and the spatial distribution of benefits to industries and local economies.<sup>1</sup> In addition to deterministic simulation modeling, POLYSYS is also capable of incorporating crop yield and export uncertainty. In a stochastic version of POLYSYS, random yield and export variability (based on historical variability) are introduced in multiple iterations of the simulation to allow formation of probability distributions around endogenous model variables.<sup>2</sup>

## Quantitative Limitations of Policy Analysis

Yet with the technologies and information available – and even with those the future promises – policy analysis is still as much art as it is science (Wildavsky, 198?). The purpose of quantitative policy analysis is to provide pertinent information to individuals charged with designing, implementing, and evaluating policies (Nelson, 198?; Schelling, 198?). Quantitative analysis, regardless of the sophistication of the model or empirical analysis, remains a *tool* for decision-makers, and is not intended to be a replacement for decision-makers. While quantitative policy analysis deals well with estimating measurable impacts, it is less capable

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<sup>1</sup> This documentation covers only the core POLYSYS model which considers agricultural production, demand, and income effects. Other versions of POLYSYS are available which support expansion of the crop supply LP models to consider a variety of production techniques and a variety of environmental indicators for each crop in each region. In other POLYSYS versions, the LP models may allocate available acreage not only among model crops within a region, but among alternative crops produced by alternative enterprises and with varied environmental or other impacts.

<sup>2</sup> Only the deterministic version of POLYSYS is presented in this documentation. Additional details of the stochastic version may be found in Ray et al., 1998. A general description of the stochastic version of POLYSYS is included in the final chapter.

of dealing with the qualitative aspects of policy impacts (Leman and Nelson, 198?).

## **Purpose of this Publication**

This publication is intended to present concisely the economic foundations that underlie the core modules of the deterministic POLYSYS modeling framework. The documentation also presents the empirical relationships of the model. The model's core includes modules representing crop supply, crop demand, livestock supply and demand, and income. The integration of additional modules into POLYSYS is documented in additional titles in this series. A companion publication in this series – *The POLYSYS Modeling Framework: An Overview* – provides a nontechnical summary of the modeling framework. While this documentation is intended to present the logic, structure, and relationships of the model, it is not meant to serve as a technical guide for POLYSYS users. For more detailed information on model input, operation, and output, the reader is referred to *The POLYSYS Modeling Framework: A Guide for Users*, also available in this publication series.

## **Organization of the Documentation**

Since an extensive introductory overview of the model is available elsewhere, this publication begins by presenting the modeling system's overall structure and theoretical underpinnings. First, a variant of an equilibrium displacement model is developed in which a simulation estimates the proportional change in endogenous variables (quantities and prices) resulting from small, finite proportional changes in exogenous variables. While providing a conceptual theoretical basis for POLYSYS, such a structure does not provide insight into its organization as interdependent, yet highly autonomous modules. Subsequently, the structure of POLYSYS is recast as a group of interdependent livestock, crop supply, crop demand, and income modules, highlighting generalized relationships within and among modules. Following a description of the regional POLYSYS baseline developed from a national agriculture baseline, each of the four modules is presented in greater detail, specifying internal relationships. The documentation concludes with comments on the stochastic version of POLYSYS and extensions of the POLYSYS modeling framework in progress.

# Conceptual Structure

## Equilibrium Displacement Modeling

The POLYSYS modeling framework can be conceptualized as a variant of an equilibrium displacement model (EDM). EDMs establish simultaneous systems of generalized functions where endogenous variables are measured as proportionate changes and are a function of proportionate changes in exogenous, or curve-shifting, variables. The equilibrium market is shocked exogenously and the impacts of this disturbance are approximated by linear combinations of the products of the exogenous variables and their elasticities. The EDM approach is appropriate for studying the impacts of small, finite changes in exogenous variables. The model also is useful for examining the impacts of multiple changes in exogenous variables, with the proportionate change in each endogenous variable being the sum of products of elasticities and proportionate changes in exogenous variables. A system of EDM structural equations is solved simultaneously for the reduced form solutions where the reduced form parameters are a function of the structural parameters (elasticities). The values of the structural parameters in an EDM generally are estimated, gleaned from relevant studies or otherwise are assumed to be known. Use of structural parameter estimates allows estimation of resulting impacts with minimal effort and time through an EDM.

The wide appeal of EDMs in analytical work results in part from their flexibility in modeling a wide variety of market structures (Piggot, Piggot, and Wright, 1995; Wohlgenant, 1993; Wohlgenant, 1989; Brown, 1995; Kinnucan, 1996; Alston, Chalfant, and Piggot, 1995; Duffy and Wohlgenant, 1991; Gardner, 1975). The simplicity of an EDM also contributes to its usefulness and popularity (Piggot, 1991). Given the

elasticities associated with prices and curve-shifter variables, estimates of the impacts associated with a percentage change in an exogenous variable (or multiple variables) may be easily and quickly obtained.

An EDM assumes that the structural parameters are known with certainty. Thus, one caveat of EDMs is that errors in estimating structural parameters are transferred to the EDM, biasing the central tendencies of the estimates.<sup>3</sup> Additionally, unless the true functional forms are linear, the results are only a first-order approximation of the true impacts. While such criticisms may warrant further consideration for application of an EDM for some research purposes, the conceptual framework is useful for presenting the theoretical underpinnings of the POLYSYS model of U.S. agriculture.

## **POLYSYS as an Equilibrium Displacement Model**

Piggott (1992) suggests that use of equilibrium displacement modeling is particularly relevant (i.e., preferable to econometric estimation of a simultaneous system of market equations) in cases where (1) sufficient data for econometric modeling may be unavailable, (2) where data are unreliable (which is often the case in developing countries), or (3) where “good” data and extensive prior research results and experience are available to develop large-scale models of complex relationships. The latter describes the objective and setting of POLYSYS; a national model of U.S. agriculture is understandably large and complex, and a large volume of data and research exist to establish and corroborate response parameter estimates required by an EDM.

At a simplified level, the POLYSYS structural model of U.S. agriculture can be thought of as a system of demand and supply equations

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<sup>3</sup> To address potential bias in EDM results due to selection of structural parameter estimates, researchers generally conduct sensitivity analysis by selectively varying the parameter estimate and generating alternative estimates of endogenous variables. However, recent research and criticisms indicate that such sensitivity analysis may be misleading with respect to central tendencies (Davis and Espinoza, 1997; Babula, Jubara, and Reeder, 1996). While alternative methods have been suggested (Davis and Espinoza, 1997), researchers must balance the potential bias in EDM results with the complexity and transaction costs associated with more accurate measurement of such bias.

for the livestock and crop sectors and an equilibrium condition in each sector:

$$[2.1] \quad D_C^* = \varepsilon_{C,P_C} P_C^* + \varepsilon_{C,P_L} P_L^* + \varepsilon_W W^*$$

$$[2.2] \quad S_C^* = \eta_{C,P_C} P_C^* + \eta_{C,P_L} P_L^* + \eta_X X^*$$

$$[2.3] \quad D_L^* = \varepsilon_{L,P_C} P_C^* + \varepsilon_{L,P_L} P_L^* + \varepsilon_Y Y^*$$

$$[2.4] \quad S_L^* = \eta_{L,P_C} P_C^* + \eta_{L,P_L} P_L^* + \eta_Z Z^*$$

$$[2.5] \quad Q_C^* = D_C^* = S_C^*$$

$$[2.6] \quad Q_L^* = D_L^* = S_L^*$$

The percentage change in demand for a (1 x C) vector of crop commodities ( $D_C^*$ )<sup>4</sup> is a function of a (1 x C) vector of percentage changes in the price of crops ( $P_C^*$ ), a (1 x L) vector of percentage changes in the price of livestock ( $P_L^*$ ), and a (1 x W) vector of percentage changes in exogenous shift variables for crops ( $W^*$ ). The coefficients  $\varepsilon_{C,P_C}$ ,  $\varepsilon_{C,P_L}$ ,  $\varepsilon_W$  represent the transpose of (1 x C), (1 x L), and (1 x W) vectors of demand elasticities, with respect to crop prices, livestock prices, and demand curve shifters, respectively.

The percentage change in demand for a (1 x L) vector of livestock commodities ( $D_L^*$ ) is a function of a (1 x C) vector of percentage changes in the price of crops ( $P_C^*$ ), a (1 x L) vector of percentage changes in the price of livestock ( $P_L^*$ ), and a (1 x Y) vector of percentage changes in exogenous shift variables for livestock ( $Y^*$ ). The coefficients  $\varepsilon_{L,P_C}$ ,  $\varepsilon_{L,P_L}$ ,  $\varepsilon_Y$  represent the transpose of (1 x C), (1 x L), and (1 x Y) vectors of demand elasticities, with respect to crop prices, livestock prices, and demand curve shifters, respectively.

Similarly, the percentage change in supply for a (1 x C) vector of crop commodities and a (1 x L) vector of livestock commodities is a function of a (1 x C) vector of crop price percentage changes, (1 x L) vector of livestock price percentage changes, and a vector of percentage changes in exogenous shift variables,  $X^*$  for crops and  $Z^*$  for livestock.

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<sup>4</sup> The percentage change in any variable X, indicated by a superscript asterisk, is defined as  $X^* = d \ln X = \frac{dX}{X}$ .

The  $\eta$  coefficients represent the transpose of vectors of supply elasticities associated with crop and livestock prices and supply curve shifters  $X^*$  for crops and supply curve shifters  $Z^*$  for livestock.

$(Q_C^*)$  represents the equilibrium (1 x C) vector of crops (measured as percentage changes in quantity) and the equilibrium condition in equation 2.5 requires that demand equal supply of crops in equilibrium.  $(Q_L^*)$  represents the equilibrium (1 x L) vector of livestock (measured as percentage changes in quantity) and the equilibrium condition in equation 2.6 requires that demand equal supply of livestock in equilibrium.

Thus, the endogenous variables in the system of structural equations include the equilibrium quantities of crops ( $Q_C^*$ ) and livestock ( $Q_L^*$ ) and the equilibrium market clearing prices of crops ( $P_C^*$ ) and livestock ( $P_L^*$ ). To simplify the presentation, assume that C, L, W, X, Y, Z are all equal to one, so that the vectors collapse to scalars.<sup>5</sup> These structural equations can be rearranged so that endogenous variables are a function of exogenous variables:

$$[2.7] \quad Q_C^* - \varepsilon_{C,P_C} P_C^* - \varepsilon_{C,P_L} P_L^* = \varepsilon_W W^*$$

$$[2.8] \quad Q_C^* - \eta_{C,P_C} P_C^* - \eta_{C,P_L} P_L^* = \eta_X X^*$$

$$[2.9] \quad Q_L^* - \varepsilon_{L,P_C} P_C^* - \varepsilon_{L,P_L} P_L^* = \varepsilon_Y Y^*$$

$$[2.10] \quad S_L^* - \eta_{L,P_C} P_C^* - \eta_{L,P_L} P_L^* = \eta_Z Z^*$$

Arrange equations 2.7 - 2.10 in matrix form  $\mathbf{\Gamma}\mathbf{\Delta} = \mathbf{B}\mathbf{\Omega}$  where  $\mathbf{\Gamma}$  is a matrix of demand and supply crop and livestock elasticities,  $\mathbf{\Delta}$  is a matrix of exogenous variables,  $\mathbf{B}$  is a matrix of elasticities of demand and supply curve shifter variables for crops and livestock, and  $\mathbf{\Omega}$  is a matrix of exogenous variables:

$$[2.11] \quad \begin{bmatrix} 1 & 0 & -\varepsilon_{C,P_C} & -\varepsilon_{C,P_L} \\ 1 & 0 & -\eta_{C,P_C} & -\eta_{C,P_L} \\ 0 & 1 & -\varepsilon_{L,P_C} & -\varepsilon_{L,P_L} \\ 0 & 0 & -\eta_{L,P_C} & -\eta_{L,P_L} \end{bmatrix} \begin{bmatrix} Q_C^* \\ Q_L^* \\ P_C^* \\ P_L^* \end{bmatrix} = \begin{bmatrix} \varepsilon_W & 0 & 0 & 0 \\ 0 & \varepsilon_X & 0 & 0 \\ 0 & 0 & \varepsilon_Y & 0 \\ 0 & 0 & 0 & \varepsilon_Z \end{bmatrix} \begin{bmatrix} W^* \\ X^* \\ Y^* \\ Z^* \end{bmatrix}$$

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<sup>5</sup> Intuitively, one might interpret the scalars as indices: an index of the production of all crops, all livestock; a price index of all crop prices, all livestock prices; a curve shift index for demand, for supply.



Solving the system of equations in equation 2.11 for the endogenous variables,  $\Delta$ , expresses the percentage change in the endogenous variables (equilibrium quantities and prices of crops and livestock) as a function of the demand and supply shifters. Solution to the system yields  $\Delta = \Pi\Omega$  where  $\Pi$  indicates a matrix of reduced form parameters, such that  $\Pi = \Gamma^{-1} \mathbf{B}$ . The structural model (equations 2.1 - 2.6) may then be solved for the reduced form solutions. A complete derivation of the reduced form solutions is included as Appendix A. The reduced form parameters may be interpreted as “general equilibrium” elasticities in the sense that they measure the percentage change in the equilibrium level of each endogenous variable attributed to each exogenous variable. As an example, by the system of reduced form solutions, the equilibrium proportionate change in the price of crops is given by:

$$[2.12] \quad P_L^* = (Y^* - W^* - X^* - Z^*) \frac{\eta_z (\eta_{21} - \varepsilon_{11})}{\varepsilon_{12} \eta_{21} + \varepsilon_{21} \eta_{12}}$$

where the percentage change is a linear combination of the products of the general equilibrium elasticities and the proportionate changes in the exogenous variables. Thus, a proportionate change in the price of livestock is influenced by the percentage change in each exogenous variable and (a) the elasticity of the supply of livestock with respect to a bundle of livestock demand curve shifters, (b) the supply elasticity of livestock with respect to the price of crops, (c) the own price demand elasticity of crops, (d) the demand elasticity of crops with respect to livestock prices, (e) the demand elasticity of livestock with respect to crop prices, and (f) the supply elasticity of crops with respect to livestock prices.

A POLYSYS simulation may be conceptualized as a series of multiperiod annual EDM adjustments. As the EDM comparative static analysis is repeated annually over the simulation period, POLYSYS traces a path of adjustment resulting from the introduction of finite exogenous shocks. While not included in the model presented above, the structure may also include a Nerlov partial adjustment model to allow a multi-year time path toward its new equilibrium. Such inclusion allows for time path adjustment consideration and is a feature of the POLYSYS modeling framework.

# 3

## OPERATIONAL STRUCTURE

Conceptually, the POLYSYS modeling framework is structured as a multiperiod EDM. Baseline estimates of supply, demand, and prices are obtained. Then a proportional exogenous change is imposed upon the baseline. The impacts of the change depends upon the proportional response relationships (own and cross elasticities) associated with that exogenous variable. The proportional impacts are aggregated to estimate movement away from baseline levels of endogenous variables.

The simplicity of an EDM is intuitively appealing for development of a national model of U.S. agriculture. However, this simplicity is only one of several considerations. An additional consideration is the factual complexity of relationships within agriculture. Many agricultural resources are fixed in the short run, and there is a high degree of substitutability and complementarity in production of many agricultural products and commodities. Thus, an exogenous change affecting the production of one commodity can have widespread impacts on the production of other commodities. A credible model should adequately reflect this complex web of relationships. Even the necessarily oversimplified model previously presented quickly became complex when all market relationships were considered in determining reduced form (general equilibrium) elasticities. And as just one of many examples, no distinction was made regarding crop demand by use (e.g., exports, feed, industrial, food, fiber). As even one additional consideration such as crop demand by use is introduced, the complexity of the model increases exponentially.

Another important consideration is the large number of agricultural commodities and products that comprise U.S. agriculture. An adequate representation of this diversity increases the complexity of a simultaneous equilibrium model. Additionally, a national agricultural model should consider the significant regional variation in factors affecting production outcomes. Factors such as the mix of feasible production activities, the yield or output performance of crops or livestock, the costs of production, and the market price may vary significantly regionally. Such disaggregation of supply further complicates the solution of a simultaneous model.

## **POLYSYS Organized as Interdependent Modules**

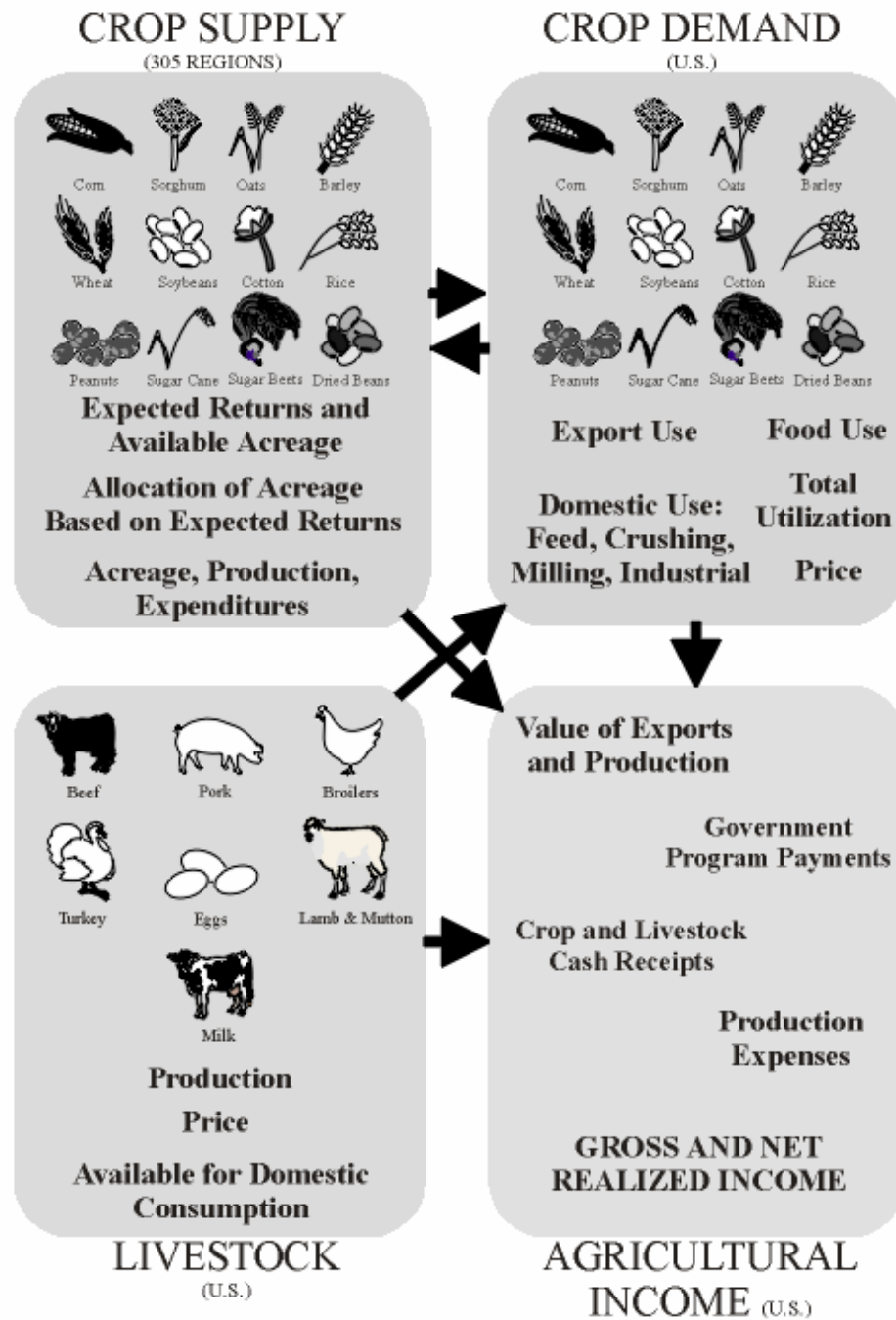
POLYSYS retains the EDM structure but organizes the system of equations as four interdependent though highly autonomous modules. This core consists of livestock, crop supply, crop demand, and income modules. In addition to the core modules, other modules may be added to or excluded from the core to address a specific problem in the most appropriate and efficient manner.

