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The ERS Country-Commodity Linked System: Documenting Its International Country and Regional Agricultural Baseline Models

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Abstract

To facilitate development of USDA's annual 10-year agricultural projections, the Economic Research Service (ERS) maintains models of the agricultural sector of 44 major exporting and importing countries and regions, including the United States. These models, customized to the specific countries and regions, produce medium- to long-term projections of the supply and use of major agricultural commodities based on behavioral responses to world market prices, trade and domestic agricultural policies, and domestic commodity prices. ERS also uses the models for research on contemporary global or country-specific, agriculture-related issues. While the models, which together make up the Country-Commodity Linked System (CCLS), can be run in isolation, they also can be linked to simultaneously solve 24 commodity markets, obtaining equilibrium world prices and balanced trade. To increase knowledge and understanding of the models, this report describes their underlying economic structure and provides an overview of the CCLS. It also presents an illustrative example of how the models were used to examine the impact on domestic and world markets of increasing crop yields in one region of the world.

Keywords: agriculture, agriculture policy, agricultural sector model, documentation, agricultural trade, supply, demand, price, projections, USDA agricultural baseline, Country-Commodity Linked System, CCLS, linked system, partial equilibrium model

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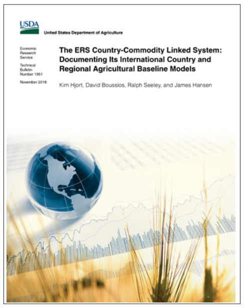

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What Is the Issue?

In agriculture, many policy and business decisions require consideration of long timeframes. Public and private projections of market indicators help decision makers evaluate the potential costs and benefits of alternative courses of action. With quantitative and qualitative input from many of its agencies, the U.S. Department of Agriculture publishes annual, 10-year agricultural projections that are instrumental in policy and budgetary matters. Quantitative input includes data from country and regional partial equilibrium agricultural sector models maintained by USDA's Economic Research Service (ERS). To expand understanding of these analytical tools, which constitute the Country-Commodity Linked System (CCLS), this report describes the models' underlying economic structure and presents an overview of the CCLS.

What Did the Study Find?

ERS uses a system of 44 country- and region-specific recursive partial equilibrium models to generate projections for 5 to 20 years into the future, with 10 years used for the official USDA baseline. Each model contains up to 32 commodities or commodity aggregates, with an average of 12 commodities per model. The standard commodity set includes livestock products, grains, oilseeds and oilseed products, cotton, and sugar. The models use economic behavioral relationships to project production, use, and trade quantities based on world and domestic commodity market prices and assumed macroeconomic conditions. Domestic market prices are usually linked to world prices, but the models filter the world prices through import and export taxes and domestic agricultural policy variables such as support prices and producer and consumer subsidies.

How Was the Study Conducted?

The ERS analytical agricultural sector models are used as inputs to the annual USDA agricultural baseline projections and, subsequently, to answer questions posed by U.S. Government agencies related to agricultural trade and other policies. The models also are tools for conducting country- or region-specific research on export competitiveness, the impact of macroeconomic factors on commodity trade, yield and area shocks, the effects of potential agricultural or trade policy changes, and other contemporary issues. The standard determinants of area, yield, demand variables (e.g., food, feed, other demand, and stocks), and imports and exports, are identified by examining the content of numerous country models. Alternative specifications for supply and demand variables are also identified and reported.

The ERS Country-Commodity Linked System: Documenting Its International Country and Regional Agricultural Baseline Models

Introduction

Farmers often look out over long planning horizons when making decisions on capital expenditures and production. When contemplating plans and policies, other agricultural market participants and Government policymakers also require a long view. USDA's annual 10-year agricultural projections are instrumental in policy and budgetary matters. For these projections, USDA relies on both quantitative and qualitative analysis. USDA's Economic Research Service (ERS) maintains partial equilibrium models of the agricultural sector of 44 major exporting and importing countries and regions, including the United States. These, in conjunction with commodity models, fall in the quantitative category.

Markets within countries that trade internationally can be affected by commodity supply and demand fluctuations in other countries or regions. Hence, world agricultural trade projections cannot be made by considering each country or region in isolation. Instead, country and regional models must be able to translate global market signals into domestic market responses. Therefore, when ERS uses its 44 Excel-based country and regional models to produce baseline projections, it also simultaneously solves them in a computerized procedure that makes a price-endogenous modeling system from the individual country and region models. This procedure allows the individual models to be run together, effectively linking domestic behavior with world outcomes to project worldwide endogenous equilibrium prices and supply, use, and trade quantities. Combining the country and regional models in the Country-Commodity Linked System (CCLS) allows transmission of market-clearing price signals across countries, regions, and commodities.