The modules use a combination of models and identity equations to estimate crop and livestock supply, demand, and prices. POLYSYS then takes the EDM structure one step further and tracks supply, demand, government program, price, and cost variables to calculate agricultural income variables. A schematic interpretation of the POLYSYS core organized by modules is presented in figure 3.1. Operationally, POLYSYS incorporates regional linear programming (LP) crop supply models and a crop demand and price simultaneous block. A POLYSYS simulation estimates supply, demand, price, and income variables recursively over the simulation period – most commonly five to ten years. Thus, a POLYSYS simulation yields a dynamic performance path for crop and livestock supply, demand, price, and agricultural income variables. The calculation of most variables is driven by deviations from a baseline and elasticity parameters.

The objective of the livestock module is to estimate national production, demand, and prices for seven livestock commodities. Presently, the livestock module functions primarily as a dynamic link to the crop supply module, through feed demand. Efforts are in progress to further develop the livestock module and to account for regional livestock

variation. The model livestock commodities endogenously considered by POLYSYS include beef, pork, broilers, turkeys, eggs, lamb and mutton,

**Figure 3.1. POLYSYS Core Modules.**



and milk. Due to the length of livestock production cycles, production of any livestock category in a given simulation year is determined by lagged livestock prices and production input prices. Baseline and predetermined production and prices interact with production elasticities to estimate production of model livestock commodities. Because livestock ending stocks are minimal, domestic demand is equivalent to the quantity available for domestic consumption. Since livestock imports and exports are exogenous to the model, the quantity of livestock commodities available for domestic consumption is calculated as the level of production adjusted for imports and exports. These estimates are then combined with direct and cross price flexibilities to estimate prices for each livestock commodity. Indices of livestock prices and production are later used by the crop demand and income modules to estimate feed demand, cash receipts, and production expenditures.

The crop supply module estimates production of corn, grain sorghum, oats, barley, wheat, soybeans, cotton, rice, peanuts, dry beans, sugar beets, and sugar cane. As noted earlier, factors influencing crop production vary regionally. Therefore, crop production is estimated for 305 production regions. POLYSYS regions correspond to Agricultural Statistic Districts and are geographically defined areas with relatively homogeneous crop production characteristics. Initially, POLYSYS uses baseline and exogenous variables to estimate average expenditures per acre, price expectations, government program participation (as appropriate), and expected returns for a simulation period. Using this data, POLYSYS then makes a portion of baseline acreage available to 305 regional LP models to allocate among competing model crops based on expected net returns. Upon allocation of marginal changes in acreage over the baseline, the supply module estimates regional planted and harvested acreage, total variable and cash expenditures, acreage enrolled in government programs, and production. Regional crop supply variables are then aggregated over all 305 regions to estimate national crop acreages, production, and expenditures. Crop supply estimates are utilized by the crop demand module in the determination of crop prices, and also by the income module in the determination of crop production value, government program outlays, crop cash receipts, and production expenditures.

The crop demand module in POLYSYS estimates demand by use and prices for twelve model crops and two crop derivative products. Crops endogenously considered include corn, grain sorghum, barley, oats, wheat, soybeans, cotton, rice, peanuts, dry beans, sugar beets, and sugar

cane. Crop derivative products considered include soybean oil and soybean meal. The demand module combines estimated demand elasticities, price flexibilities, exogenous, and baseline variables to estimate prices and demands by utilization – export demand, food demand, and domestic demand (including demand for feed, crushing, milling, and industrial uses). Crop demands and prices are estimated as a simultaneous block. Estimated national prices are then returned to the crop supply module where they are used to estimate regional market prices for 305 regions.<sup>6</sup>

The national agricultural income module utilizes output from the crop supply, crop demand, and livestock modules to calculate gross and net realized agricultural income. The income module calculates national crop and livestock cash receipts, production expenses, and relevant government program payments for individual model crops and livestock commodities and also for aggregate model crops and aggregate model livestock commodities. Finally, model crop and livestock receipts, payments, and expenses are combined with exogenous non-model crop and livestock receipts, payments, and expenses to determine net realized agricultural income.

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<sup>6</sup> Estimates of national crop prices are also used by the supply module to estimate crop year deficiency payments, as appropriate.

# DEVELOPING A REGIONAL BASELINE

## 4

Baseline crop production estimates available to POLYSYS are national estimates by crop. For POLYSYS to estimate crop supply regionally, the national baseline must be disaggregated by 305 ASD's. There are five categories of national baseline estimates that must be regionalized for construction of a POLYSYS regional baseline. These include estimates of acreage, input expenditures, crop yields, season average prices, and government program variables.

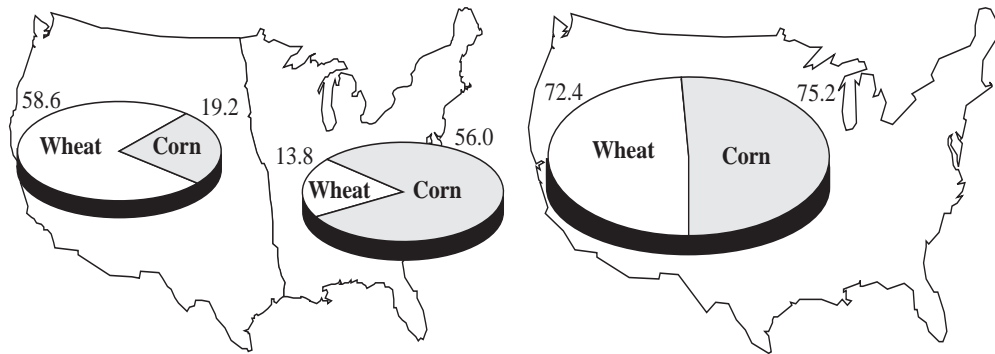
Developing a regional baseline from a national baseline of projections is a three-step process. Initially, the 1995-96 average value of each regional variable is used to distribute national baseline values for the first projection year among the 305 ASD's. At this stage, the 1995-96 regional distribution of each variable is scaled to the national baseline while keeping the distributions among regions proportionately fixed at their 1995-96 levels. In the second step, current baseline prices, yields, and costs of production are assigned to each region based on the ratio of national and regional values in 1995-96. Regional prices, yields, and costs for the projection year are then used in 305 regional linear programming (LP) models to re-distribute acreage and production in each region based on current prices and expected returns. The resulting regional allocation is then summed over all 305 ASD's again to compute a new adjustment factor – the ratio of the national baseline value to the LP solution values aggregated over all regions. This adjustment factor is then applied to all regional variables and the LP models are again solved with baseline regional prices. The resulting regional allocation then becomes the regional baseline allocation for the first baseline year. The process is repeated for each year of the baseline period.

This section provides details of POLYSYS regional baseline construction through a simplified example that illustrates the process. For simplicity, the example assumes that there are only two crops produced – corn and wheat – and that there are two production regions – East and West. More extensive details of the regional LP models used to allocate national baseline acreage among 305 regions are included in Chapter 6.

## Initial Regional Acreage Assignment

The first panel of figure 1 presents the historical 1995-96 average planted acreage for each crop in each region. Of the 77.8 million acres planted in the West, 58.6 million acres (75 percent) were planted to wheat and 19.2 million acres (25 percent) were planted to corn. About 80 percent of the East's acreage was planted to corn in 1995-96 (56 million acres) and the remaining 20 percent (13.8 million acres) was planted to wheat.

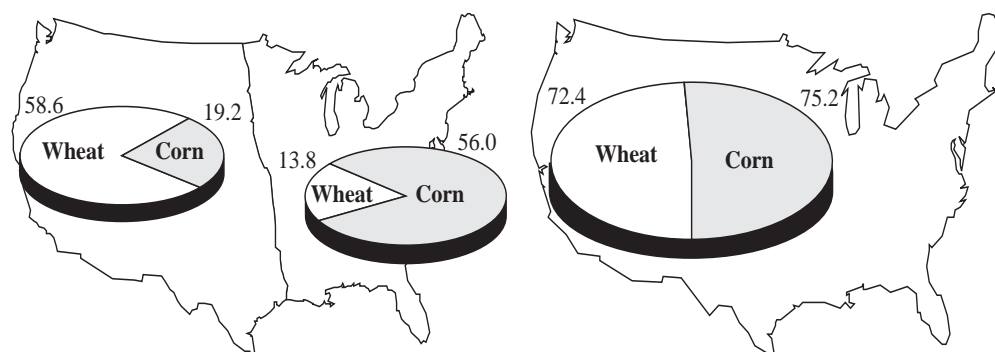
**Figure 4.1. Average planted acres, 1995-96, by region (A) and aggregated nationally (B).**



Regional acreages are summed by crop to calculate the distribution of all acreage by crop for 1995-96, as shown in panel B of figure 1. An external agriculture baseline provides a similar national crop allocation over a projection period. National agricultural baselines are regularly estimated by FAPRI, USDA, and CBO. Figure 2 presents the national baseline value of planted acreage for the two crops for the initial year of a baseline projection (1998 in this example).



**Figure 4.2. National baseline planted acreage, 1998.**



The next step is to disaggregate the national baseline estimates by allocating baseline acreages among the regions. An adjustment coefficient for each crop is calculated by forming a ratio of the baseline value of planted acreage to the aggregated 1995-96 planted acreage for each crop. The third column of table 4.1 presents the initial adjustment factors for this example.

**Table 4.1. Initial and final adjustment factors for example.**

Crop	A	B	Initial Adjustment Factor (B/A)	C	
	1995-96 Planted Acreage	1998 Base Planted Acreage		$\Sigma$ Reg. Planted Ac. After Initial Re-Dist.	Final Adjustment Factor (B/C)
Corn	75.2	83.2	1.1064	87.8	0.9476
Wheat	72.4	70.6	0.9751	63.7	1.1083

The initial adjustment factor for each crop is then applied to the 1995-96 regional planted acreage to scale the 1995-96 acreage to the 1998 baseline projections. The result is a regional distribution of the baseline acreage values, proportionate to the 1995-96 distribution. Figure 3 shows the resulting initial regional baseline. At this stage, the relative share of crop acreage within a region may change from its share in 1995-96, but the relative share of national crop production contributed by each region is fixed at the 1995-96 distribution. Corn planted acreage is 8 million acres

higher in 1998 than it was in 1995-96, but wheat planted acreage is 1.8 million acres lower. The allocation of the additional corn acreage and loss of wheat acreage is assigned to each region in the same proportion as its share of national production in 1995-96. Seventy-five percent of all corn will still be planted in the East and 25 percent will still be planted in the West, as was the case in 1995-96. However, the share of regional acreage planted to each crop may change from the 1995-96 level. In panel A of figure 1, the West region planted wheat on 80 percent of its acreage in 1995-96, with 20 percent planted in corn. After the initial adjustment, figure 3 shows that wheat planted acreage in the West now covers 73 percent of all planted acres and corn's share of planted acreage has increased to 27 percent.

**Figure 4.3. Initial regional baseline distribution of crops for 1998, scaled to 1995-96 regional distribution.**



The next step in developing a regional baseline is to re-distribute planted acreage within regions based on current baseline crop prices, yields, and costs. If the 1998 baseline corn price is projected to be significantly higher than it was in 1995 and 1996, then profit maximizing producers will likely re-distribute resources to take advantage of potential gains. The re-distribution is accomplished by solving 305 regional LP models of crop supply. Each region seeks to maximize net returns by allocating acreage among productive uses (corn and wheat in this example) based on relative expected returns.

## **Regional Expected Prices**

The regional LP models require that the national baseline projections of crop prices be disaggregated by regions. Thus, a regional index relating the ratio of national to regional values during the 199-95 period is applied to the national baseline. The regional price index is constructed by forming a ratio of the national loan rate to the loan rate in an individual region over the same period. For each of the 305 regions, a ratio of the 1994-95 national average loan rate to the 1994-95 regional average loan rate is applied to national baseline season average prices to scale prices among regions. Continuing the example, if corn prices in the East were 8 percent higher than the national average in 1994-95 (as measured by the ratio of the national loan rate to the loan rate in the East), then the baseline price of corn in the East in the initial baseline year will be 8 percent higher than the baseline season average price. The same regional price indices are applied to national baseline prices in each year of the projection period. Thus, the relative distribution of prices among regions is fixed across simulation years.

## **Regional Crop Yields**

Similar national-to-regional indices for the 1995-96 values of crop yields are applied to baseline projections to form regional baseline yield projections. Regional data for average crop yields in 1995 and 1996 are summed over all 305 regions to obtain a national average yield for 1995-96. The ratio of 1995-96 individual regional average yield to the national average yield in 1995-96 then becomes the regional yield index. Similar to regional prices, the relative distribution of yields among regions is fixed at the 1995-96 level across simulation years.

## **Regional Costs of Production**

National average costs of production for each crop are also disaggregated by region. Similar to the procedure used for obtaining regional yields, the ratio of national average production costs to regional production costs over the same period becomes a regional indexing factor for costs of production. POLYSYS includes the following categories of production costs: seed, fertilizer, chemicals (herbicide and insecticide),

fuel, repairs, handling, drying, labor, water purchases, variable irrigation, fixed irrigation, technical services, ginning, operating interest, overhead, taxes, and interest. Average regional costs by category are averaged over all regions to estimate the national average cost, which is then divided by the average regional cost to obtain the cost index for that region. The production cost indices for each crop are regularly updated as new USDA Costs of Production Survey data become available. If national baseline projections do not disaggregate national average costs of production by cost categories, then the relative proportion of regional average total costs contributed by that category in the index period may be used to assign average total costs to cost categories.

## **Initial LP Re-allocation**

Once national baseline planted acreage has been distributed among 305 regions proportionate to the 1995-96 regional acreage distribution, a portion of the initial regional planted acreage is made available to 305 regional LP models to re-allocate based on current regional baseline prices, yields, and costs. A pre-determined acreage shift rate and expected regional returns jointly determine the portion of the initial acreage available to shift to alternative productive uses. As a producer's ability to cover production costs diminishes, land can shift among competing activities more rapidly.<sup>7</sup>

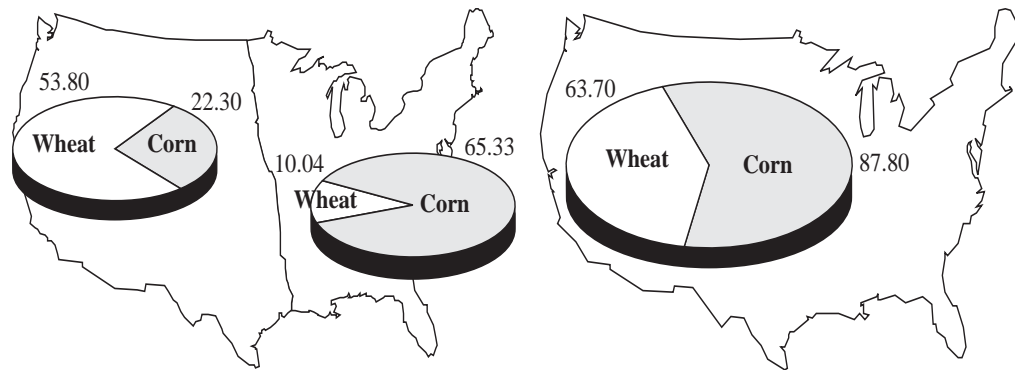
Continuing the example, the initial regional planted acreage shown in figure 4.3 is made available to 305 regional LP models to re-allocate based on current regional baseline prices, yields, and costs. The first panel in figure 4.4 shows the new regional distribution of planted acreage resulting from solution of the LP's using baseline projections for prices, yields, and costs. Compared to the allocation before solving the LP models (figure 4.3), wheat has lost acreage in both regions and corn has gained acreage. Regional crop acreages are then summed across regions to obtain the national aggregate crop planted acreage distribution shown in the second panel of figure 4.4. Note that this national distribution does not match the actual distribution of the baseline, in the second panel of figure 4.1. Total planted acreage in the baseline was 153.8 million acres, with 54 percent

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<sup>7</sup> Extensive details of the structure and constraints of the regional supply LP models are presented in Chapter 6.

planted to corn and 46 percent planted to wheat. After initial re-allocation by the LP models, total planted acreage has been reduced by 2.3 million acres and corn acreage now accounts for 58 percent of the total with wheat accounting for 42 percent. The loss of total planted acreage can result when acreage is made available to the model to re-allocate among competing uses, but expected returns and model constraints force idling of some acreage.

**Figure 4.4. Regional baseline (A) and aggregate baseline (B) planted acreage, 1998, after initial re-distribution through solution of regional LP's.**

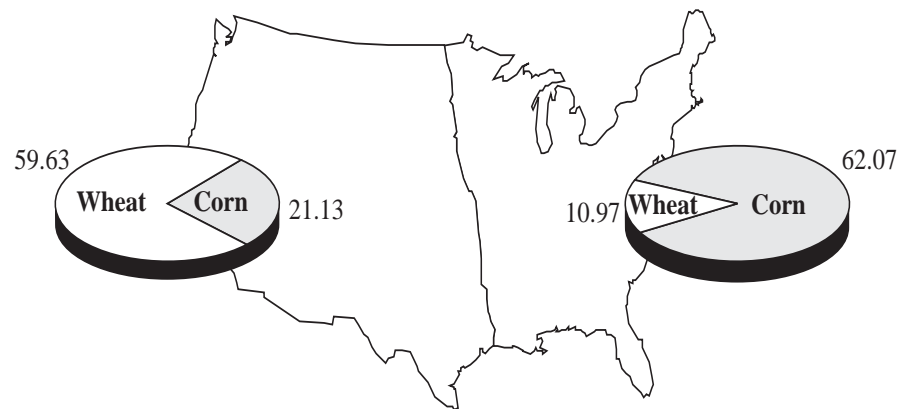


## Final Regional Baseline

Upon the initial re-allocation of planted acreage by the LP models, a final adjustment factor is calculated. Calculated similarly to the initial adjustment factor, the ratio of the baseline acreage to the aggregate acreage obtained in the initial LP solution now forms the final adjustment factor, as shown in the final column of table 4.1. The final adjustment factor is then applied to the regional initial LP solution (the distribution shown in the first panel of figure 4.4). This becomes the adjusted initial regional LP allocation of planted acreage, as shown in figure 4.5. The adjustment factor is necessary to scale the original national baseline values to the new regional distribution based on current prices, yields, and costs. As illustrated in the example, total planted acreage after solution of the initial LP models does not necessarily equal total baseline planted acreage. Total planted acreage in both figure 4.5 and figure 4.2 is 153.8 million acres. The final adjustment factor preserves the regional distribution

obtained in the LP solution, but forces all baseline acreage to again become available to the aggregate regions.

**Figure 4.5. Adjusted initial regional LP planted acreage allocation, 1998.**



A portion of adjusted regional LP planted acreage is then made available to the regional LP models to re-allocate based on expected returns formulated with current regional baseline prices, yields, and costs of production. The second pass through the regional LP models begins from a regional distribution that was determined by current prices and returns (the solution of the first LP models). Because the regional LP solutions will not necessarily sum to the national baseline (due to potential acreage “loss” described above), the initial LP solution was re-calibrated to the baseline prior to re-solving the regional LP models. Upon final solution of the regional LP models, the regional acreage allocation becomes one component of the baseline regional acreage. The other component is a new variable to account for the difference between the aggregated regional LP acreage assignment and the national baseline, i.e., a variable equal to the acreage “loss” from the final LP solution. POLYSYS regional baseline planted acreage is then calculated as the portion of the initial regional acreage (the distribution that results from the first LP solution) that was not available to be re-allocated among competing uses plus any acreage gain from the final LP re-allocation solution plus the value of the regional baseline adjustment variable required to reconcile aggregate regional and national baseline values.

# LIVESTOCK MODULE

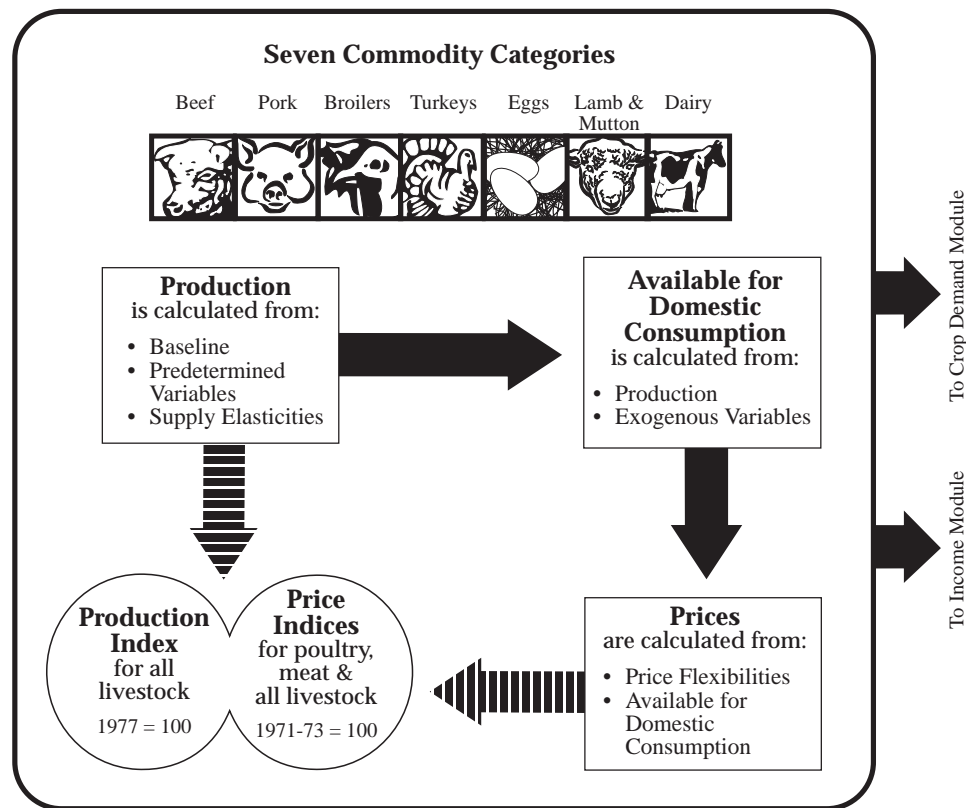
## 5

The livestock module estimates supply, demand, and price for seven livestock commodities. These commodity categories and their respective production and price units are listed in table 5.1. A list of variables included in the livestock module and their definitions is included as Appendix B.2. An overview of the livestock module is presented in figure 5.1.

**Table 5.1. Livestock module commodities, production units, and price units.**

<b>Livestock Commodities</b>	<b>Production Unit</b>	<b>Price Unit</b>
Beef	Carcass weight in million pounds	\$/cwt
Pork	Carcass weight in million pounds	\$/cwt
Lamb and Mutton	Carcass weight in million pounds	\$/cwt
Broilers	Million pounds, ready-to-cook	¢/lb
Turkeys	Million pounds, ready-to-cook	¢/lb
Eggs	Million dozen	¢/doz
Milk	Billion pounds	\$/cwt

**Figure 5.1. Overview of POLYSYS Livestock Module.**



## Production

Livestock production cycles generally exceed one year, so that current production levels are determined in part by production decisions that were made based on price expectations and other production decision influences in place at an earlier time. A POLYSYS simulation, then, begins by estimating livestock production levels, which are a function of baseline and predetermined (or lagged) prices, production, and other production shifting factors. The livestock module initially estimates national production for each of the seven categories from baseline variables, lagged livestock price variables, lagged feed and input price index variables, and production elasticities, according to the following equation:



$$\begin{aligned}
LVSPDN^t &= LVSPDN^b * \\
[5.1] \quad &\left[ \begin{aligned} &1 + \eta_{LV,LV}(\% \Delta LVDPRI^{t-1}) + \eta_{LV,BF}(\% \Delta BFDPRI^{t-1}) \\ &+ \eta_{LV,PK}(\% \Delta PKDPRI^{t-1}) + \eta_{LV,LM}(\% \Delta LMDPRI^{t-1}) \\ &+ \eta_{LV,IPIFED}(\% \Delta IPIFED^{t-1}) + \eta_{LV,IPIOTH}(\% \Delta IPIOTH^{t-1}) \end{aligned} \right] \\
&+ \lambda_L(\Delta LVSPDN^{t-1})
\end{aligned}$$

where percentage change variables are the percentage change in the value in the previous year (t - 1) over the baseline value in the previous year (b-1), the  $\eta$  variables are production elasticities, and the  $\lambda$  variable is a long run production adjustment factor. Production of a livestock commodity in year t ( $LVSPDN^t$ ) is the baseline production level ( $LVSPDN^b$ ) adjusted up or down by the sum of the production responses due to the previous year's percentage change in own price, beef price, pork price, lamb and mutton price, input price index for feed, and input price index for other production inputs, and adjusted for the long-run production response. Production elasticity coefficients for each livestock category are presented in table 5.2 and the long-run Nerlovian distributed lag production adjustment coefficients are presented in table 5.3.

**Table 5.2. Direct and cross supply elasticities for model livestock categories.**

Prod'n Response of	With Respect to Percentage Change in Lagged					
	Own Price	Beef Price	Pork Price	Lamb- Mutton Price	Feed Price Index	Input Price Index
Beef	0.38	-	-0.04	-0.01	-0.11	0
Pork	0.30	-0.20	-	0	-0.25	0
Lamb-Mutton	0.14	-0.001	-0.005	-	-0.14	0
Broilers	0.31	0	0	0	-0.26	0
Turkeys	0.57	0	0	0	-0.35	0
Eggs	0.20	0	0	0	-0.16	0
Milk	0.15	0.10	0	0	-0.10	0

**Table 5.3. Long run production adjustment coefficients for model livestock categories.**

	Beef	Pork	Lamb & Mutton	Broilers	Turkeys	Eggs	Milk
Long-Run Adjustment Coefficient ( $\lambda_L$ )	0.536	0.60	0.60	0.75	0.75	0.85	0.60

For example, the total production of beef (millions of carcass pounds) in any year  $t$ , ( $BFSPDN^t$ ) is given by the sum of the following:

- (1) the baseline projected production of beef in year  $t$  ( $BFSPDN^b$ );
- (2) the percentage change in the previous year's beef price over baseline beef price ( $\% \Delta BFDPRI^{t-1}$ ) multiplied by the own price elasticity, 0.38, multiplied by the baseline projected production of beef in year  $t$ ;
- (3) the percentage change in the previous year's pork price over baseline pork price ( $\% \Delta PKDPRI^{t-1}$ ) multiplied by the production elasticity of beef with respect to pork, -0.04, multiplied by the baseline projected production of beef in year  $t$ ;
- (4) the percentage change in the previous year's lamb and mutton price over baseline lamb and mutton price ( $\% \Delta LMDPRI^{t-1}$ ) multiplied by the production elasticity of beef with respect to lamb and mutton, -0.01, multiplied by the baseline projected production of beef in year  $t$ ;
- (5) the percentage change in the previous year's index price for feed over the baseline index price for feed ( $\% \Delta IPIFED^{t-1}$ ) multiplied by the elasticity of beef production with respect to the feed price index, -0.17, multiplied by the baseline projected production of beef in year  $t$ ;
- (6) the percentage change in the previous year's index price for all production items (other than feed) over the baseline index price for all production items ( $\% \Delta IPIOTH^{t-1}$ ) multiplied by the elasticity of beef production with respect to the production item price index, 0.0, multiplied by the baseline projected production of beef in year  $t$ ; and

(7) the change in the production of beef in the previous year over baseline beef production ( $\Delta BFSPDN^{t-1}$ ) multiplied by the long run production adjustment coefficient for beef, 0.54.

To continue the example of calculation of beef production in year t, assume that baseline and lagged beef production, lagged and baseline lagged prices for beef, pork, lamb and mutton, index of feed price, and index of production input price:

$BFSPDN^b$	baseline projected production of beef (mil. lbs.)	26,082.00
$BFSPDN^{t-1}$	actual lagged production of beef (mil. lbs.) <sup>8</sup>	25,709.00
$BFDPRI^{b-1}$	lagged baseline projected price of beef (\$/cwt.)	65.50
$BFDPRI^{t-1}$	actual lagged price of beef	62.64
$PKDPRI^{b-1}$	baseline lagged projected price of pork (\$/cwt.)	48.00
$PKDPRI^{t-1}$	actual lagged price of pork (\$/cwt.)	50.93
$LMDPRI^{b-1}$	baseline lagged projected price of L&M (\$/cwt.)	60.00
$LMDPRI^{t-1}$	actual lagged price of lamb and mutton (\$/cwt.)	60.00
$IPIFED^{b-1}$	baseline lagged projected price index for feed	526.00
$IPIFED^{t-1}$	actual lagged price index for feed	480.00
$IPIOTH^{b-1}$	baseline lagged price index for lvsk. prod'n items	1020.00
$IPIOTH^{t-1}$	actual lag. index of prices paid for lvsk. prod. items	1018.00

Given these values and the elasticities and long run adjustment factor values in table 5.2 and table 5.3, production of beef in year t is calculated according to equation 5.1 as:

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<sup>8</sup> In the initial year of a POLYSYS simulation (t=1), the lagged variables take on their actual historical lagged value. Beyond the initial simulation year (t>1), lagged variables take on their simulated value obtained in the previous annual iteration (t-1). Similarly, lagged baseline variables take on the baseline value in the previous year (b-1) except in the initial baseline year (b=1) where lagged values are equal to historical values.

$$\begin{aligned}
BFSPDN^t &= 26,082 * \\
[5.1b] \quad &\left[ 1 + 0.38 \left( \frac{62.64 - 65.5}{65.5} \right) - 0.04 \left( \frac{50.93 - 48}{48} \right) - 0.01 \left( \frac{60 - 60}{60} \right) \right] \\
&\quad - 0.11 \left( \frac{480 - 526}{526} \right) + 0.0 \left( \frac{1018 - 1020}{1020} \right) \\
&\quad + 0.536(25,709 - 26,082) \\
BFSPDN^t &= 26,082 [1 - 0.166 - 0.0024 + 0.0 + 0.0096 + 0.0] - 199.93 \\
BFSPDN^t &= 26,082 - 432.96 - 62.60 + 250.39 + 199.93 \\
BFSPDN^t &= 25,636.9
\end{aligned}$$

The first line substitutes baseline projected, actual lagged, elasticity and long run adjustment values into equation 5.1. Upon algebraic manipulation, the second equality shows that the baseline value of production is adjusted downward by the own price effect of beef price and the cross effect of pork price. The baseline production value is adjusted upward by the cross effect of the feed price index. There is no net impact on the baseline production of beef from effects of the lamb and mutton price or the price index of all production items. The baseline production value – adjusted for own price effects, pork price effects, and feed price index effects – is then further adjusted downward by the long run production adjustment effect. Further algebraic manipulation in the third equality shows that the baseline production level is influenced most heavily by the own price effect (-432.96). In decreasing order of impact, adjustments are also attributed to the feed price index effect (+250.39), the long run production adjustment effect (-199.93), and the pork price effect (-62.60). The last line shows that the value of beef production in time period t is 445.1 million pounds less than the baseline projected level, or 25,636.9 million pounds.

### Livestock Production Units Index

Upon calculation of production estimates for each of the seven livestock categories, a share weighted linear combination of production levels for each category yields a livestock production units index. The index is calculated as:

$$[5.2] \quad MLIPDN^t = \sum_{LV=1}^7 (\alpha_{LV} LVS PDN^t)$$

where each  $\alpha_{LV}$  represents a weighted index share for that livestock category. and are presented in the following equation:

$$\begin{aligned}
 [5.2b] \quad MLIPDN^t = & 0.00117 BFSPDN^t + 0.001666 PKSPDN^t \\
 & + 0.000673 LMSPDN^t + 0.000939 BLSPDN^t \\
 & + 0.001078 TKSPDN^t + 0.001482 EGSPDN^t \\
 & + 0.000105 MKSPDN^t
 \end{aligned}$$

The model livestock production units index is later used in the estimation of livestock production expenses and livestock cash receipts.

## Available for Domestic Consumption

Once the production level of each livestock category is estimated ( $LVSPDN^t$ ), it is then used in the calculation of livestock demand, where demand for each livestock category is equivalent to the amount available for domestic consumption. The estimated production is summed with exogenous estimates of livestock imports ( $LVSIMP^t$ ). Then exogenous estimates of exports ( $LVDEXP^t$ ) and exogenous estimates of stocks held by the Commodity Credit Corporation ( $MKDCCC^t$ ) – only relevant for the case of milk – are subtracted to estimate the total amount of each livestock category available for domestic consumption ( $LVDDOM^t$ ), which is analogous to domestic demand:

$$[5.3] \quad LVDDOM^t = LVSPDN^t + LVSIMP^t - LVDEXP^t - LVDCCC^t$$

## Price

Upon calculation of supply and demand in time period  $t$  for each livestock category, the price is then calculated as the baseline projected price adjusted by the aggregate impacts of changes in the amount of each category available for domestic consumption over baseline projections. More formally, the price equation for each livestock category is given by:

$$[5.4] \quad LVDPRI^t = LVDPRI^b \left[ 1 + \sum_{i=1}^7 \varepsilon_{LV,i} (\% \Delta LVDDOM^t) \right]$$

where  $i$  = (beef, pork, lamb & mutton, broilers, turkeys, eggs, milk) and  $\varepsilon_{LV,i}$  represents the price flexibility of the livestock category (element of LV matrix) under consideration with respect to the quantity available for

domestic consumption of the  $i^{\text{th}}$  livestock category. The demand price flexibility coefficients are presented in table 5.4.<sup>9</sup>

**Table 5.4. Direct and cross demand price flexibilities for model livestock categories.**

Price Response of	With Respect to Logarithm of Quantities Available for Dom. Demand of						
	Beef	Pork	Lamb & Mutton	Broilers	Turkeys	Eggs	Milk
Beef	-1.1558	-0.1786	-0.0746	-0.1599	-0.0382	-0.0611	0.0114
Pork	-0.3140	-1.1420	-0.0478	-0.1854	-0.0085	-0.0551	0.0715
Lamb-Mutton	-0.5026	-0.4460	-0.4832	-0.1917	-0.0317	-0.0212	-0.0243
Broilers	-0.8364	-0.5498	-0.0450	-1.2391	-0.1142	-0.3172	0.0965
Turkeys	-0.6769	-0.0869	-0.0295	-0.3932	-0.5941	-0.5345	0.0384
Eggs	-0.3121	-0.1644	-0.0262	-0.2512	-0.1208	-3.6893	-0.0301
Milk	0.0328	0.0848	-0.0089	0.0438	0.0051	0.0079	-0.2942

As an example, the price of beef in simulation period  $t$  would be calculated according to the following equation:

$$[5.4b] \quad BFDPRI^t = BFDPRI^b \left[ \begin{aligned} &1 + \varepsilon_{BF,BF}(\% \Delta BFDDOM^t) + \varepsilon_{BF,PK}(\% \Delta PKDDOM^t) \\ &+ \varepsilon_{BF,LM}(\% \Delta LMDDOM^t) + \varepsilon_{BF,BL}(\% \Delta BLDDOM^t) \\ &+ \varepsilon_{BF,TK}(\% \Delta TKDDOM^t) + \varepsilon_{BF,EG}(\% \Delta EGDDOM^t) \\ &+ \varepsilon_{BF,MK}(\% \Delta MKDDOM^t) \end{aligned} \right]$$

<sup>9</sup> Demand elasticity estimates are from a 1991 USDA Report by Huang et al {need more info.}.

$$BFDPRI^t = BFDPRI^b \begin{bmatrix} 1 - 1.1558(\% \Delta BFDDOM^t) - 0.1786(\% \Delta PKDDOM^t) \\ -0.0746(\% \Delta LMDDOM^t) - 0.1599(\% \Delta BLDDOM^t) \\ -0.0382(\% \Delta TKDDOM^t) - 0.0611(\% \Delta EGDDOM^t) \\ + 0.0114(\% \Delta MKDDOM^t) \end{bmatrix}$$

Thus, the baseline projected price of beef is adjusted by the change in the amount available for domestic demand for all livestock categories, and the associated demand price flexibilities.

## Livestock Price Indices

All livestock price indices are calculated as a Laspeyres price index, where the quantities chosen as the weights for computing the averages are base period quantities. All livestock price indices use the historical 1971-1973 average as the base period. Calculated livestock price indices are used by POLYSYS in the estimation of crop demand for use as feed.

### Index of Meat Prices

A meat price index is computed for beef and pork prices:

$$[5.5] \quad MTIPRI^t = \frac{BFSPDN^{71-73} (BFDPRI^t) + PKSPDN^{71-73} (PKDPRI^t)}{BFSPDN^{71-73} (BFDPRI^{71-73}) + PKSPDN^{71-73} (PKDPRI^{71-73})}$$

where the price index for meat is the sum of the products of base quantities and current prices, divided by the sum of the products of base quantities and base prices. Thus, the denominator in the meat price index equation represents the base period value of production for beef and pork.

### Index of Poultry Prices

An index of poultry prices is computed similarly to the meat price index and includes the prices of broilers, turkeys, and eggs. The poultry price index also uses the 1971-1973 average as a base period.

$$[5.6] \quad PLIPRI^t = \frac{BLSPDN^{71-3} (BLDPRI^t) + TKSPDN^{71-3} (TKDPRI^t) + EGSPDN^{71-3} (EGDPRI^t)}{BLSPDN^{71-3} (BLDPRI^{71-3}) + TKSPDN^{71-3} (TKDPRI^{71-3}) + EGSPDN^{71-3} (EGDPRI^{71-3})}$$

### Index of All Livestock Prices

Prior to calculation of an index of all model livestock prices, a milk price index is calculated as the base period milk production multiplied by the current price of milk, divided by the base period value of milk production:

$$[5.7] \quad MKIPRI^t = \frac{MKSPDN^{71-3} (MKDPRI^t)}{MKSPDN^{71-3} (MKDPRI^{71-3})}$$

Finally, the meat price index, poultry price index, and milk price index are combined to calculate an index of all livestock prices in a manner similar to the calculation of the meat, poultry, and milk price indices. As previously noted, the denominator in equation 5.5 is the value of meat production in the base period ( $MTVPDN^{71-3}$ ) and the denominator in equation 5.6 is the value of poultry production in the base period ( $PLVPDN^{71-3}$ ). Similarly, the denominator in equation 5.7 is the base period milk value of production ( $MKVPDN^{71-3}$ ). The sum of each previously calculated index price multiplied by its base period value of production is then divided by the base period value of production summed over all model livestock commodities to estimate a price index for all model livestock commodities:

$$[5.8] \quad MLIPRI^t = \frac{MTIPRI^t MTVPDN^{71-3} + PLIPRI^t PLVPDN^{71-3} + MKIPRI^t MKVPDN^{71-3}}{\sum_{LV} (LVSPDN^{71-3} LVDPRI^{71-3})}$$

Note that the calculation of the meat price index in equation 5.5 includes beef and pork commodities. However, lamb and mutton is also included in the calculation of the base period value of production in the denominator of equation 5.8 estimating an index price for all model livestock commodities.



# CROP MODULE

# SUPPLY

# 6

POLYSYS estimates production and related variables for twelve crops in 305 geographic regions of the continental U.S. The twelve model crops and their yield, production, production expense, and price units are presented in table 6.1. The 305 POLYSYS crop production regions are geographic areas with relatively homogeneous crop production characteristics. POLYSYS regions correspond to Agricultural Statistic Districts (ASD's), as defined by the USDA's National Agriculture Statistics Service (NASS, 1988). A map of the continental U.S. by POLYSYS region is displayed in figure 6.1. A complete list of the counties comprising each POLYSYS region is included in Appendix C. Figure 6.2 presents an overview of the crop supply module. A list of crop-related POLYSYS variables and their descriptions are included in Appendix B.3.