ERS uses output from this system of models not only to provide input to USDA's annual agricultural baseline projections (e.g., *USDA Agricultural Projections to 2027 (*OCE, 2018)), but also as a tool for analyzing various scenarios from a domestic and global perspective. These scenarios—such as estimating the domestic or world market impacts of a petroleum price shock (Valdes et al., 2016) or simulating the way resource competition affects commodity trade in Central Asia (Motamed et al., 2013)—allow researchers to analyze the impact of driving forces in country and global commodity markets. In addition to these public reports, ERS also uses the CCLS to respond to requests from Congress and Federal agencies to help officials and staff better understand and evaluate changes in factors affecting domestic and global agricultural markets.

This report is aimed at increasing understanding of the system within the U.S. Department of Agriculture and among other interested parties. While the rest of the report documents the typical content of the country/region models, the solution process within the CCLS is detailed in the box, "The Country-Commodity Linked System Solution Mechanism."

The Country-Commodity Linked System Solution Mechanism

To allow a global solution for equilibrium prices and trade, the Excel-based country and regional model equations are extracted, converted to Fortran programs, and run together with a linking procedure. The linking procedure iteratively adjusts world prices until the world imbalance between imports and exports for each major agricultural commodity market is driven below a predetermined low level. The solution algorithm uses a numerical version of Newton's method, with each slope (trade change versus price change) observed from the previous price-adjustment iteration. The price adjustments are repeated within Gauss-Seidel loops until all commodity markets are simultaneously cleared (world imports and exports are balanced). During the solution, each country model receives the adjusted world prices and responds by adjusting its domestic prices, generating changes in its production, consumption, imports, exports, and other variables.

The linked system includes a "residual region," which measures exported quantities that are in transit and have not yet been imported. This ensures that total exports equal total imports for all commodities. In the baseline preparation process, imports for the linked system's residual region are calculated in each historical data year and for each commodity, such that world imports will equal world exports. Residual region imports in the projected years usually are held constant at the same levels calculated in the last historical data year (e.g., 2017/18 for the 2018 baseline projections). However, if the final historical data year's residual region imports are outliers, or residual region imports in the data years show pronounced trends, projected residual region imports may be adjusted before being held constant.

The baseline scenario involves clearing the initial imbalances between projected world imports and exports. The imbalances result from the new baseline assumptions for macroeconomic, price, policy, and quantity data, and for residual-region imports. After the baseline is finalized, residual-region imports are calculated to balance the world in all years and then made exogenous (i.e., fixed or valued). When the CCLS subsequently is used to analyze a scenario such as, for example, faster income growth in Africa, no world price adjustments occur until introduction of that scenario, which allows identification of the scenario effects.

The country/regional models may also be used outside the CCLS—in stand-alone mode—to examine policy or trade issues within a single country. In such cases, the country of interest is often assumed to have little or no impact on world prices. This assumption may apply when a country participates in international commodity markets but its trade is insufficient to significantly alter world commodity prices. Stand-alone mode also may be used when a country's border and/or domestic policies create a barrier between domestic and world market prices. In stand-alone mode, the model is solved by simply invoking a full calculation of the spreadsheet.

Note that when an individual country model is run in stand-alone mode, world price projections usually remain exogenous. Alternatively, one or more world prices may respond to the country's trade via flexibility parameters that relate world price changes to trade changes. The latter is necessary when models for major market players such as the United States, Brazil, China, and India are being used in stand-alone mode. However, in most circumstances, models for major market players are not used in stand-alone mode.

While the CCLS is quantitative in design, the signature component of its use, facilitating USDA's baseline projections, incorporates qualitative input based on the knowledge, experience, and expert judgment of commodity, policy, and regional experts throughout USDA. The blend of the quantitative and qualitative aspects of the USDA baseline projection process is highlighted in the box, "The USDA International Baseline Projections Process," and described in greater detail in Appendix E.