**Table 6.1. POLYSYS model crops and yield, production, expense, and price units.**

Model Crop	Units			
	Yield	Production	Expenses	Price
Corn	bu/acre	mil bu	\$/acre (mil \$)	\$/bu
Grain Sorghum	bu/acre	mil bu	\$/acre (mil \$)	\$/bu
Oats	bu/acre	mil bu	\$/acre (mil \$)	\$/bu
Barley	bu/acre	mil bu	\$/acre (mil \$)	\$/bu
Wheat	bu/acre	mil bu	\$/acre (mil \$)	\$/bu
Soybeans	bu/acre	mil bu	\$/acre (mil \$)	\$/bu
Cotton	lbs/acre	mil bales	\$/acre (mil \$)	¢/lb
Rice	cwt/acre	mil cwt	\$/acre (mil \$)	\$/cwt
Peanuts	lbs/acre	mil lbs	\$/acre (mil \$)	¢/lb
Sugar Beets	s. tons/acre	mil s. tons	\$/acre (mil \$)	\$/s. ton

Sugar Cane	s. tons/acre	mil s. tons	\$/acre (mil \$)	\$/s. ton
Dry Beans	cwt/acre	mil cwt	\$/acre (mil \$)	\$/cwt

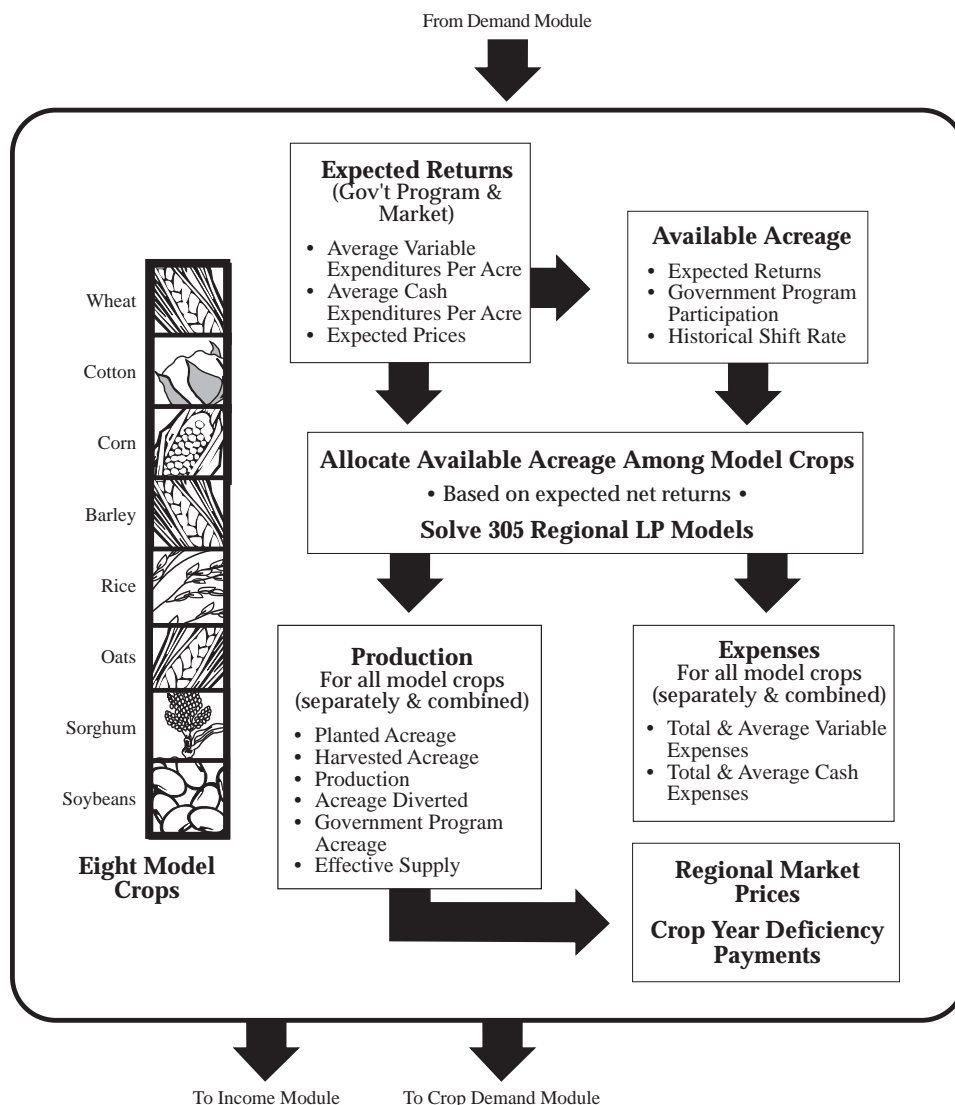
**Figure 6.1. Continental United States by POLYSYS Production Region.**



The POLYSYS crop supply module first estimates the amount of acreage in each of the 305 regions which may be available to (a) enter into crop production, (b) switch to production of a different crop, or (c) move out of crop production. Once this amount is determined, the supply module uses a set of 305 linear programming (LP) models – one for each POLYSYS region – to allocate available acreage in each region among competing model crops, based on maximization of net returns. Thus POLYSYS generates crop production and supply estimates for each model crop in each region. Regional supply estimates are then aggregated across regions to obtain national crop supply estimates.

Government program variables have historically been important factors in determining the mix and levels of crop production. Upon passage of the 1996 Federal Agriculture Improvement and Reform Act

**Figure 6.2. Overview of POLYSYS Crop Supply Module.**



(FAIR), many of these historically important government program variables became irrelevant for crop production decision making. However, they are included as part of the POLYSYS crop supply module structure as they are important for comparison of variable performance under historical and potential future policy environments. Exclusion of a

government program variable currently irrelevant is accomplished by a zero element in the model where applicable.

## **Determining Acreage Available for LP Allocation**

Important considerations in solving the regional LP models include: (a) maintaining strong scientific and empirical foundations, (b) reducing the possibility of an infeasible solution, and (c) reducing the time required to obtain LP model solutions. One important theoretical consideration of the crop supply module is the elasticity of crop supply. Thus the estimation of crop production must take into account supply elasticity. By introducing a function to disallow some portion of crop production from shifting to an alternative production use in any given simulation year, supply elasticity is implicitly accounted for in the model. Consideration of the production decision associated with only the portion of acreage allowed to shift to an alternative production use also reduces the size and complexity of the LP model to a manageable model which can generate a feasible solution quickly.

The total acreage available to each crop in each region in the current year is established from the base acreage in the previous year from the baseline. Thus, the total amount of cropland is set by the baseline. The LP is used only to allocate or reallocate the total amount of cropland available among various crops. The LP solution does not require that the total planted acres across crops and regions be equal to the baseline value of total cropland, but the solution can not allocate more acres than the baseline value. However, exogenous increases or decreases in acreage can be made to baseline numbers by crop and region that would allow for the total planted acres in the LP solution to be greater than the initial baseline total.

Prior to allocating regional acreage to competing model crop uses, the portion of available acreage eligible to *shift* to an alternative production use must be determined. The shift rate, cost, return, and relevant government program variables are required to determine the acreage eligible for allocation by the LP models and to establish the LP objective function and constraints. Required variables that must be calculated prior to solution of the LP model include average variable and cash expenditure per acre for each crop in each region; the price expectation for each crop in each region; the market and government

commodity program expected returns above variable expenditures and above cash expenditures for each crop in each region; the government commodity program participation rate; and finally, the total acreage in region R available to the LP model to allocate among competing production alternatives.

### Regional Expenditure Per Acre

Initially, the crop supply module calculates the average variable expenditure and cash expenditure per acre for each crop in each POLYSYS region. Average variable expenditures per acre for each crop in region R is given by:

$$\begin{aligned}
 [6.1] \quad CRXAVA_R^t = & CRXSED_R^t + CRXFRT_R^t + CRXPST_R^t + CRXMAC_R^t + CRXFUL_R^t \\
 & + CRXRPR_R^t + CRXHND_R^t + CRXDRY_R^t + CRXPLB_R^t \\
 & + CRXWAT_R^t + CRXIRV_R^t + CRXTCS_R^t + CRXGIN_R^t
 \end{aligned}$$

where average variable expenditure is the sum of the variable expenses per acre for seed ( $CRXSED_R$ ), fertilizer ( $CRXFRT_p$ ), pesticides ( $CRXPST_p$ ), machinery services (and custom operations costs) ( $CRXMAC_p$ ), fuel and lube ( $CRXFUL_p$ ), repairs ( $CRXRPR_p$ ), handling ( $CRXHND_p$ ), drying ( $CRXDRY_p$ ), paid labor ( $CRXPLB_p$ ), water purchases ( $CRXWAT_p$ ), irrigation variable expenses ( $CRXIRV_p$ ), technical services ( $CRXTCS_p$ ), and ginning ( $CRXGIN_p$ ), for each crop in region R.

Average cash expenditure per acre includes average variable expenditures per acre, as well as the per acre overhead ( $CRXOVH_p$ ), tax and insurance ( $CRXTXI_p$ ), real estate interest ( $CRXREI_p$ ), fixed irrigation ( $CRXIRF_p$ ), and operating interest expenses ( $CRXOPI_p$ ) for each crop in region R, expressed:

$$\begin{aligned}
 [6.2] \quad CRXACA_R^t = & CRXAVA_R^t + CRXOVH_R^t + CRXTXI_R^t + CRXREI_R^t \\
 & + CRXIRF_R^t + CRXOPI_R^t
 \end{aligned}$$

For each model crop in each region, a significant amount of exogenous data specific to that crop and that region is required for the calculation of average variable and cash expenditures per acre. POLYSYS draws upon the Farm Costs and Returns Survey to estimate costs of production for each crop and region (ERS, 1992)

### Price Expectations

POLYSYS incorporates a price expectation function by which producers develop expectations about future prices of crops and make decisions accordingly. There are several alternative expectation formations that may be relevant for decision-makers. However, development of the supply estimates requires a modeler to specify one price expectation structure. Two such price expectation structures are available in POLYSYS: naive price formation and a weighted, three-year lag structure. The naive price expectation formation structure is given by:

$$[6.3] \quad CRDEPR_R^t = CRDPRI^{t-1} (CRIPRI_R^t)$$

where the expected price for each crop in region R is the national price of the crop in the previous year multiplied by the regional price index for that crop. The regional price index for region R is the ratio of the average loan rate in that region to the national average loan rate, and is exogenously introduced in the crop supply module. Alternatively, the modeler may select the following three-year lag price expectation formation structure:

$$[6.4] CRDEPR_R^t = [0.5(CRDPRI^{t-1}) + 0.3(CRDPRI^{t-2}) + 0.2(CRDPRI^{t-3})] CRIPRI_R^t$$

where the expected price for each crop in region R weights the national price of that crop in the previous three years – with more recent price observations receiving higher weights – and multiplies the weighted past price sum by the regional price index. The previous year's price receives a weight of 0.5, the price lagged two years receives a weight of 0.3, and the price lagged three years receives a weight of 0.2. The same regional price index relevant in the naive price expectation formulation then calibrates the expected price among individual regions.

### Expected Returns

It should first be noted that references to *returns* are in fact *expected* returns, as the calculation of returns is based on estimated expected crop prices and costs of production. In any simulation period  $t$ , expected prices are predetermined (thus considered exogenous in that period) and costs of production are exogenous. Two estimates of returns are potentially relevant: market returns and, as appropriate, returns from participation in government programs. Current agricultural policy has disassociated government program payments – production flexibility contract payments – from production decision making and from

commodity prices. Thus, expected government program returns are not currently relevant for determining the amount and mix of crop acreage to plant in a simulation period; only expected market returns influence crop production decision making. Expected returns are calculated above both variable costs per acre and cash costs per acre. While POLYSYS calculates both returns above variable and cash expenditures, the modeler must indicate in initial POLYSYS simulation settings whether expected returns above variable costs or expected returns above cash costs will be used in the LP objective function.

**Market Returns** Expected market returns per acre above variable expenditures for each crop in region R are calculated as the product of the expected price and the yield per acre, less estimated average variable expenditures per acre:

$$[6.5] \quad CRRMAV'_R = [CRDEPR'_R (CRAYLD'_R)] - CRXAVA'_R$$

where the per acre yield for each crop in region R ( $CRAYLD'_R$ ) is exogenous to the model. In a similar manner, expected market returns above average cash expenditures per acre are calculated:

$$[6.6] \quad CRRMAC'_R = [CRDEPR'_R (CRAYLD'_R)] - CRXACA'_R$$

where average *variable* expenditure used in the calculation of market returns above average variable expenditures are replaced by average *cash* expenditures.

**Regional Yield and Cost Adjustment** The ratio of 1994-1995 average yield in region R to the 1994-1995 average national yield for the crop is multiplied by the average national yield in any year t to compute a regional market yield for that crop in any year t. Thus, the average yields maintain their relative value between regions across years. The relative value of yields in each region may be adjusted only by inserting a new set of average yields for all regions. While the baseline average yield is imposed on the LP, the LP solution may not produce a national average yield equal to the baseline due to the reallocation of acreage.

Costs are adjusted similar to yields. The costs may be aligned to the baseline by adjusting each regional cost by determining the product of the national average cost in the current period by the ratio of the regional cost to the national average in the previous period. Unlike the yields however, costs may be adjusted by indexing individual expenses. This

indexing will change the relative value of total cash and variable expenses across crops and regions. The newly indexed costs may then be aligned to the national average values in the same way that national average yields are aligned. Again, the LP solution may not produce a national average cash or variable expense equal to the baseline due to changes in the allocation of land across crops within regions.

**Government Program Returns** When government commodity programs are in effect that influence production decision-making, calculation of expected government program returns may also be relevant. Producers participating in government commodity programs may be eligible for additional payments on some portion of program base acreage.<sup>10</sup> Prior to passage of the 1996 FAIR Act, government program participants were eligible for deficiency payments, or entitlement payments, on some portion of program crop acreage. Eligibility for the payments required adherence to program acreage reduction and other requirements. The deficiency payment rate was determined in part by the performance of market prices. Upon passage of the 1996 FAIR Act, deficiency payments were eliminated and replaced by seven year production flexibility contract payments, determined independently of market prices. Production flexibility contract payments are lump sum payments made to producers for a specified time period that are based on the producer's historical base acreage and are decoupled from current production decisions. Thus the payments are not included as part of the crop supply module<sup>11</sup>.

The estimation of government program returns incorporates program structures effective prior to passage of the 1996 FAIR Act.. Program participants may be required to idle some percentage of their program crop base acreage, as determined by program minimum acreage reduction requirements ( $CRGMAR^t$ ). On the portion of program crop base acreage not idled by minimum acreage reduction requirements ( $1 - CRGMAR^t$ ), expected returns are equivalent to expected market returns.

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<sup>10</sup> Program base acreage, also referred to as base acreage or program acreage, is equal to the average of acres planted and considered planted during the previous five years (wheat and feed grains) and three years (cotton and rice), or determined by an alternative government-defined structure.

<sup>11</sup> Production flexibility payments are, however, relevant in estimating farm income variables and appear in the income module as appropriate.



By participating in relevant government commodity program, the producer was also entitled to a deficiency payment on the portion of base acreage not idled by acreage reduction and not considered normal flex acreage<sup>12</sup> ( $CRGNFR^t$ )<sup>13</sup>. The deficiency payment rate for this acreage is the government-set target price for that crop ( $CRGTAR^t$ ) less the greater of the market price or the program basic loan rate ( $CRGBLR^t$ ), multiplied by the exogenous program yield rate for that crop ( $CRGYLD^t$ ). Thus, expected government program returns above variable expenditures per acre are calculated as:

$$[6.7] \quad CRRGAV_R^t = CRRMAV_R^t (1 - CRGMAR^t) + \left[ CRGTAR^t - \max\{CRDEPR_R^t, CRGBLR_R^t\} \right] (CRGYLD_R^t) (1 - CRGMAR^t - CRGNFR^t)$$

The sum of the expected market return and deficiency payment yield the expected return above average variable expenditures per acre for participating government program acreage. The per acre market yield for each crop in region R is exogenous to the model and is constant throughout the simulation period. Similarly, the government program per acre yield for each crop in region R is exogenous and constant for all t years of the simulation.<sup>14</sup> In a similar manner, government program returns above cash expenditures are calculated:

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<sup>12</sup> Normal flex acreage is a government-determined portion of program base acreage not eligible for government program deficiency payments which may be planted to any crop(s) not precluded by the government program without loss of crop acreage base.

<sup>13</sup> In addition to normal flex acreage, participating farms were also eligible for optional flex acreage ( $CRGOFR^t$ ) participation, where a percentage of base acreage beyond normal flex acreage could also be allocated to another crop (under certain guidelines) without losing base acreage. Deficiency payments were paid on optional flex acreage only if the original program crop was planted. POLYSYS implicitly assumes that all was planted to the program crop and eligible for deficiency payment in the calculation of expected program returns.

<sup>14</sup> The national per acre yield for crop K ( $CRAYLD^t$  and  $CRGYLD^t$ ), however, may vary across simulation periods, as changes in regional allocations to crop K may change the average yield. Further discussion is included in the later presentation of the calculation of a national yield variable.

$$\begin{aligned}
CRRGAC_R^t &= CRRMAC_R^t (1 - CRGMAR^t) + \\
[6.8] \quad &\left[ CRGTAR^t - \max\{CRDEPR_R^t, CRGBLR_R^t\} \right] \\
&\quad (CRGYLD_R^t)(1 - CRGMAR^t - CRGNFR^t)
\end{aligned}$$

where average *variable* expenditures used in the calculation of program returns above variable expenditures in equation 6.7 are replaced by average *cash* expenditures.

### Government Program Participation

Under policy provisions effective prior to 1996, POLYSYS must also calculate an expected government program participation rate. The following step function is used to estimate the government program participation rate for program crops in region R:

$$[6.9] \quad CRGPAR_R^t = CRGMNP_R^t + \omega_R \left( \frac{CRRGAV_R^t - CRRMAX_R^t}{CRRMAV_R^t} \right)$$

subject to the following restrictions:

$$\begin{aligned}
[6.10] \quad &\text{If } CRGPAR_R^t > CRGMXP_R^t \quad \text{then} \quad CRGPAR_R^t = CRGMXP_R^t \\
&\text{If } CRRMVX_R^t < 0 \quad \quad \quad \text{then} \quad CRGPAR_R^t = CRGMXP_R^t
\end{aligned}$$

The variable  $CRGPAR_R^t$  is the commodity program participation rate for each crop in region R. The variables  $CRGMNP_R^t$  and  $CRGMXP_R^t$  are exogenous coefficients indicating the minimum and maximum values for  $CRGPAR_R^t$  respectively. The estimated parameter  $\omega_R$  indicates the change in the government program participation rate in region R due to the relative difference between program and market returns. The predetermined maximum program participation rate cannot be exceeded, so that if the participation rate estimated in equation 6.9 exceeds the maximum threshold participation rate, then the rate assumes the maximum value. Also, if market returns above total variable expenditures are negative, then the program participation rate assumes its maximum value.

### Acreage Available to the LP Model to Allocate

POLYSYS is designed to allocate marginal changes in acreage over the baseline crop acreage within each region. Each simulation period, some portion of the baseline acreage allocated to each crop is

available to shift to production of another model crop. This available acreage is aggregated within a region and the LP model then allocates that available acreage to eligible crops based on their expected returns in that region. Such a structure also reduces the probability of obtaining a corner solution from the LP model, since the model is not allocating all agricultural land in a region in each simulation period, but rather the aggregate portion of baseline agricultural land eligible to *shift* to a competing use, as defined by the model.

A structure must be introduced to govern the percentage of regional acreage planted to each crop allowed to shift. This is accomplished in POLYSYS according to an acreage shift rate variable,  $CRASFR_R^t$ . The crop acreage shift rate variable represents the percentage of baseline acres planted to a model crop in region R that the crop can lose in any given simulation period. To allow for the possibility of an increase in supply response within a region, a rule of thumb relating the value of  $CRASFR_R^t$  to returns (either government program or market returns, as appropriate) is introduced. The value of  $CRASFR_R^t$  is defined by the following:

$$\begin{aligned}
 & \text{If } CRRGAV_R^t > 0 & \text{then } CRASFR_R^t = CRASFR_R^{ha} \\
 [6.11] \quad & \text{If } CRRGAV_R^t \leq 0 \text{ \& } CRRGAC \geq 0 & \text{then } CRASFR_R^t = \min\{2(CRASFR_R^{ha}), 1\} \\
 & \text{If } CRRGAC_R^t \leq 0 & \text{then } CRASFR_R^t = 1
 \end{aligned}$$

The variable  $CRASHR_R^{ha}$  represents the historical-average percentage of crop acreage planted in region R that has been available to shift to production of another crop. The  $CRASFR_R^{ha}$  variable is a function of 1957-1995 historical county-level crop acreage data. The function presented in equation 6.11 indicates that land can shift between crop and other land use activities more rapidly as a producer's ability to cover production costs diminishes.<sup>15</sup> The smaller the value of  $CRASFR_R^t$ , the more inelastic the supply of the crop in that region. For example, if  $CNASFR_{220}^2 = 0.15$ , then 15 percent of the baseline acreage planted to corn in region 220 in the second simulation period would be made available to the LP model to reallocate

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<sup>15</sup> An alternative formulation is to compare the rate of return to farm assets in a particular crop and region; as the rate of return approaches a threshold rate of return, the rate at which land can shift away from a crop would increase. Currently, available data is insufficient to estimate such a function by crop.

among the twelve model crops (including corn), based on their expected net returns.

A crop's baseline acreage planted allowed to shift to production of another crop, then, is determined by the product of the baseline acreage planted to the crop in a given region and the acreage shift rate for that crop and region:

$$[6.12] \quad CRAASF_R^t = CRASFR_R^t (CRAPLT_R^b)$$

To continue the example above, if (a) the historical-average corn acreage in region 220 allowed to shift to production of another crop is 15 percent,  $CNASFR_{220}^2 = 0.15$ , (b) corn expected returns above average variable expenditures in that region in the simulation period are positive, and (c) baseline acreage planted to corn in region 220 in the second simulation period is 300,000 acres, then POLYSYS would allow up to 45,000 of those acres to shift to production of another crop or out of production, if it maximizes net returns in the region. If the circumstances were the same except that expected returns above average cash expenditures were negative for corn in region 220 in the second simulation period, then POLYSYS would allow up to the entire 300,000 baseline corn acres to shift to production of another model crop or out of crop production.

A POLYSYS estimate of crop acreage eligible to shift production use in a region is measured as a portion of baseline crop acreage planted in that region. Thus it is important to understand the estimation procedure for baseline planted acreage. Baseline crop production estimates obtained from most sources are generally national estimates by crop and must be allocated among the regions that produce that crop. For the initial baseline year, this is accomplished by a two-step procedure. First, national baseline planted acreage is assigned to individual regions based on the average of 1994 and 1995 crop year regional acreage allocations. Then, the 305 regional LP models are solved based on expected returns to allow changes in the initial allocation due to baseline price impacts. In subsequent baseline years, the baseline acreage available to shift is determined by the product of the lagged baseline planted acreage for that region and a baseline acreage shift rate estimated identically to the simulation shift rate estimated in equation 6.11. Baseline regional acreage available to shift is then made available to the set of regional LP models to allocate based on expected returns.

The baseline acreage planted to each model crop available to shift within a region, as estimated in equation 6.12, is then summed over all crops in the region and any exogenous nonprice-related regional changes in acreage ( $TLANPC_R^t$ ) are added or subtracted as relevant to obtain the acreage available to the LP model to allocate among competing crops:

$$[6.13] \quad TLAALP_R^t = \sum_{CR} CRAASF_R^t \pm TLANPC_R^t$$

Examples of exogenous nonprice changes in acreage available in region R may be a conversion of pasture acreage, forest land, or other non-crop land to crop acreage, crop acreage reduction due to nonagricultural development, enrollment of environmentally sensitive cropland in a conservation program, return of such conservation land to production upon the expiration of conservation contracts or other acreage reduction programs.<sup>16</sup>

Thus, in any given region in any given simulation period, the LP model has available some portion of regional baseline planted acreage which is available to shift to production of competing model crops based on net returns in that region. The portion of the regional baseline planted crop acreage that will remain in production of the crop ( $CRAPLT_R^b (1 - CRASFR_R^t)$ ) is not available to the LP model to allocate among competing crops based on net returns.

## LP Objective Function

Estimated acreage available to the LP model for each region is then optimally allocated among model crops, as determined by the solution of a regional linear programming (LP) model.<sup>17</sup> The LP model maximizes the expected returns above either average variable or average cash costs per acre for the alternative production uses available in each

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<sup>16</sup> Presently, nonprice changes in regional acreage available to the LP model to allocate among competing crops are exogenously introduced into POLYSYS. Expansion of the POLYSYS framework is underway to endogenize many of the nonprice regional changes in crop acreage available for production.

<sup>17</sup> As noted earlier, a more complex version of this module is capable of handling multiple production practices, soil types, and irrigation methods for each crop in each region, provided sufficient regional data are available to the model.

POLYSYS region. The modeler may select either expected average variable or average cash returns to be used by the LP objective function, but not both. Irrespective of the expected returns used to allocate available acreage by the LP models – either variable or cash – POLYSYS calculates both variable and cash average and total expenditures upon solution of the regional LP models.

The activities in the LP include government commodity programs effective under the 1990 Federal Agriculture, Conservation and Trade Act, including deficiency payments for eligible acres enrolled in commodity programs as well as existence of normal and optional flex acreage. In policy settings where such program options are not relevant (e.g., under 1996 FAIR Act provisions), program and flex activities have zero elements in the tableau and right hand side. The objective function of the linear programming model is given by<sup>18</sup>:

$$\begin{aligned}
 \text{Max } CRRENT_R^t &= \sum_{CR} [CRRGAV_R^t (CRAGPR_R^t)] + \sum_{CR} [CRRMAV_R^t (CRANGP_R^t)] \\
 [6.14] \quad &+ \sum_{CR} [CRRMAV_R^t (CRAGPR_R^t)] + \\
 &\sum_{CR} \sum_j [CRRGAV_R^t (CRANFX_{R,j}^t) + CRRMAV_R^t (CRAOFX_{R,j}^t)]
 \end{aligned}$$

The LP model seeks to maximize expected net returns in region R ( $CRRENT_R^t$ ). Expected net returns are the sum of expected returns from government program crop acreage, model crop acreage not enrolled in government programs, and normal and optional flex acreage planted to model crops. In the objective function, government program returns above average variable expenditures per acre are applied to government program acreage ( $CRAGPR_R^t$ ). Market returns above total variable expenditures are applied to non-government program acreage ( $CRANGP_R^t$ ) and normal flex acreage ( $CRANFX_R^t$ ). Optional flex acreage ( $CRAOFX_R^t$ ) receives government program returns above average variable expenditures per acre if the acreage is planted to the original program crop and receives market returns above average variable expenditures if the acreage is not planted to the original program crop.

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<sup>18</sup> An objective function under the 1996 FAIR Act would be estimated:

$$\text{Maximize } CRRENT_R^t = \sum_R [CRRMAV_R^t (CRANGP_R^t)]$$

The objective function in equation 6.14 is maximized subject to the following constraints:

$$\begin{aligned}
 \sum_{CR} CRAGPR_R^t + \sum_{CR} CRANGP_R^t + \sum_{CR} CRANFX_R^t + \sum_{CR} \sum_j CRAOFX_{R,j}^t &\leq TLAALP_R^t \\
 \sum_{CR} CRANFX_R^t &\leq TLANFX_R^t \\
 \sum_j CRAOFX_{R,j}^t &\leq CRAOFX_R^t \\
 CRAGPR_R^t + CRANGP_R^t + CRANFX_R^t + \sum_j CRAOFX_{R,j}^t &\leq CRAMXG_R^t \\
 CRAGPR_R^t, CRANGP_R^t, CRANFX_R^t, CRAOFX_R^t &\geq 0
 \end{aligned}
 \tag{6.15}$$

The first constraint in equation 6.15 indicates that the sum of all acreage planted to all crops for government program acreage, non government program acreage normal flex acreage, and optional flex acreage uses must be less than or equal to the total acreage available to that region for the LP model to allocate. The second constraint indicates that the normal flex acreage allocated to all model crops must be less than or equal to the normal flex acreage in the region. Similarly, the third constraint indicates that the optional flex acreage for each of the model crops allocated to all J crops must be less than or equal to the optional flex acreage for that crop in that region. The final constraint requires that government program acreage, acreage not allocated to government programs, normal flex acreage, and optional flex acreage to be non-negative.

The fourth constraint in equation 6.15 introduces a new variable,  $CRAMXG_R^t$ , which defines the maximum acreage that each crop in region R is allowed to gain in any single simulation year. The  $CRAMXG_R^t$  variable is set equal to twice the value of  $CRASFT_R^t$ . The equation constrains the amount of available acreage the LP solution can allocate to a single model crop for any eligible activity – the sum of the government program acres, the acres not in government programs, the normal flex acres, and the optional flex acres of crop K summed over all J crops – to be less than or equal to twice the value of acreage initially made available to the LP for optimizing allocation. Continuing the previous example, if corn baseline acreage in region 220 in simulation period 2 gave up 15 percent of its acreage to be allocated by the LP model, then regardless of corn returns, corn could not gain more than 30%, for a net corn acreage increase of 15%. In other words, if corn initially “lost” 45,000 acres to be made available to the LP to allocate according to equation 6.12, then corn acreage gain is restricted to be less than or equal to 90,000 acres, which is

the 45,000 acres (15 percent) it made available to the LP plus an additional 45,000 acre (15 percent) gain over the baseline acreage.

It bears noting that acreage allocation by the LP model is based on expected returns for each model crop. As expected returns decrease and become negative, more of that acreage is “lost” to the LP for optimizing allocation. Since the same expected returns that caused a zero or negative profit crop to lose acreage are also determining acreage gain, that acreage will not be recovered through the LP allocation and will instead be allocated to more profitable crops, up to the maximum acreage gain threshold.

Upon solution of the regional LP models, the marginal acreage change over the baseline for each model crop in region R is the baseline acreage planted ( $CRAPLT_R^b$ ) less the crop acreage made available to the LP to allocate ( $CRAALP_R^t$ ), plus any acreage gain contributed by the LP solution. The acreage of each crop in region R gained through the solution of the LP model is the sum of the acreage allocated by the LP model to government program use, nongovernment program use, normal flex acreage use, and optional flex acreage use, indicated by  $CRASOL_R^t$ . Thus, the change in crop acreage in a given simulation period in region R is estimated to be:

$$[6.16] \quad CRACHG_R^t = CRAPLT_R^t - CRASFT_R^t + CRASOL_R^t$$

Recalling that the maximum acreage any crop can gain is equal to twice the acreage it initially lost to the LP to allocate, the marginal change in acreage for the simulation is related to the maximum acreage gain value for each crop as follows:

$$\begin{aligned}
 & \text{If } CRASOL_R^t = 0 && \text{then crop lost maximum acreage allowed} \\
 & \text{If } CRASOL_R^t < 0.5 CRAMXG_R^t && \text{then crop lost acreage} \\
 [6.17] \quad & \text{If } CRASOL_R^t = 0.5 CRAMXG_R^t && \text{then crop experienced no change in acreage} \\
 & \text{If } CRASOL_R^t > 0.5 CRAMXG_R^t && \text{then crop gained acreage} \\
 & \text{If } CRASOL_R^t = CRAMXG_R^t && \text{then crop gained maximum acreage allowed}
 \end{aligned}$$

## Regional Supply Variables

Once the LP solution is obtained and the marginal acreage is allocated to competing model crops in each region, regional crop supply



variables may be computed. These variables include (1) planted and harvested acres by crop (2) production by crop, and (3) total variable and cash expenditures by crop.

### Crop Production Variables

Planted acres of each model crop in region R is then determined by:

$$[6.18] \quad CRAPLT_R^t = CRAPLT_R^b (1 - CRASFR_R^t) + CRASOL_R^t$$

where the acreage of each crop planted in region R is determined by summing the baseline acreage of the crop planted in region R multiplied by the percentage of crop acreage in region R not available to shift to production of another crop with the acreage allocated to that crop in that region by solution of the linear programming model.

The value of the crop planted acreage in region R is then multiplied by the exogenously determined harvested-to-planted acreage ratio ( $CRAHPR_R^t$ ) for that region to obtain the harvested acreage of each crop in region R<sup>19</sup>:

$$[6.19] \quad CRAHAR_R^t = CRAPLT_R^t (CRAHPR_R^t)$$

Then the harvested acreage variable is multiplied by the per acre market yield variable for that crop and region to obtain an estimate of production by crop by region:

$$[6.20] \quad CRSPDN_R^t = CRAHAR_R^t (CRAYLD_R^t)$$

### Crop Total Variable and Cash Expenditures

Total variable and total cash expenditures for each crop in a region are then calculated by the crop supply module. To calculate total expenditures, the baseline level of expenditures for that crop and region is adjusted for any change in average variable expenditures per acre over the baseline level (applied to planted acreage) and also for expenses incurred

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<sup>19</sup> The harvested acreage to planted acreage ratio is currently set equal to the 1994-1995 average, but can be changed exogenously by the user.

for maintaining idled acreage. For corn, oats, barley, soybeans, cotton, and rice, total variable expenditures per acre are calculated as:

$$[6.21] \quad CRXTLV_R^t = CRXTLV_R^b + (CRXAVA_R^t - CRXAVA_R^b) CRAPLT_R^t + 0.7[(CRGMAR^t - CRGMAR^b)(CRGPAR_R^t)(CRXAVA_R^t)]$$

Total variable expenditures for grain sorghum in region R are calculated identically, except that the coefficient for idled acreage expenses is 0.20 instead of 0.70, as in equation 6.21. Total variable expenditures for wheat in region R are calculated identically, except that the coefficient for idled acreage expenses is 0.45 instead of 0.70, as in equation 6.21. Total cash costs for each crop in each region are calculated similarly:

$$[6.22] \quad CRXTLC_R^t = CRXTLC_R^b + (CRXACA_R^t - CRXACA_R^b) CRAPLT_R^t + 0.7[(CRGMAR^t - CRGMAR^b)(CRGPAR_R^t)(CRXACA_R^t)]$$

As for total variable costs, the coefficient for idled acreage expenses is 0.20 for grain sorghum and 0.45 for wheat, and 0.7 for all other crops as indicated in equation 6.22.

## National Supply Variables

Previous crop supply variables have been relevant for individual POLYSYS regions. These regional variables may then be aggregated across all 305 POLYSYS regions to compute national supply variables. These aggregations correspond to the following statements:

### Crop Total Variable Expenditures

A national estimate of crop total variable expenditures is calculated as:

$$[6.23] \quad CRXTLV^t = \sum_R CRXTLV_R^t$$

where total variable expenditures for each crop is equal to the total variable expenditures for each crop in region R summed over all R regions.

### Crop Total Cash Expenditures

Similarly, the total cash expenditures for each crop is calculated as the total cash expenditures for each crop in region R summed over all 305 regions:

$$[6.24] \quad CRXTLC^t = \sum_R CRXTLC_R^t$$

### Crop Total Planted and Harvested Acreage

Acreage of each model crop planted and harvested in region R is summed over all 305 regions to estimate the total planted and harvested acreage of each crop:

$$[6.25] \quad CRAPLT^t = \sum_R CRAPLT_R^t$$

$$[6.26] \quad CRAHAR^t = \sum_R CRAHAR_R^t$$

### Crop Total Production

Similarly, the production of each crop in region R is summed over all regions to estimate national production of each model crop:

$$[6.27] \quad CRSPDN^t = \sum_R CRSPDN_R^t$$

### Crop Average Expenditures per Acre

National estimates of average variable and cash expenditures per acre by crop are then obtained by dividing the corresponding estimates of the total variable and cash expenditures (estimated by equations 6.21 and 6.22) by the harvested acreage of the crop:

$$[6.28] \quad CRXAVA^t = \frac{CRXTLV^t}{CRAHAR^t}$$

$$[6.29] \quad CRXACA^t = \frac{CRXTLC^t}{CRAHAR^t}$$

### Crop Government Program Acreage and Participation

Total government program acreage allocated to each crop is defined as:

$$[6.30] \quad CRAGPR^t = \sum_R CRAGPR_R^t$$

which is then divided by the total acreage planted to each crop to obtain an estimate of the national government program participation rate for each model crop:

$$[6.31] \quad CRGPAR^t = \frac{CRAGPR^t}{CRAPLT^t}$$

### Crop Beginning Stocks and Effective Supply

The identify equation,

$$[6.32] \quad CRSBEG^t = CRDEND^{t-1}$$

defines the beginning stock of each crop in a simulation period as equivalent to the ending stock of the crop in the previous simulation period. The beginning stock is then added to the total production of each crop and the exogenous estimate of total crop imports to obtain the total supply of the crop in any simulation year. From this supply, the value of the average crop stock held by the Commodity Credit Corporation and the Farmer-Owned-Reserve are netted out to obtain the effective supply for each model crop, where :

$$[6.33] \quad CRSEFF^t = CRSBEG^t + CRSPDN^t + CRSIMP^t - CRDCCC^t - CRDFOR^t$$

## **Aggregate Supply Variables**

### Aggregate Planted and Harvested Acreage

The above aggregated crop results over all POLYSYS regions are further aggregated across model crops to compute national aggregate crop supply estimates. These aggregations correspond to the following statements:

$$[6.34] \quad TLAPLT^t = \sum_{CR} CRAPLT^t$$

$$[6.35] \quad TLAHAR^t = \sum_{CR} CRAHAR^t$$

where the total acreage planted to all model crops is the sum of the national acreage planted to each crop and the total acreage harvested is the sum of the national acreage harvested over all model crops.

### Aggregate Acreage Diverted

Aggregate acreage in paid and unpaid government program land diversion is also estimated by the crop supply module. Exogenous estimates of acreage idled due to program eligibility acreage reduction ( $CRAARP^t$ ), acreage diverted under the 0/92 or 0/50 program, where a producer is eligible for a portion of deficiency payments on acreage idled for conservation use, or planted to minor oilseeds according to program guidelines ( $CRAZ92^t$ ), and other government program acreage in land diversion ( $CRAGLD^t$ ) are summed to estimate the total land diverted under government programs ( $TLADIV^t$ ):

$$[6.36] \quad TLADIV^t = \sum_{CR} (CRAARP^t + CRAZ92^t + CRAGLD^t)$$

### **Index of Feed Prices**

The crop supply module also contains an equation used to estimate an index of feed prices for a given simulation year, where:

$$[6.37] \quad \begin{aligned} IPIFED^t = & 7.27342 + 13.92004 CNDPRI^{t-1} + 7.09467 SYDPRI^{t-1} + \\ & 0.00309 \left[ \frac{(CNSPDN^t + SYSPDN^t) - (CNSPDN^{t-1} + SYSPDN^{t-1})}{(CNSPDN^{t-1} + SYSPDN^{t-1})} \right] + 0.33180 IQSFDI^{t-1} \end{aligned}$$

stating that the index of prices paid by U.S. farmers for feed is a function of the price of corn in the previous year, the price of soybeans in the previous year, the change in the level of production of corn and soybeans over the previous year's level of production, and the total volume of imports in the previous year.

### **Variables Computed Upon Interaction with Demand**

The following variables are computed after the crop demand module has estimated simulated market prices at the national level for each crop.

### Regional Market Prices

The same regional price index introduced in equation 6.3 for estimation of expected regional price of each crop is now multiplied by the simulation estimate of the price of the crop generated in the crop demand module to calculate a simulation price for the crop specific to region R:

$$[6.38] \quad CRDPRI_R^t = CRDPRI^t (CRIPRI_R^t)$$

### Crop Year Deficiency Payments by Crop

Deficiency payments were calculated using the expected price of each crop in region R to estimate expected program returns prior to the solution of the LP models. Upon solution of simulation prices in the crop demand module and calculation of regional prices in equation 6.38, simulation deficiency payments are then estimated for each crop. It should be noted that deficiency payments are made for crop years, not calendar years. Deficiency payments are the product of eligible program acreage, program yield, and the deficiency payment rate, which is the target price less the higher of market price or the basic loan rate. Acreage eligible for deficiency payments is the acreage allocated by the LP model to government program use ( $CRAGPR_R^t$ ), less acreage ineligible due to normal flex acreage requirements ( $CRGNFR^t$ ). Thus, deficiency payments for each model crop in crop year t are equal to the eligible program acreage multiplied by the program yield, multiplied by the deficiency payment rate which is calculated using simulated regional prices:

$$[6.39] \quad CRPDEF^{(cy)t} = \sum_R \left[ \frac{CRAGPR_R^t (1 - CRGNFR^t) CRGYLD_R^t}{\left( CRGTAR^t - \max \{ CRDPRI_R^t, CRGBLR^t \} \right)} \right]$$

The estimated deficiency payment for each of R regions is then summed over all R regions to obtain a deficiency payment estimate for each of the model crops.