The USDA International Baseline Projections Process

Production of USDA's annual baseline projections begins each year in mid-summer and culminates in winter of the following year with publication of a new set of 10-year projections. The process:

- ERS economists present macroeconomic and petroleum price projections for modeled countries and regions.
- The ERS Domestic Baseline Coordinator updates U.S. commodity and fertilizer price projections from the previous year's baseline.
- The ERS International Baseline Coordinator generates international reference price projections from U.S. price projections, based on historical relationships.
- The ERS Baseline Modeling Coordinator loads macroeconomic data, international reference prices, and production, supply, and distribution data into the models.
- ERS and other USDA analysts develop projections of exogenous biofuel supply and demand for major producing countries.
- ERS modelers identify and make necessary changes to important agricultural, trade, or other country-specific policies. They also update country-specific data—such as domestic prices, land use, and crop or livestock production costs—that affect the projections.
- ERS hosts 6 daylong commodity workshops with experts from numerous USDA agencies, which start from preliminary CCLS projections and develop consensus production, demand, and trade projections for foreign countries and regions.
- Model adjustments are made once consensus projections for exports, imports, and other variables are agreed upon.
- When all model adjustments are complete, the country/regional models are solved simultaneously within the CCLS.
- The USDA World Agricultural Outlook Board (WAOB) hosts six U.S. market commodity meetings to develop expert consensus projections for U.S. supply, use, and market prices.
- Commodity analysts at ERS and the WAOB produce final projections of country-specific exports and imports.

— continued

The USDA International Baseline Projections Process—continued

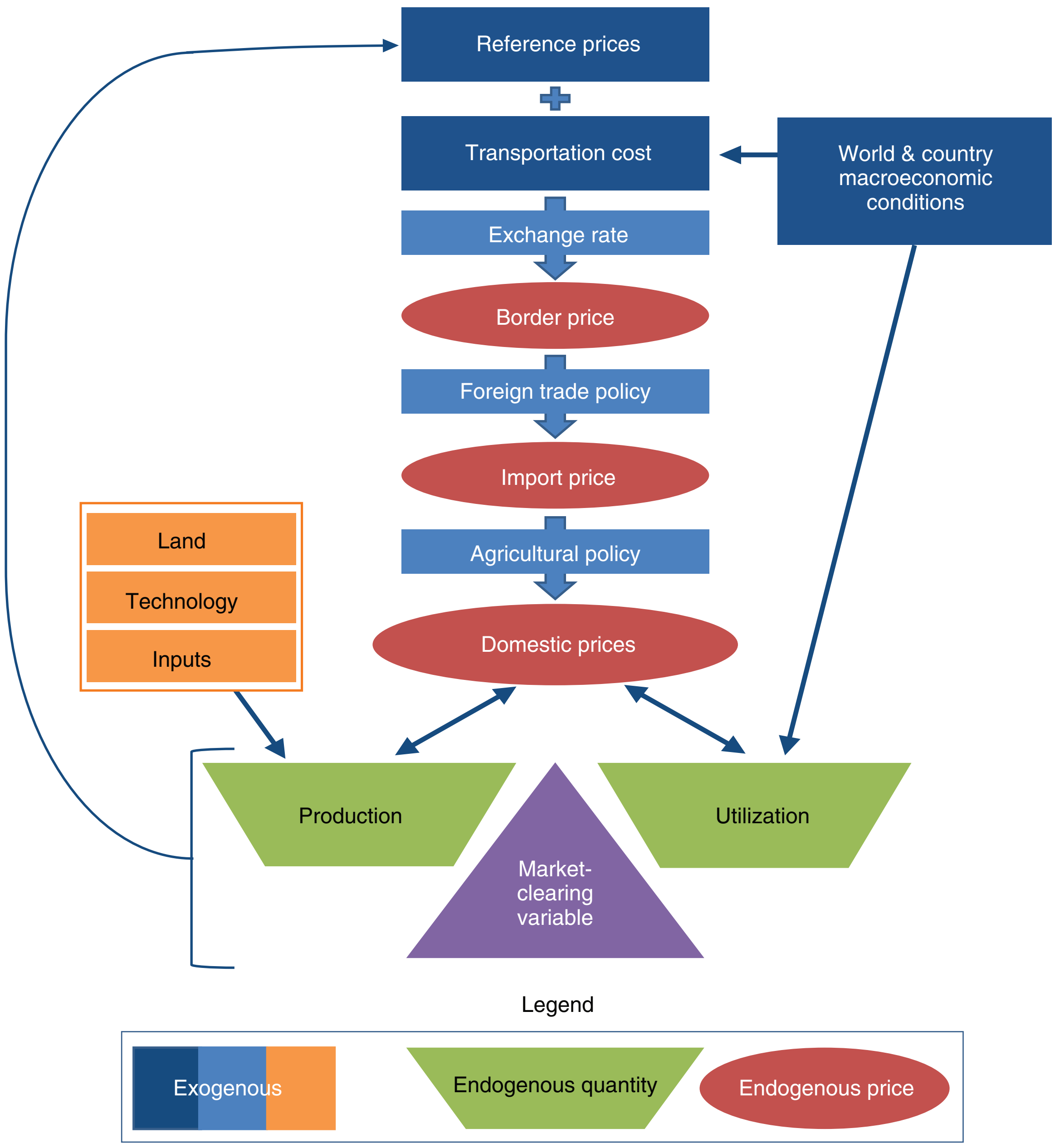
- Final international reference prices derived from the final U.S. prices, as well as projections of exports and imports, are loaded into the country models.
- ERS modelers produce final supply and demand projections that are consistent with the final export and import projections.
- The final projections for the United States are reported in the annual USDA baseline projections publication (e.g., *USDA Agricultural Projections to 2027,* published by USDA's Office of the Chief Economist, USDA Agricultural Outlook Board (USDA, OCE, 2018)) and presented at the USDA Agricultural Outlook Forum, held annually in February. Projections for other major trading countries are reported on the ERS website (e.g., USDA, ERS, 2018a).