# CROP MODULE

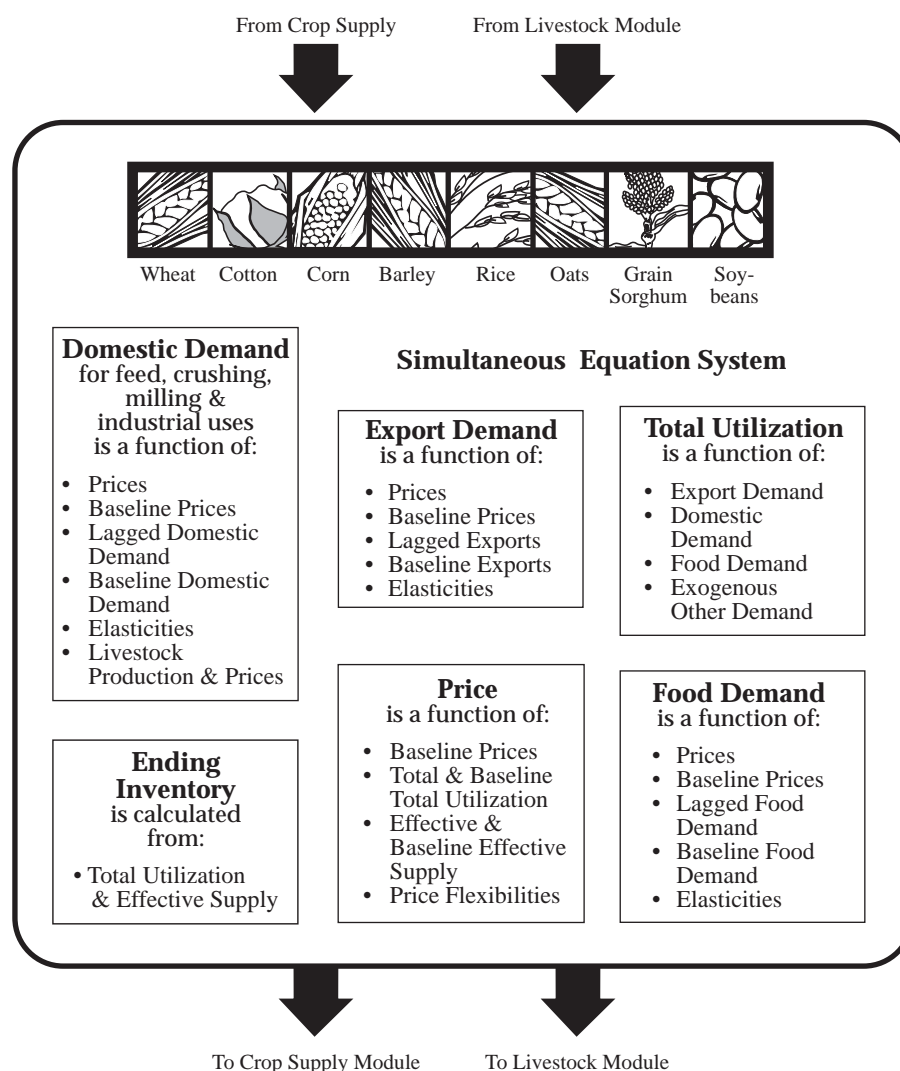
# DEMAND

# 7

Crop demands and prices are estimated for model crops including corn, grain sorghum, barley, oats, wheat, soybeans, cotton, rice, peanuts, sugar cane, sugar beets, and dry beans and for crop derivative products including soybean oil and soybean meal. An overview of the crop demand module is presented in figure 7.1. Crop demands and prices are estimated via solution to a system of simultaneous equations based on econometrically estimated price and demand parameters, using the Gauss-Seidel iterative optimization algorithm. This technique estimates a weighted average of the variable values in simulation period  $t$  and simulation period  $t-1$  for inclusion in the variable estimation in simulation period  $t+1$ . Iterations continue until the change in the variable value across iterations reaches a threshold level near zero.

While crop supply variables are estimated for each of 305 POLYSYS geographic regions, crop demands and prices are estimated nationally. Crop demand is a function of price, cross-price shifters, and non-price shifter variables. Estimation of POLYSYS baseline demand and price variables incorporates population levels, consumer incomes, nonagricultural prices, and other general and specific commodity and macroeconomic variables. A POLYSYS simulation assumes that such variables remain unchanged over their baseline levels, and estimates the change in baseline demands and prices that are driven by changes in model crop own and cross prices. However, exogenous changes in other

demand shifters may also be incorporated into a POLYSYS simulation if warranted.



**Figure 7.1. Overview of POLYSYS Crop Demand Module.**

In general, model crop demands are based on changes in the baseline levels of prices and relevant demand elasticities, long run adjustment elasticities, and price flexibilities. Demand by use and crop price is estimated by a system of nine demand use and price equations



with nine unknowns. Additionally, the POLYSYS crop demand system incorporates estimation of demands and prices for products derived from model crops. Presently, the only derivative products included in POLYSYS are soybean oil and soybean meal. While the crop demand system estimates demand and price for model crops and model crop derivative products simultaneously, they are presented separately below for simplicity.

## Estimating Crop Demands and Prices

The demand system is comprised of a system of equations which estimate crop demand by use and crop price for a vector of model crops. The model crops are the same twelve model crops presented in table 6.1 in the supply module. The crop demand module's demand and price units are equivalent to the production and price units in table 7.1. The endogenous variables in the model crop portion of the demand system are presented in table 7.1. A list of variables relevant to the model crops is included in Appendix B.3.

In general, demand for each crop is estimated by adjusting baseline demand in that period for changes in own and cross prices or other demand shifters. The impact of a percentage change in prices or other demand shifters on commodity demand is directly related to estimated short run demand elasticities. The baseline demand is further adjusted for long run demand adjustment impacts, as determined by an estimated long run elasticity, or long run adjustment factor. Equations 7.1 – 7.9 present the generalized functions for each of the nine crop demand system equations. Demand elasticity estimates ( $\epsilon$  coefficients) are presented in table 7.2.

**Table 7.1. Endogenous variables in crop demand portion of crop demand module.**

Variable	Definition	Relevant for Model Crops
CRDEXP	Demand for model crop for export use	CN, GS, OT, BR, WH, SY, CT, RC, PN, SC, SB, DB
CRDFED	Demand for model crop for feed use	CN, GS, OT, BR, WH
CRDCRS	Demand for model crop for crushing use	SY, PN
CRDMIL	Demand for model crop for milling use	CT
CRDIND	Demand for model crop for industrial use	RC
DRDFOD	Demand for model crop for food use	WH, RC, PN
CRDDOM	Domestic demand for model crop	CN, GS, OT, BR, WH, SY, CT, RC, PN, SC, SB, DB

CRDTOT	Total demand for model crop	CN, GS, OT, BR, WH, SY, CT, RC, PN, SC, SB, DB
CRDPRI	Price of model crop	CN, GS, OT, BR, WH, SY, CT, RC, PN, SC, SB, DB

**Table 7.2. Crop demand module demand elasticities for model crops.**

Export Demand		Feed Demand					Crushing Demand			Mill Demand	Indust. Demand	Food Demand
Elasticity Of:	Own Price	Livestock Index	Soybean Index	Livestock Meal Price	Index of Livestock Prod'n	Corn Prices	Soybean Crush	Margin	Corn Price	Own Price	Own Price	Own Price
With Respect To:	Own Price	Own Price	Price	Meal Price	Prod'n	Prices	Own Price	Margin	Corn Price	Own Price	Own Price	Own Price
Corn	-0.42	-0.26	0.23	0.05	1.05							
Grain Sorg.	-0.50	-0.59	0.66			0.59						
Oats	-0.35	-0.79				0.79						
Barley	-0.50	-1.08				1.08						
Wheat	-0.38	-0.62				0.19						-0.02
Soybeans	-0.57						-0.27	0.10	0.02			
Cotton	-1.0									-0.05		
Rice	-0.48										-0.26	-0.33
Peanuts	-0.40						-1.00					-0.20
Sugar Cane	0											-0.05
Sugar Beets	0											-0.05
Dry Beans	0											0

### Export Demand

Export demand for each model crop is the baseline estimated export demand for that crop adjusted by the demand response due to a percentage change in the price of that crop over the baseline price, then further adjusted by a long run adjustment effect. While long run adjustment coefficients are included for each demand use equation, only corn and wheat export demand currently have a defined long run adjustment coefficient. For these two crops, the long run adjustment factor is approximately twice the value of the short run elasticity.

$$\begin{aligned}
 [7.1] \quad CRDEXP^t = CRDEXP^b & \left[ 1 - \varepsilon_{CRDEXP, CRDPRI} \left( \frac{CRDPRI^t - CRDPRI^b}{CRDPRI^t} \right) \right] \\
 & + \lambda_{CRDEXP} (CRDEXP^{t-1} - CRDEXP^{b-1})
 \end{aligned}$$

## Feed Demand

For feed grain crops – corn, grain sorghum, oats, barley, and wheat – feed demand for each crop is the baseline feed demand adjusted by the demand response due to percentage changes in own price, model livestock index of prices, the price of soybean meal, the model livestock index of production, and the price of corn. Then the estimate is further adjusted by a long run adjustment response.

[7.2]

$$CRDFED^t = CRDFED^b \left[ \begin{aligned} &1 - \varepsilon_2 \left( \frac{CRDPRI^t - CRDPRI^b}{CRDPRI^b} \right) + \varepsilon_3 \left( \frac{MLIPRI^t - MLIPRI^b}{MLIPRI^b} \right) \\ &+ \varepsilon_4 \left( \frac{SMDPRI^t - SMDPRI^b}{SMDPRI^b} \right) + \varepsilon_5 \left( \frac{MLIPDN^t - MLIPDN^b}{MLIPDN^b} \right) \\ &+ \varepsilon_6 \left( \frac{CNDPRI^t - CNDPRI^b}{CNDPRI^b} \right) \end{aligned} \right] \\ + \lambda_{CRDFED} (CRDFED^{t-1} - CRDFED^{b-1})$$

## Crushing Demand

The soybean demand for crushing is estimated to be the baseline crush demand adjusted by the demand response due to percentage changes in soybean and corn price over their baseline levels, and the percentage change in the crushing margin for soybeans over its baseline crushing margin. The crushing demand is further adjusted by a long run adjustment response.

$$[7.3] \quad CRDCRS^t = CRDCRS^b \left[ \begin{aligned} &1 - \varepsilon_7 \left( \frac{CRDPRI^t - CRDPRI^b}{CRDPRI^b} \right) \\ &+ \varepsilon_8 \left( \frac{CRCCRM^t - CRCCRM^b}{CRCCRM^b} \right) \\ &+ \varepsilon_9 \left( \frac{CNDPRI^t - CNDPRI^b}{CNDPRI^b} \right) \end{aligned} \right] \\ + \lambda_{CRDCRS} (CRDCRS^{t-1} - CRDCRS^{b-1})$$

### Milling Demand

The demand for cotton for milling is the baseline level of mill demand adjusted by the response to a percentage change in the price of cotton over the baseline cotton price, then adjusted for the long run mill demand response.

$$[7.4] \quad \begin{aligned} CRDMIL^t = CRDMIL^b & \left[ 1 - \varepsilon_{10} \left( \frac{CRDPRI^t - CRDPRI^b}{CRDPRI^b} \right) \right] \\ & + \lambda_{CRDMIL} (CRDMIL^{t-1} - CRDMIL^{b-1}) \end{aligned}$$

### Industrial Demand

Soybean industrial demand is the baseline level of industrial soybean demand adjusted by the response due to a percentage change in the price of soybeans over the baseline soybean price, then adjusted for the long run industrial demand response.

$$[7.5] \quad \begin{aligned} CRDIND^t = CRDIND^b & \left[ 1 - \varepsilon_{11} \left( \frac{CRDPRI^t - CRDPRI^b}{CRDPRI^b} \right) \right] \\ & + \lambda_{CRDIND} (CRDIND^{t-1} - CRDIND^{b-1}) \end{aligned}$$

### Domestic Demand

Domestic demand for the model crops is the sum of demand for feed, crushing, milling, and industrial uses. Since each of the model crops is eligible for only one of these demand uses, then domestic demand is equivalent to feed demand for corn, grain sorghum, oats, barley, and wheat; equivalent to crushing demand for soybeans, equivalent to milling demand for cotton, and equivalent to industrial demand for rice.

$$[7.6] \quad CRDDOM^t = CRDFED^t + CRDCRS^t + CRDMIL^t + CRDIND^t$$

Domestic demand for each of the model crops would be estimated as follows:

$$CNDDOM^t = CNDFED^b \left[ \begin{aligned} & 1 - 0.26(\% \Delta CNDPRI^t) + 0.23(\% \Delta MLIPRI^t) \\ & + 0.05(\% \Delta SMDPRI^t) + 1.02(\% \Delta MLIPRI^t) \end{aligned} \right]$$

$$\begin{aligned}
GSDDOM^t &= GSDFED^b \left[ 1 - 0.59(\% \Delta GSDPRI^t) + 0.66(\% \Delta MLIPRI^t) \right. \\
&\quad \left. + 0.59(\% \Delta CNDPRI^t) \right] \\
OTDDOM^t &= OTDFED^b \left[ 1 - 0.79(\% \Delta OTDPRI^t) + 0.79(\% \Delta CNDPRI^t) \right] \\
BRDDOM^t &= BRDFED^b \left[ 1 - 1.08(\% \Delta BRDPRI^t) + 1.08(\% \Delta CNDPRI^t) \right] \\
WHDDOM^t &= WHDFED^b \left[ 1 - 0.62(\% \Delta WHDPRI^t) + 0.19(\% \Delta CNDPRI^t) \right] \\
SYDDOM^t &= SYDCRS^b \left[ 1 - 0.27(\% \Delta SYDPRI^t) + 0.10(\% \Delta STCCRM^t) \right. \\
&\quad \left. + 0.02(\% \Delta CNDPRI^t) \right] \\
CTDDOM^t &= CTDMIL^b \left[ 1 - 0.05(\% \Delta CTDPRI^t) \right] \\
RCDDOM^t &= RCDIND^b \left[ 1 - 0.26(\% \Delta RCDPRI^t) \right]
\end{aligned}$$

## Food Demand

Food demand is estimated for wheat and rice, and is estimated as the baseline food demand level adjusted by the change in food demand resulting from a percentage change in own price and adjusted for a long run food demand adjustment response.

$$\begin{aligned}
[7.7] \quad CRDFOD^t &= CRDFOD^b \left[ 1 - \varepsilon_{12} \left( \frac{CRDPRI^t - CRDPRI^b}{CRDPRI^b} \right) \right] \\
&\quad + \lambda_{CRDFOD} (CRDFOD^{t-1} - CRDFOD^{b-1})
\end{aligned}$$

## Total Utilization

Total utilization for each model crop is the sum of the quantities demanded for export use, domestic use, food use, or other use, where *other use* is an exogenously-determined quantity demanded.

$$[7.8] \quad CRDTOT^t = CRDEXP^t + CRDDOM^t + CRDFOD^t + CRDOTH^t$$

## Price

The price of each model crop is estimated as the intersection of the supply and demand curves for that crop. Since crop supply is a function of past prices (i.e., once crop year production is determined, supply is fixed), price of each crop is determined by the intersection of the perfectly inelastic (horizontal) crop supply function and the expected demand function. Thus, the simulation price of each crop is estimated to be the baseline price adjusted for the price response due to a change in the relationship between supply and demand from the baseline level. Given a fixed supply curve, the demand system simultaneously solves for price and demand where price is the intersection of demand and supply.

Simulated crop price is the baseline price and an adjustment to the baseline price computed as the percentage change in quantity from the baseline level multiplied by the inverse of the demand elasticity, or price flexibility, for that crop. Price flexibilities for each model crop as they relate to the stock-to-use ratio are presented in table 7.3. The price flexibility coefficient for each crop relates the price responsiveness to the ratio of ending year commodity carryover and total utilization demand. When the stock-to-use ratio is low – the ending year inventory is small relative to demands – price flexibility is high and prices are more responsive to supply shifts. As the stock-to-use ratio increases, price is less responsive to supply shifts.

$$[7.9] \quad CRDPRI^t = CRDPRI^b \left[ 1 + CRDPFX \left( \frac{(CRSEFF^t - CRSEFF^b) - (CRDTOT^t - CRDTOT^b)}{CRSEFF^b} \right) \right]$$

## **Estimating Model Crop Derivative Products' Demands and Prices**

In addition to estimating model crop demands and prices, the demand system also simultaneously estimates demands and prices for model crop derivative products. Currently, only soybean derivative products (oil and meal) are included in the POLYSYS demand module. A set of six

derivative product demand and price equations are included in the demand system to estimate demand by use, effective supply, price, and a crushing margin. Demand equations relative to soybean products are presented below. Elasticities for soybean derivative product demand are presented in table 7.4 and price flexibilities are presented in table 7.5.

**Table 7.3. Price flexibility functions for demand module model crops.**

Crop	Price Flexibility for Stock-to-Use Ratio Value												
	< 0.033	0.033 - 0.05	0.05 - 0.066	0.066 - 0.10	0.10 - 0.15	0.15 - 0.20	0.20 - 0.25	0.25 - 0.30	0.30 - 0.35	0.35 - 0.50	0.50 - 0.55	0.55 - 0.60	> 0.60
Corn	-3.5	-3.5	-3.5	-3.5	-3.5	-2.75	-2.0	-2.0	-1.0	-1.0	-1.0	-1.0	-1.0
G. Sorg.	-3.5	-3.5	-2.64	-2.64	-2.31	-1.82	-1.32	-1.32	-1.0	-1.0	-1.0	-1.0	-1.0
Oats	-3.0	-3.0	-2.0	-2.0	-1.75	-1.38	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Barley	-2.16	-2.16	-1.44	-1.44	-1.26	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Wheat	-3.5	-3.5	-3.5	-3.5	-3.5	-3.0	-2.4	-2.4	-2.0	-2.0	-1.5	-1.5	-1.0
Soybean	-3.5	-3.5	-3.5	-3.0	-2.4	-2.0	-1.75	-1.75	-1.75	-1.75	-1.75	-1.75	-1.75
Cotton	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5	-3.0	-2.25	-2.25	-1.75	-1.75	-1.0	-1.0
Rice	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5	-3.0	-2.25	-2.25	-1.75	-1.75	-1.0	-1.0
Peanuts													
Sugar Cane	-3.0	-3.0	-3.0	-3.0	-2.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Sugar Beets	-3.0	-3.0	-3.0	-3.0	-2.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Dry Beans	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3

**Table 7.4. Demand elasticities for crop derivative products.**

	Elasticity Of			
	DPDEXP	DPDDOM	DPDDOM	DPDDOM
	With Respect To			
	DPDPRI	DPDPRI	MLIPRI	MLIPDN

Product	$\varepsilon_{13}$	$\varepsilon_{14}$	$\varepsilon_{15}$	$\varepsilon_{16}$
Soybean Oil	-0.25	-0.05		
Soybean Meal	-0.61	-0.25	0.19	1.00

**Table 7.5. Price flexibilities for crop derivative products.**

Product	Price Flexibility for Stock-to-Use Ratio of										
	< 0.005	0.005 - 0.0075	0.0075 - 0.01	0.01 - 0.015	0.015 - 0.020	0.020 - 0.05	0.05 - 0.08	0.08 - 0.10	0.10 - 0.12	0.12 - 0.15	> 0.15
Soybean Oil	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.25	-0.75	-0.5	-0.25	-0.0
Soybean Meal	-2.25	-1.9	-1.55	-1.2	-0.85	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5

### Beginning Stocks

Prior to estimation of the crop demand (and crop derivative product demand) system, the crop demand module estimates beginning stocks for a set of soybean products, currently including soybean oil and soybean meal. Beginning stocks for each derivative product are set equal to ending stocks in the previous period through an identity equation:

$$[7.10] \quad DPSBEG^t = DPDEND^{t-1}$$

### Export Demand

Export demand for each derivative product is the baseline estimated export demand for that product adjusted by the demand response due to a percentage change in the price of that product over the baseline price:

$$[7.11] \quad DPDEXP^t = DPDEXP^b \left[ 1 - \varepsilon_{13} \left( \frac{DPDPRI^t - DPDPRI^b}{DPDPRI^b} \right) \right]$$



## Domestic Demand

Domestic demand for each product is the baseline domestic demand adjusted by the demand response due to percentage changes in own price over baseline price. Soybean meal demand is further adjusted by the demand response due to percentage changes in the model livestock index price and the model livestock index of production, as soybean meal is used as a component of livestock feed:

$$[7.12] \quad DPDDOM^t = DPDDOM^b \left[ \begin{array}{l} 1 - \varepsilon_{14} \left( \frac{DPDPRI^t - DPDPRI^b}{DPDPRI^b} \right) \\ + \varepsilon_{15} \left( \frac{MLIPRI^t - MLIPRI^b}{MLIPRI^b} \right) \\ + \varepsilon_{16} \left( \frac{MLIPDN^t - MLIPDN^b}{MLIPDN^b} \right) \end{array} \right]$$

## Total Utilization

Total utilization for each product is the sum of the quantities demanded for export, domestic use, and other use, where *other use* is an exogenously-determined quantity demanded.

$$[7.13] \quad DPDTOT^t = DPDEXP^t + DPDDOM^t + DPDOTH^t$$

## Effective Supply

The effective supply of each product is the sum of production, imports, and beginning (or carryover) stocks. Production is calculated as the baseline level of production ( $DPSPDN^t$ ) plus the product of a conversion factor from whole soybeans to respective oil and meal products ( $DPCSOY$ ) and the change in the crushing demand over the baseline level, as estimated in the model crops portion of the demand module. Imports of each product are exogenously determined.

$$[7.14] \quad DPSEFF^t = \left[ DPSPDN^b + DPCSOY(SYDCRS^t - SYDCRS^b) \right] + DPSIMP^t + DPSBEG^t$$

## Price

Similarly to the estimation of price in the crop demand portion of the demand module, simulated prices in the derivative products portion of the demand system are estimated by adjusting a baseline price by the product of the percentage change in supply and a price flexibility. Price flexibilities for crop derivative products are related to the stock-to-use ratio, as before, and are presented in table 7.6.

$$[7.15] \quad DPDPRI^t = DPDPRI^b \left[ 1 + DPDPFX \left( \frac{(DPSEFF^t - DPSEFF^b) - (DPDTOT^t - DPDTOT^b)}{DPSEFF^b} \right) \right]$$

## Crushing Margin

A crushing margin for soybeans, with oil and meal derivative products, is estimated as the sum over all products of the price of the product multiplied by the conversion factor from soybeans to that derivative product (*SOC**SOY* and *SMC**SOY*) and multiplied by a production units conversion factor ( $\psi$ ) if necessary.

$$[7.16] \quad SYCCRM^t = SODPRI^t (SOC\text{SOY}) \psi_{SO} + SMDPRI^t (SMC\text{SOY}) \psi_{SM}$$

## **Ending Year Inventories**

### Ending Year Inventories

Upon the demand module's estimation of demands and prices for model crops and derivative products, ending year inventory for each model crop is calculated as the effective supply (as estimated in the crop supply module) less the total demand for all uses of that crop. Similarly, ending inventory for crop derivative products is calculated as the effective supply (as estimated in the crop demand module) less the total demand for all uses of that product.

$$[7.17] \quad \begin{aligned} CRDEND^t &= CRSEFF^t - CRDTOT^t \\ DPDEND^t &= DPSEFF^t - DPDTOT^t \end{aligned}$$

## **Example: Estimating Demands and Prices for Soybeans**

Although the crop demand module solves for demands and prices for all model crops and model crop derivative products simultaneously, presentation of the relevant crop demand equations for one specific commodity may serve as a useful example. Following are the demand system equations relevant to soybeans, with elasticities, long run adjustment coefficients, and price flexibilities inserted.

### **Export Demand**

Soybean export demand is the baseline export demand adjusted by the product of the soybean export demand elasticity with respect to own price and the percentage change in soybean price over the baseline level. There is no long run adjustment made to the baseline price since the soybean adjustment coefficient is zero. Export demand for soybean products is calculated similarly.

$$[7.18] \quad \begin{aligned} SYDEXP^t &= SYDEXP^b \left[ 1 - 0.57(\% \Delta SYDPRI^t) \right] + \left[ 0.0(\Delta SYDEXP^{t-1}) \right] \\ SODEXP^t &= SODEXP^b \left[ 1 - 0.25(\% \Delta SODPRI^t) \right] \\ SMDEXP^t &= SMDEXP^b \left[ 1 - 0.61(\% \Delta SMDPRI^t) \right] \end{aligned}$$

### **Crushing Demand**

Crushing demand for soybeans is calculated as the baseline crushing demand adjusted by the impacts of changes in own price, the soybean crushing margin, and the price of corn. Again, there is no long run adjustment made to the baseline crushing demand since the soybean crushing demand adjustment coefficient is zero.

$$[7.19] \quad SYDCRS^t = SYDCRS^b \left[ \begin{array}{l} 1 - 0.27(\% \Delta SYDPRI^t) \\ + 0.10(\% \Delta SYCCRM^t) \\ + 0.02(\% \Delta CNDPRI^t) \end{array} \right] + [0.0(\Delta SYDCRS^{t-1})]$$

### Crushing Margin

The soybean crushing margin is estimated as the price of soybean oil multiplied by the conversion factor from soybeans to soybean oil added to the product of the soybean meal price and the conversion factor from soybeans to soybean meal, which must be divided by 2000 to convert meal units to oil units.

$$[7.20] \quad SYCCRM^t = \frac{SODPRI^t(SOCSOY) + SMDPRI^t(SMCSOY)}{2000}$$

### Domestic Demand (Soybean Products)

An equation is not required for estimation of domestic demand for soybeans since domestic demand is identical to the crushing demand for soybeans, as they are not utilized for feed, milling, or industrial uses. Domestic demand equations are relevant for soybean oil and meal. Soybean oil is primarily used for industrial purposes and its domestic demand is calculated as the baseline demand adjusted by the impact of the percentage change in own price. Soybean meal is primarily used as a feed ingredient, so its domestic demand is its baseline level adjusted by the impact of the percentage change in own price, the percentage change in the livestock price index, and the percentage change in the livestock production index.

$$[7.21] \quad SODDOM^t = SODDOM^b [1 - 0.05(\% \Delta SODPRI^t)]$$

$$SMDDOM^t = SMDDOM^b \left[ \begin{array}{l} 1 - 0.25(\% \Delta SMDPRI^t) + 0.19(\% \Delta MLIPRI^t) \\ + 1.00(\% \Delta MLIPDN^t) \end{array} \right]$$

## Total Utilization

Total utilization of soybeans is the sum of soybean demand for utilization as exports, domestic demand, and other demand uses. Note that an equation was not required for estimation of domestic demand for soybeans since domestic demand is identical to the crushing demand for soybeans.

$$SYDTOT^t = SYDEXP^t + SYDCRS^t + SYDOTH^t$$

$$[7.22] \quad SODTOT^t = SODEXP^t + SODDOM^t + SODOTH^t$$

$$SMDTOT^t = SMDEXP^t + SMDDOM^t + SMDOTH^t$$

## Effective Supply (Soybean Products)

Production of soybean oil and meal is estimated as the baseline production level adjusted by the change in the soybean crushing demand over baseline levels multiplied by the soybean to derivative product conversion factor. Then effective supply of soybean oil and meal is the sum of the production level of each product, imports (exogenous), and beginning stocks (previously estimated by the demand module).

$$[7.23] \quad SOSEFF^t = [SOSEFF^b + SOC\text{SOY}(\Delta SYDCRS^t)] + SOSIMP^t + SOSBEG^t$$

$$SMSEFF^t = [SMSEFF^b + SMC\text{SOY}(\Delta SYDCRS^t)] + SMSIMP^t + SMSBEG^t$$

## Price

Soybean (soybean product) price is calculated as the baseline price adjusted by the price impacts of a change in soybean (soybean product) supply over the baseline level. The price impact is the percentage change in the difference between the supply change and demand change over baseline levels multiplied by the appropriate price flexibility, which is determined by the stocks-to-use ratio. If the soybean stock-to-use ratio is 0.12 for soybeans, 0.09 for soybean oil, and 0.007 for soybean meal, then the corresponding price flexibilities would be -2.4, -0.75, and -1.90 respectively, and soybean and soybean product prices would be calculated as:

$$\begin{aligned}
& SYDPRI^t = SYDPRI^b \left[ 1 + 0.12 \left( \frac{\Delta SYSEFF^t - \Delta SYDTOT^t}{SYSEFF^b} \right) \right] \\
[7.24] \quad & SODPRI^t = SODPRI^b \left[ 1 + 0.09 \left( \frac{\Delta SOSEFF^t - \Delta SODTOT^t}{SOSEFF^b} \right) \right] \\
& SMDPRI^t = SMDPRI^b \left[ 1 + 0.007 \left( \frac{\Delta SMSEFF^t - \Delta SMDTOT^t}{SMSEFF^b} \right) \right]
\end{aligned}$$

### Ending Year Inventory

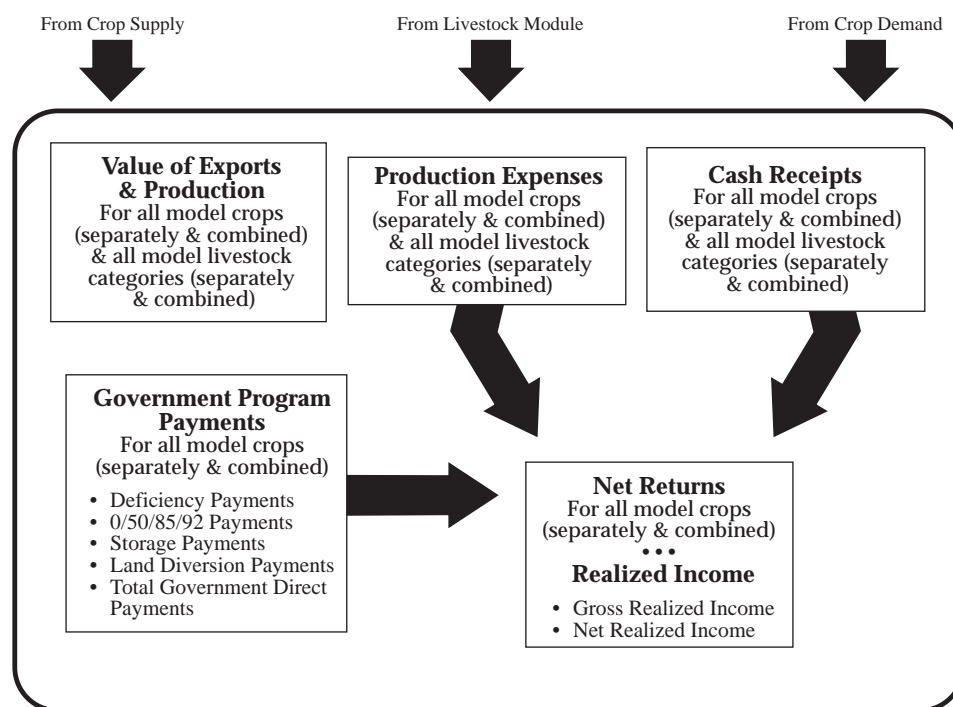
Finally, ending year inventories for soybeans, soybean oil, and soybean meal are calculated as the effective supply less the total utilization in simulation year t:

$$\begin{aligned}
& SYDEND^t = SYSEFF^t - SYDTOT^t \\
[7.25] \quad & SODEND^t = SOSEFF^t - SODTOT^t \\
& SMDEND^t = SMSEFF^t - SMDTOT^t
\end{aligned}$$

# INCOME MODULE

The POLYSYS income module receives data generated in the livestock, crop supply, and crop demand modules and uses a set of identity equations and econometric models to determine crop and livestock receipts and expenses accruing to producers, and receipts and expenses accruing to government programs. These estimates are then combined in the income module to estimate net realized income. An overview of the income module is presented in figure 8.1.

**Figure 8.1. Overview of POLYSYS Income Module.**



## Crop and Livestock Value of Production and Exports

### Value of Production and Crop Exports

Prior to the estimation of cash receipts, the income module calculates the total value of production by crop and the total value of production by livestock category. Estimates of crop production by crop ( $CRSPDN^t$ ) are supplied by the crop supply module and crop price estimates ( $CRDPRI^t$ ) are provided by the crop demand module. Estimates of livestock production by category ( $LVSPDN^t$ ) and livestock price estimates ( $LVDPRI^t$ ) are supplied by the livestock module. Value of production for each model crop ( $CRVPDN^t$ ) and model livestock category ( $LVVPDN^t$ ) are estimated as:

$$[8.1] \quad CRVPDN^t = CRSPDN^t (CRDPRI^t)$$

$$[8.2] \quad LVVPDN^t = LVSPDN^t (LVDPRI^t)$$

In a similar manner, the value of crop exports is estimated as the product of export demand and price. Crop export demand and price are supplied by the crop demand module.

$$[8.3] \quad CRVEXP^t = CRDEXP^t (CRDPRI^t)$$

## Crop and Livestock Cash Receipts

Because some portion of crop and livestock commodities produced in year  $t$  are not sold on the market (due to storage, use as a livestock production input, etc.), cash receipts are not equivalent to the value of production in time period  $t$ . Crop cash receipts are estimated as a function of current and lagged prices and production. Some of the equations for crop and livestock cash receipts are characterized by autocorrelation. To correct for autocorrelation, an estimate of rho ( $\rho$ ) is included for some crops and livestock commodities. The general form for estimation of crop cash receipts, including correction for autocorrelation where applicable, is:



$$\begin{aligned}
[8.4] \quad CRRCSH^t = & \alpha_1(1-\rho) + \alpha_2(CRVPDN^{t-1} - \rho CRVPDN^{t-2}) + \\
& \alpha_3(CRVPDN^t - \rho CRVPDN^{t-1}) + \\
& \alpha_4 \left[ \frac{(CRDEND^{t-1} - CRDEND^{t-2}) - \rho(CRDEND^{t-2} - CRSBEG^t)}{\rho(CRDEND^{t-2} - CRSBEG^t)} \right] + \rho(CRRCSH^{t-1})
\end{aligned}$$

$$\begin{aligned}
[8.5] \quad LVRCSH^t = & \beta_1(1-\rho) + \beta_2(LVVPDN^{t-1} - \rho LVVPDN^{t-2}) + \\
& \beta_3 \left[ \frac{(LVDPRI^t - LVDPRI^{t-1}) - \rho(LVDPRI^{t-1} - LVDPRI^{t-2})}{\rho(LVDPRI^{t-1} - LVDPRI^{t-2})} \right] + \rho(LVRCSH^{t-1})
\end{aligned}$$

Without correction for autocorrelation ( $\rho=0$ ) the cash receipt equations for crops and livestock reduce to:

$$\begin{aligned}
[8.5a] \quad CRRCSH^t = & \alpha_1 + \alpha_2(CRVPDN^{t-1}) + \alpha_3(CRVPDN^t) \\
& + \alpha_4(CRDEND^{t-1} - CRDEND^{t-2})
\end{aligned}$$

$$[8.6a] \quad LVRCSH^t = \beta_1 + \beta_2(LVVPDN^{t-1}) + \beta_3(LVDPRI^t - LVDPRI^{t-1})$$

Parameter estimates for  $\alpha$  and  $\beta$  for estimating cash receipts in equations 8.4 and 8.5 are presented in Tables 8.1 and 8.2. As an example, cash receipts for corn in year  $t$  would be calculated as:

$$\begin{aligned}
[8.4b] \quad CNRCSH^t = & -235.21 + 0.454(CNVPDN^{t-1} - 0.576 CNVPDN^{t-2}) + \\
& 0.258(CNVPDN^t - 0.576 CNVPDN^{t-1}) + 0.576(CNRCSH^{t-1})
\end{aligned}$$

**Table 8.1. Model Crop Cash Receipt Coefficients.**

Crop	$\alpha_1$	$\alpha_2$	$\alpha_3$	$\alpha_4$	$\rho$
Corn	-555.750	0.435	0.278	0	0.576
Grain Sorghum	81.396	0.286	0.461	0	0
Barley	79.967	-0.077	0.357	0	0
Oats	-22.732	0.490	0.340	-0.451	0
Wheat	77.239	0.108	0.839	0	0
Soybeans	-73.626	0.542	0.455	0	0.628
Cotton	283.960	0.375	0.631	0	0
Rice	283.960	0.375	0.631	0	0

**Table 8.2. Model Livestock Cash Receipt Coefficients.**

<b>Livestock</b>	<b><math>\beta_1</math></b>	<b><math>\beta_2</math></b>	<b><math>\beta_3</math></b>	<b><math>\rho</math></b>
Beef	-106.358	0.073	103.402	0
Pork	133.939	0.014	13.373	0
Lamb & Mutton	36.582	0.020	2.094	0.564
Broilers	-25.306	0.009	-29.923	0
Turkeys	-51.240	0.009	0	0.565
Eggs	-75.173	0.010	0	0
Milk	-160.538	0.001	-28.982	0

## Crop Government Program Payments

For each of the model crops, the income module then utilizes production and demand data estimated in the crop supply and demand modules in a series of identity equations to estimate direct government program crop payments.

Recall that upon estimation of crop prices in the crop demand module, the crop supply module then estimated crop year government program deficiency payments for each crop. Deficiency payments were estimated to be the product of eligible program acreage (base acreage less acreage idled due to minimum acreage reduction requirements and ineligible acreage due to normal flex acreage requirements) and government program yield and the deficiency payment rate (the target price less the higher of the market price or the price support (CCC loan rate)).

### Conversion to Calendar Year Deficiency Payments

Deficiency payments are made on each crop for the crop year. Since POLYSYS simulations are for calendar year intervals, the income module must convert deficiency payments to calendar year payments. Government program deficiency payments for each model crop in calendar year  $t$  ( $CRPDEF^t$ ), are the sum of government program deficiency payments in *crop year*  $t$  ( $CRPDEF^{(cy)t}$ ) multiplied by the percentage of

payments made in *calendar year t* ( $CRCPHC$ ) and the government program deficiency payments in the *previous crop year* ( $CRPDEF^{(cy)t-1}$ ) multiplied by the percentage of previous crop year payments ( $(cy)t-1$ ) made in *calendar year t* ( $1 - CRCPHC$ ).

$$[8.5] \quad CRPDEF^t = \frac{CRCPHC(CRPDEF^{(cy)t}) + (1 - CRCPHC)CRPDEF^{(cy)t-1}}{100}$$

Since the exogenous variable indicating the percentage of deficiency payments that occur in a given calendar year is expressed as a percentage ranging from zero to 100, the estimates must then be converted back to a decimal expression, accomplished by dividing the diversion payment by 100.

### 0/85/92 and 50/85/92 Payments

Recall that the deficiency payments previously estimated were made on all eligible program acreage – base acreage less required reduced acreage less normal flex acreage. Under the 0/85/92 and 0/50/92 government program guidelines, participating producers had the option of receiving a predetermined percentage of deficiency payments for a portion of eligible deficiency payment acreage idled for conservation use or planted to some minor oilseeds (under program restrictions). The income module calculates government outlays under the 0/85/92 and 50/82/92 programs ( $CRPZ92^t$ ) as the acreage in the program ( $CRAZ92^t$ ) multiplied by the deficiency payment rate (target price less the higher of the market price or basic loan rate) multiplied by the program percentage of deficiency payment rate received ( $CRGDPR^t$ ):

$$[8.6] \quad CRPZ92^t = CRAZ92^t \left( CRGTAR^t - \max\{CRDPRI^t, CRGBLR^t\} \right) \theta^t CRGDPR^t$$

### Storage Payments for Farmer Owned Reserves

Government program payments also accrue to producers for storage payments made on the portion of the crop held in the farmer-owned reserve (FOR) program. Government outlays are the exogenous storage payment rate for the crop ( $CRGSPR^t$ ) multiplied by the lagged average stock level of farmer-owned reserves ( $CRDFOR^{t-1}$ ), where:

$$[8.7] \quad CRPSTR^t = CRGSPR^t (CRDFOR^{t-1})$$

### Land Diversion Payments

Payments made on acreage in land diversion are calculated using the estimate of acreage in land diversion ( $CRADIV^t$ ) from the crop supply module. The diverted acreage is multiplied by the exogenous payment rate for diverted land ( $CRGDVR^t$ ) and multiplied by the government program yield for the crop to estimate diversion payments. This is then summed to the estimate of diversion payments from acreage held in the 0/85/92 and 50/85/92 program to yield an estimate of total land diversion payments.

$$[8.8] \quad CRPDIV^t = CRADIV^t (CRGDVR^t) CRGYLD^t + CRPZ92^t$$

### Total Direct Government Payments

Total direct government payments for each crop are then calculated as the sum of crop deficiency payments (paid in calendar year  $t$ ), storage payments for crops held in farmer-owned reserves, crop diversion payments for land diverted under optional paid diversion programs or 0/85/92 and 0/50/92 programs, and exogenously-determined fixed lump sum payments.

$$[8.9] \quad CRPGPD^t = CRPDEF^t + CRPSTR^t + CRPDIV^t + CRPPFC^t$$

Most government crop payment programs were replaced by lump sum production flexibility contract (PFC) payments in the 1996 FAIR Act. Thus total direct government payments in such a policy setting would be equal to the fixed lump sum government PFC payments ( $CRPPFC^t$ ). PFC payments are determined in part by a producer's historical program acreage base for each crop, but payments are made independent of present or future production decisions. The lump sum PFC payments to producers are exogenously determined by the farm's historical level of commodity program acreage, program yield, total commodity payment level, number of producers enrolled in the PFC program, and aggregate payment limits.