To increase transparency and better understanding of the economic underpinnings of these valuable modeling resources, this report provides an overview of the data, the CCLS, and the country/regional agriculture sector models. It also presents examples of additions to, or variations from, the standard structure to provide a robust picture of these quantitative tools. Appendix C includes a scenario analysis that examines the domestic and world market impacts of higher projected soybean yields in South American countries other than Brazil and Argentina. This scenario analysis provides an example of the potential questions that can be answered with the country and regional models that make up the CCLS.

Model Structure and Commodity Content

Figure 1 illustrates the conceptual framework for the model for a typical importing country, with exogenous global and country-specific macroeconomic conditions, world commodity prices, and resource endowments contributing to determination of commodity supply and demand.

Figure 1
Conceptual modeling framework for an importing country



Source: USDA, Economic Research Service conceptualization based on Hjort and Van Peteghem (1991).

Each exogenous reference (or world market) price1 is converted, via the country's real exchange rate and addition of transportation cost, to a border price. Foreign trade policy measures (i.e., import tariffs) are applied to obtain the import price. The import price is, in turn, filtered through domestic agricultural policies before yielding a domestic market price. Domestic market prices, plus macroeconomic variables such as income, and the land base, technology, and inputs yield projections of production and utilization.

Each commodity market is cleared (production and utilization are balanced) by a trade, supply, or demand variable, or with an equilibrium price. The choice of this market-clearing variable in each market depends on the nature of the modeled country's link to world markets. The most common market-clearing variables are imports, exports, or both.2 If trade is small relative to supply or consumption, a large consumption variable such as feed or food may be the market-clearing variable. When domestic prices are insulated from world prices, an internal market equilibrium producer, or consumer price, often acts as the market-clearing mechanism.

Country and Commodity Coverage

ERS currently has 33 individual country models and 11 regional models (including a rest-of-the-world residual region) that, in combination, represent the world (table 1). The countries that are modeled individually are major exporters or importers of one or more commodities.[3] The regional models ensure coverage of all participants in each commodity market.

Table 1
Country and regional models

Countries modeled individually		Regions[1]
Argentina	Malaysia	Central America and Caribbean[2]
Australia	Mexico	European Union
Bangladesh	Morocco	Other Asia and Oceania
Brazil	Nigeria	Other ECOWAS[3]
Burma	New Zealand	Other Europe
Cambodia	Pakistan	Other Former Soviet Union
Canada	Philippines	Other Middle East
China	Russia	Other North Africa
Cuba	Saudi Arabia	Other South America
Egypt	South Africa, Republic of	Other Sub-Saharan Africa
Hong Kong	Taiwan	Rest-of-the-world
Indonesia	Thailand	
India	Turkey	

—continued

[1] When a model is being used in stand-alone mode, the reference price is exogenous. When a model is combined with country and regional models in the CCLS, the reference price is endogenous.