## Crop Receipts and Net Returns

### Total Cash Receipts & Government Payments

Crop cash receipts and direct government payments are then summed to estimate total cash receipts and government direct payments for each crop.

$$[8.10] \quad CRRCGP^t = CRRCSH^t + CRPGPD^t$$

### Crop Net Returns

Recall that expected average variable expenditures per acre for each crop in each region were estimated in the crop supply module prior to solution of the LP models (equation 6.1). Upon solution of the regional LP models, total variable expenditures were estimated according to equation 6.21. These estimates of total variable expenditures were then summed over all POLYSYS regions to estimate national total variable expenditures for each model crop ( $CRXTLV^t$ ), according to equation 6.23. The income module then subtracts the estimate of total variable expenditures from the sum of the estimates of total value of production for each crop and government total direct payments to estimate net returns for each crop.

$$[8.11] \quad CRRNET^t = CRVPDN^t + CRPGPD^t - CRXTLV^t$$

## Aggregate Value, Receipt, Payment, and Net Return Variables

Upon estimation of production and export value, cash receipts, government direct payments, cash receipts and government payments, and net returns, the income module then aggregates the estimated variables across all model crops (or model livestock commodities as appropriate) to obtain aggregate value, receipt, payment, and return variables for all model crops and livestock.

### Value of Production

$$[8.12] \quad MCVPDN^t = \sum_{CR} CRVPDN^t$$

$$[8.13] \quad MLVPDN^t = \sum_{LV} LVVPDN^t$$

### Value of Exports

$$[8.14] \quad MCVEXP^t = \sum_{CR} CRVEXP^t$$

### Cash Receipts

$$[8.15] \quad MCRCSH^t = \sum_{CR} CRRCSH^t$$

$$[8.16] \quad MLRCSH^t = \sum_{LV} LVRCSH^t$$

### Deficiency Payments

$$[8.17] \quad MCPDEF^t = \sum_{CR} CRPDEF^t$$

### Storage Payments

$$[8.18] \quad MCPSTR^t = \sum_{CR} CRPSTR^t$$

### Diversion Payments

$$[8.19] \quad MCPDIV^t = \sum_{CR} CRPDIV^t$$

### Total Direct Government Payments

$$[8.20] \quad MCPGPD^t = \sum_{CR} CRPGPD^t$$

### Cash Receipts and Government Payments

$$[8.21] \quad MCRCGP^t = \sum_{CR} CRRCGP^t$$

### Total Variable Expenditures

$$[8.22] \quad MCXTLV^t = \sum_{CR} CRXTLV^t$$

### Net Returns

$$[8.23] \quad MCRNET^t = \sum_{CR} CRRNET^t$$

## U.S. Total Receipt, Payment, Expense, and Income Variables

### Total Cash Receipts

The income module then estimates total cash receipts for crops and livestock as the sum of the cash receipt estimates for the model crops or model livestock commodities and an exogenous estimate of other crop ( $TLROCC^t$ ) or livestock ( $TLROL C^t$ ) cash receipts.

$$[8.24] \quad TLRCCS^t = MCRC SH^t + TLROCC^t$$

$$[8.25] \quad TLRLCS^t = MLRC SH^t + TLROL C^t$$

Total cash receipts for all U.S. crops and livestock are then the sum of the estimated crop and livestock cash receipts plus national agriculture cash receipts from any other sources ( $TLROCS^t$ ), which are exogenously introduced into the POLYSYS income module.

$$[8.26] \quad TLRC SH^t = TLRCCS^t + TLRLCS^t + TLROCS^t$$

### Total Government Payments

Total U.S. government program payments are calculated as the sum of model crop government total direct payments and government payments made to U.S. agriculture for programs other than model crop programs ( $TLPOGP^t$ ), which are exogenously introduced into the income module.

$$[8.27] \quad TLP GPR^t = MCP GPD^t + TLPOGP^t$$

### Total Cash Receipts And Government Payments

Total U.S. cash receipts (from model crops, model livestock, other crops, other livestock, and other agricultural programs) are then added to the estimate of total government payments (model crop payments and other government program payments) to estimate national total cash receipts and government payments.

$$[8.28] \quad TLRCGP^t = TLRC SH^t + TLP GPR^t$$

### Realized Gross Income

Realized gross income for U.S. agriculture is then estimated as the sum of total national crop receipts and government payments and national non-monetary agricultural income, which is exogenously introduced into the income module.

$$[8.29] \quad TLRRGI^t = TLRCGP^t + TLRNMI^t$$

### Livestock Expenses

The income module then estimates national livestock feed expenses ( $TLXFED^t$ ) and purchased livestock expenses ( $TLXPLV^t$ ). For both estimates, the baseline estimate of feed or purchased livestock expenses is adjusted by the product of the ratios of the estimated producer price index for feed and the farm production index for livestock to their baseline levels.

$$[8.30] \quad TLXFED^t = TLXFED^b \left( \frac{IPIFED^t}{IPIFED^b} \right) \left( \frac{MLIPDN^t}{MLIPDN^b} \right)$$

$$[8.31] \quad TLXPLV^t = TLXPLV^b \left( \frac{IPIFED^t}{IPIFED^b} \right) \left( \frac{MLIPDN^t}{MLIPDN^b} \right)$$

### Other And Fixed Production Expenses

Other and fixed production expenses are calculated as a function of the baseline level of fixed and other production expenses adjusted by the impact of a lagged percentage change in the estimate of net realized income over the baseline value. The response parameter is estimated to be 0.05, and national other and fixed production expenses are estimated as:

$$[8.32] \quad TLXOTH^t = TLXOTH^b \left( 1 + 0.05 \frac{TLRRNI^{t-1} - TLRRNI^{b-1}}{TLRRNI^{b-1}} \right)$$

### Total Production Expenses

The income module then sums the estimates of livestock feed expenses, purchased livestock expenses, other and fixed production expenses, and total variable expenses for model crops to estimate total agricultural production expenses.

$$[8.33] \quad TLXPDN^t = TLXFED^t + TLXPLV^t + TLXOTH + MCXTLV^t$$



### Value of Crop Production and Total Direct Payments Less Variable Expenses

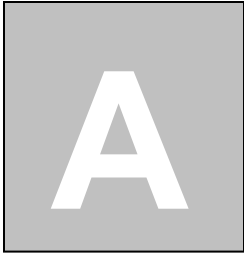
The sum of model crop value of production and model crop total government direct payments are then netted model crop total variable expenditures to estimate a crop value of production and payments less expenses.

$$[8.34] \quad TLRPPV^t = MCVPDN^t + MCPGPD^t - MCXTLV^t$$

### Net Realized Income

Finally, the income module estimates realized net income for U.S. agriculture as total realized gross income less total production expenses.

$$[8.35] \quad TLRRNI^t = TLRRGI^t - TLXPDN^t$$



# **APPENDIX**

## **Derivation of Equilibrium Displacement Model Reduced Form Solutions**

Structrual Equations:

$$[A.1] \quad D_C^* = \varepsilon_{C,P_C} P_C^* + \varepsilon_{C,P_L} P_L^* + \varepsilon_W W^*$$

$$[A.2] \quad S_C^* = \eta_{C,P_C} P_C^* + \eta_{C,P_L} P_L^* + \eta_X X^*$$

$$[A.3] \quad D_L^* = \varepsilon_{L,P_C} P_C^* + \varepsilon_{L,P_L} P_L^* + \varepsilon_Y Y^*$$

$$[A.4] \quad S_L^* = \eta_{L,P_C} P_C^* + \eta_{L,P_L} P_L^* + \eta_Z Z^*$$

$$[A.5] \quad Q_C^* = D_C^* = S_C^*$$

$$[A.6] \quad Q_L^* = D_L^* = S_L^*$$

Rearrange so that endogenous variables are a function of exogenous variables:

$$[A.7] \quad Q_C^* - \varepsilon_{C,P_C} P_C^* - \varepsilon_{C,P_L} P_L^* = \varepsilon_W W^*$$

$$[A.8] \quad Q_C^* - \eta_{C,P_C} P_C^* - \eta_{C,P_L} P_L^* = \eta_X X^*$$

$$[A.9] \quad Q_L^* - \varepsilon_{L,P_C} P_C^* - \varepsilon_{L,P_L} P_L^* = \varepsilon_Y Y^*$$

$$[A.10] \quad S_L^* - \eta_{L,P_C} P_C^* - \eta_{L,P_L} P_L^* = \eta_Z Z^*$$

Arrange in matrix form  $\mathbf{\Gamma}\mathbf{\Delta} = \mathbf{B}\mathbf{\Omega}$  where  $\mathbf{\Gamma}$  is a matrix of demand and supply crop and livestock elasticities,  $\mathbf{\Delta}$  is a matrix of exogenous variables,  $\mathbf{B}$  is a matrix of elasticities of demand and supply curve shifter variables for crops and livestock, and  $\mathbf{\Omega}$  is a matrix of exogenous variables:

$$[A.11] \quad \begin{bmatrix} 1 & 0 & -\varepsilon_{cP_c} & -\varepsilon_{cP_l} \\ 1 & 0 & -\eta_{cP_c} & -\eta_{cP_l} \\ 0 & 1 & -\varepsilon_{lP_c} & -\varepsilon_{lP_l} \\ 0 & 0 & -\eta_{lP_c} & -\eta_{lP_l} \end{bmatrix} \begin{bmatrix} Q_C^* \\ Q_L^* \\ P_C^* \\ P_L^* \end{bmatrix} = \begin{bmatrix} \varepsilon_W & 0 & 0 & 0 \\ 0 & \varepsilon_X & 0 & 0 \\ 0 & 0 & \varepsilon_Y & 0 \\ 0 & 0 & 0 & \varepsilon_Z \end{bmatrix} \begin{bmatrix} W^* \\ X^* \\ Y^* \\ Z^* \end{bmatrix}$$

Let the matrix  $\mathbf{E}$  represent the crop and livestock demand elasticities and let the matrix  $\mathbf{H}$  represent the crop and livestock supply elasticities, such that:

$$[A.12] \quad \mathbf{E} = \begin{bmatrix} \varepsilon_{cP_c} & \varepsilon_{cP_l} \\ \varepsilon_{lP_c} & \varepsilon_{lP_l} \end{bmatrix} = \begin{bmatrix} \varepsilon_{11} & \varepsilon_{12} \\ \varepsilon_{21} & \varepsilon_{22} \end{bmatrix}$$

$$[A.13] \quad \mathbf{H} = \begin{bmatrix} \eta_{cP_c} & \eta_{cP_l} \\ \eta_{lP_c} & \eta_{lP_l} \end{bmatrix} = \begin{bmatrix} \eta_{11} & \eta_{12} \\ \eta_{21} & \eta_{22} \end{bmatrix}$$

Solve for  $\Delta$ . Solution to the system yields  $\Delta = \Pi \Omega$  where  $\Pi$  indicates a matrix of reduced form parameters, such that  $\Pi = \Gamma^{-1} \mathbf{B}$ . The structural model (equations [A.1]-[A.6]) is solved for the reduced form solutions:

$$[A.14] \quad \begin{bmatrix} Q_c^* \\ Q_l^* \\ P_c^* \\ P_l^* \end{bmatrix} = \begin{bmatrix} \pi_{11} W^* + \pi_{12} X^* + \pi_{13} Y^* + \pi_{14} Z^* \\ \pi_{21} W^* + \pi_{22} X^* + \pi_{23} Y^* + \pi_{24} Z^* \\ \pi_{31} W^* + \pi_{32} X^* + \pi_{33} Y^* + \pi_{34} Z^* \\ \pi_{41} W^* + \pi_{42} X^* + \pi_{43} Y^* + \pi_{44} Z^* \end{bmatrix}$$

where

$$[A.15] \quad \Pi = \begin{bmatrix} \pi_{11} & \pi_{12} & \pi_{13} & \pi_{14} \\ \pi_{21} & \pi_{22} & \pi_{23} & \pi_{24} \\ \pi_{31} & \pi_{32} & \pi_{33} & \pi_{34} \\ \pi_{41} & \pi_{42} & \pi_{43} & \pi_{44} \end{bmatrix}$$

and

$$[A.16] \quad \pi_{11} = \frac{-\varepsilon_w (\eta_{11} \varepsilon_{22} + \eta_{12} \eta_{21} - \eta_{12} \varepsilon_{21} - \eta_{11} \eta_{22})}{\varepsilon_{12} \eta_{21} - \varepsilon_{21} \eta_{12}}$$

$$[A.17] \quad \pi_{12} = \frac{\varepsilon_w (\varepsilon_{11} \varepsilon_{22} + \varepsilon_{12} \eta_{21} - \varepsilon_{12} \varepsilon_{21} - \eta_{22} \varepsilon_{11})}{\varepsilon_{12} \eta_{21} - \varepsilon_{21} \eta_{12}}$$

$$[A.18] \quad \pi_{13} = \frac{-\varepsilon_w (\varepsilon_{11} \eta_{12} - \varepsilon_{12} \eta_{11})}{\varepsilon_{12} \eta_{21} - \varepsilon_{21} \eta_{12}}$$

$$[A.19] \quad \pi_{14} = \frac{\varepsilon_w (\varepsilon_{11} \eta_{12} - \varepsilon_{12} \eta_{11})}{\varepsilon_{12} \eta_{21} - \varepsilon_{21} \eta_{12}}$$

$$[A.20] \quad \pi_{21} = \frac{-\eta_x (\varepsilon_{21} \eta_{22} - \eta_{21} \varepsilon_{22})}{\varepsilon_{12} \eta_{21} - \varepsilon_{21} \eta_{12}}$$

$$[A.21] \quad \pi_{22} = \frac{-\eta_x (\varepsilon_{21} \eta_{22} - \eta_{21} \varepsilon_{22})}{\varepsilon_{12} \eta_{21} - \varepsilon_{21} \eta_{12}}$$

$$[A.22] \quad \pi_{23} = \frac{\eta_x (\eta_{11} \varepsilon_{22} + \varepsilon_{12} \varepsilon_{21} - \varepsilon_{21} \eta_{12} - \varepsilon_{11} \varepsilon_{22})}{\varepsilon_{12} \eta_{21} - \varepsilon_{21} \eta_{12}}$$

$$[A.23] \quad \pi_{24} = \frac{-\eta_x (\eta_{11} \varepsilon_{22} + \varepsilon_{12} \varepsilon_{21} - \varepsilon_{21} \eta_{12} - \varepsilon_{11} \varepsilon_{22})}{\varepsilon_{12} \eta_{21} - \varepsilon_{21} \eta_{12}}$$

$$[A.24] \quad \pi_{31} = \frac{-\varepsilon_y (\eta_{12} + \varepsilon_{12})}{\varepsilon_{12} \eta_{21} - \varepsilon_{21} \eta_{12}}$$

$$[A.25] \quad \pi_{32} = \frac{-\varepsilon_y(\eta_{12} + \varepsilon_{12})}{\varepsilon_{12}\eta_{21} - \varepsilon_{21}\eta_{12}}$$

$$[A.26] \quad \pi_{33} = \frac{-\varepsilon_y(\eta_{12} + \varepsilon_{12})}{\varepsilon_{12}\eta_{21} - \varepsilon_{21}\eta_{12}}$$

$$[A.27] \quad \pi_{34} = \frac{\varepsilon_y(\eta_{12} + \varepsilon_{12})}{\varepsilon_{12}\eta_{21} - \varepsilon_{21}\eta_{12}}$$

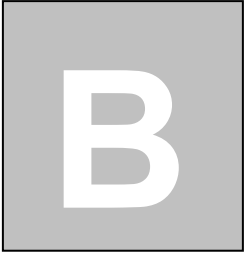
$$[A.28] \quad \pi_{41} = \frac{-\eta_z(\eta_{21} - \varepsilon_{11})}{\varepsilon_{12}\eta_{21} - \varepsilon_{21}\eta_{12}}$$

$$[A.29] \quad \pi_{42} = \frac{-\eta_z(\eta_{21} - \varepsilon_{11})}{\varepsilon_{12}\eta_{21} - \varepsilon_{21}\eta_{12}}$$

$$[A.30] \quad \pi_{43} = \frac{\eta_z(\eta_{21} - \varepsilon_{11})}{\varepsilon_{12}\eta_{21} - \varepsilon_{21}\eta_{12}}$$

$$[A.31] \quad \pi_{44} = \frac{-\eta_z(\eta_{21} - \varepsilon_{11})}{\varepsilon_{12}\eta_{21} - \varepsilon_{21}\eta_{12}}$$

The elements of the  $\Pi$  matrix may be interpreted as “general equilibrium” elasticities in the sense that they measure the percentage change in the equilibrium level of each endogenous variable attributed to each exogenous variable.



# **APPENDIX**

## **POLYSYS Variables**

**Variable Types, Categories, and Names    B.1**

**Livestock Variables    B.2**

**Crop Variables    B.3**

**Income Variables    B.4**

## POLYSYS Variables

All POLYSYS variable names consist of six characters and a superscript to indicate the relevant period and a subscript (as appropriate) to indicate the relevant region. The first two characters in the variable name indicate the variable type. The third character indicates the variable category to which the variable belongs. Finally, the last three characters indicate the variable name. A description of the variable naming strategy is included, followed by a complete list of POLYSYS variables.

### Variable Type

The first two characters of the variable name indicate the type of variable under consideration. Available types of POLYSYS variables include

- individual model crops, where CN=corn, GS=grain sorghum, BR=barley, OT=oats, WH=wheat, SY=soybeans, CT=cotton, RC=rice, PN=peanuts, SC=sugar cane, SB=sugar beets, and DB=dry beans;
- individual model livestock commodities, where BF=beef, BL=broilers, LM=lamb and mutton, PK=pork, TK=turkeys, EG=eggs, and MK=milk;
- individual crop derivative products, where SO=soybean oil and SM=soybean meal;
- aggregate model crops or livestock commodities, where MC=twelve model crops and ML=seven model livestock commodities;
- aggregate total variables, where TL=total;
- input variables, where IP=input price, IQ=input quantity, and IV=input value.

An additional shorthand variable type is used extensively in this documentation to indicate application to all model crops, livestock commodities, or derivative products. The variable type CR indicates a

matrix of twelve model crop variables; the variable type LV indicates a matrix of seven model livestock variables; and the variable type DP indicates a matrix of two crop derivative products.

### Variable Category

The third character in a POLYSYS variable name indicates the variable category to which that variable belongs. POLYSYS variables are categorized as one of the following: Acreage (A), Conversion Factor (C), Demand (D), Government Program (G), Index (N), Payment (P), Receipt (R), Supply (S), Value (V), or Expense (X).

### Variable Name

Finally, each variable is assigned a three-character variable name. A complete list of relevant POLYSYS variable names is presented in Appendix B.1. It should be noted that the same variable name may apply to multiple variable types. For example, the cash variable, CSH, may be combined with CNRCSH to indicate corn cash receipts, or may be combined with MCRC SH to indicate cash receipts from all twelve model crops or may be combined with TLRC SH to indicate total cash receipts from model crops, model livestock, and other non-model crops and livestock or non-agricultural sources). The same variable name and type may also be combined with multiple variable categories. For example, MKDPRI indicates a market demand milk price variable, while MKIPRI indicates a milk index price variable.

### Variable Period

A superscript character indicates the relevant period for the variable. Simulation periods are indicated with a superscript  $t$ . If the initial year of a simulation is  $t$ , the second simulation year is  $t+1$ , and a simulation is of duration  $N$ , such that the final year of a simulation is indicated by  $t+N-1$ . For each simulation year, the variable's baseline counterpart is indicated by a superscript  $b$ . The baseline variable corresponding to simulation year  $t$  would be  $b$ ,  $t+1$  would be  $b+1$ , and  $t+N-1$  would be  $b+N-1$ . A one-period lagged simulation (baseline) variable would be indicated by a superscript  $t-1$  ( $b-1$ ). Unless denoted otherwise, simulation periods are calendar years. In some cases, variables refer to crop year periods, where crop year  $t$  would be indicated  $(cy)t$ .



### Variable Region

Some POLYSYS variables are relevant for up to 305 production regions corresponding to ASDs. Those variables are characterized by a subscript  $R$ , where  $R$  may take on a value from one to 305.



















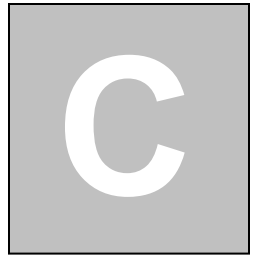








# APPENDIX



## POLYSYS Production Regions























































































































