2 A country may both import and export a particular commodity when, for example, specific characteristics are desired that are not available in domestically produced products. This is most likely to occur when there are significant varietal or quality differences (e.g., wheat, rice).

[3] The individual country models account for more than 90 percent of exports of grains, major oilseeds and products, and livestock products, and 65-80 percent of trade in sugar, cotton, and minor oilseeds.

Table 1

Country and regional models—continued

Countries modeled individually		Regions[1]
Iran	Ukraine	
Iraq	USA	
Japan	Vietnam	
Korea, Republic of		

[1]See appendix table A for a list of countries included in each region. [2]Excluding Cuba. [3]Economic Community of West African States. USA = United States of America

Source: USDA, Economic Research Service.

Each country/regional model[4] includes one or more of the standard commodities for which world market prices and trade are projected (table 2). The criterion for inclusion of a standard commodity in a country model is whether international trade of that commodity is affected by the country's supply and/or demand. When important from a domestic policy or trade perspective, a commodity included in the "other" categories may be modeled individually. For example, India is the world's largest exporter of groundnuts (peanuts), so groundnuts are modeled separately from the "other oilseeds" category. However, when the India model is linked with others in the CCLS, groundnut supply and demand are included in the global aggregate "other oilseeds" market.

Table 2

Standard commodity coverage in the country and regional models[1]

Livestock products	Grains	Other crops
Beef and veal	Rice	Cotton
Pork	Wheat	Sugar
Poultry meat (chicken and turkey)	Corn	
Eggs	Barley	
Fluid milk	Sorghum	
	Other coarse grains (oats, millet, rye, mixed grains)	
Oilseeds	**Meals**	**Oils**
Soybeans	Soybean meal	Soybean oil
Rapeseed	Rapeseed meal	Rapeseed oil
Sunflowerseed	Sunflowerseed meal	Sunflowerseed oil
Other oilseeds	Other meals	Other oils
Copra	Copra meal	Coconut oil
Cottonseed	Cottonseed meal	Cottonseed oil
Groundnuts	Groundnut meal	Groundnut oil
Palm kernel	Palm kernel meal	Palm oil
	Fishmeal	Olive oil

[1] All commodities are not necessarily included in each country or regional model.

Source: USDA, Economic Research Service.

[4] To simplify narration, the term "country/regional" is simplified to "country" from this point forward.

Some models include nonstandard commodities. For example, alternative feedstuffs like distillers' dried grains with solubles (DDGS) and cassava may be important determinants of feed demand, thereby affecting trade and world prices of one or more of the standard commodities. In such cases, interaction of the nonstandard commodity with a standard commodity may be included in a country model. However, world equilibrium prices of nonstandard commodities cannot be derived within the CCLS due to insufficient representation of global market participants. Therefore, when a nonstandard commodity is an important agricultural product within a country, prices for that commodity must be projected by the modeler. This is typically accomplished by linking the nonstandard commodity's price to that of a standard commodity. For example, the price of DDGS or cassava may be estimated from the price of domestic maize or other feed, based on an observed historical relationship between the prices of the standard and nonstandard commodity.

Note that biofuels are not included in table 2. Biofuel supply and demand projections are exogenous to the linked system. That is, prior to developing the annual agricultural baseline commodity projections, USDA experts develop consensus projections of major countries' ethanol and biodiesel supply and demand outside the CCLS. Projections of feedstock needs are then taken into account in the relevant country models[5] to ensure consistency with assumed global biofuel market developments.

[5] Exogenous biofuel projections are made for Argentina, Brazil, Canada, China, Indonesia, the United States, and the European Union.

Model Input and Basic Assumptions

USDA's annual baseline projections are one representative, longrun scenario for the global agricultural sector based on specific assumptions. The projections, which focus on long-term underlying trends, depend on specific assumptions about global macroeconomic conditions, world petroleum and fertilizer nutrient prices, and reference prices. They also depend on country-specific assumptions including macroeconomic variables (e.g., income growth, exchange rates, interest rates), the evolution of agricultural and trade policies, and, for major producers, biofuel supply and demand projections. Therefore, projections of supply, demand, trade, and prices for each modeled country are conditional on both the global and country-specific assumptions.

A country's domestic agricultural and trade policies are usually assumed to remain the same over the projection period. This does not preclude expected evolution of policies. For example, price-support policies are typically assumed to evolve as they have historically. In that case, the relative cross-commodity price relationships would be assumed constant. There are exceptions to this general rule. For example, if a country has passed legislation adopting a new agriculture policy instrument, the new policy may be added to the quantitative model beginning in the legislated year of implementation.

Each agricultural sector model contains historical and current macroeconomic data, reference (world market) prices, commodity supply and demand data, trade policy parameters, and country-specific agricultural policies. Supply and demand data for the current year (i.e., 2017/18 for the 2018 baseline projections) provide the base from which quantity projections are made. Projections of trade policy parameters are typically exogenous, while agricultural policy measures may be exogenously or endogenously determined. In combination, these data are sufficient to generate projections of supply and demand quantities. Structural and other non-policy assumptions are also often required when producing country-specific projections. Examples of such assumptions include the addition of new land to agricultural activities; infrastructure changes that increase efficiencies in domestic marketing, thereby facilitating movement of commodities within a country to local markets or export ports; changes in feeding efficiency; and technological advances that affect crop yields.

These structural and other non-policy assumptions are developed with the assistance of ERS country and regional specialists, who accumulate knowledge of not only the agricultural sector, but also of the macroeconomic, general political environment, and social characteristics of a country. Additional input is provided by the USDA, Foreign Agricultural Service (FAS) in-country agricultural attaché staff, often supplemented by FAS' Washington-based commodity experts. In addition to ERS and FAS country specialists, commodity and country experts from the Interagency Agricultural Projections Committee[6] also vet the modelers' country-specific assumptions and projections and provide information on structural, policy, and other relevant changes that may necessitate changes in economic parameters (e.g., elasticities or expectations).

[6] The committee is chaired by a representative of the World Agricultural Outlook Board with representatives not only of ERS and FAS, but also USDA's Farm Service Agency, Agricultural Marketing Service, Office of the Chief Economist, Office of Budget and Program Analysis, Risk Management Agency, Natural Resources Conservation Service, and National Institute of Food and Agriculture.

Macroeconomic Assumptions

As noted earlier, the USDA's annual domestic and international commodity projections are specific to underlying macroeconomic assumptions. Each summer, ERS economists project both global and country-specific macroeconomic variables for use in the models (USDA, ERS, 2018c). The standard macroeconomic variables are listed in table 3. Additional macroeconomic variables also may be key to the environment within which agricultural producers make production decisions. For example, many farmers obtain loans to finance the purchase of inputs, so the real cost of borrowed funds—the real interest rate—may be an important determinant of annual production costs and, subsequently, output. When such variables are needed, the modeler obtains the necessary historical data and generates projections of the variables.

Table 3
Macroeconomic variables

Consumer Price Index	Real local currency/U.S. dollar exchange rate
Gross Domestic Product (GDP) deflator	Industrial countries' GDP growth
Population	Crude oil price
Real GDP denominated in U.S. dollars	

Source: USDA, Economic Research Service.

Reference Prices

As shown in Figure 1, producers and consumers in each country model respond to domestic market prices derived from the combination of macroeconomic variables, international reference prices, and trade and domestic agricultural policies. Reference prices are those commodity prices commonly accepted as representative of world trade prices. In general, the prices are typically from various international locations such as major agricultural trade ports (e.g., the U.S. Gulf, Rotterdam, and Bangkok). When a model is used in stand-alone (unlinked) mode, producers and consumers respond to border, trade, and domestic prices derived from fixed reference prices. When a model is linked in the CCLS, worldwide equilibrium reference prices are obtained from the simultaneous interaction of all models in all commodity markets.

All commodities are assumed to be homogenous in international trade. However, in some cases, producers and consumers may respond to a differentiated world market price. Differentiated prices apply for commodities where there are distinct consumer preferences (e.g., indica versus japonica rice), end uses (e.g., feed versus malting barley), or segmented markets (e.g., beef or pork markets free from foot-and-mouth disease). Price projections for the alternative (differentiated) products vary according to their historical relationship with the primary reference price. But, since the CCLS is not a bilateral trade model, once the relevant commodity is produced within a country, it enters the world market as a homogenous product such as rice, barley, beef, and so on.[7] The implicit assumption underlying this is that importers that typically buy a differentiated product will continue to do so in the projection period and that buying behavior will not have a more or less significant impact on the price of the homogenous product than it has had in the past. The specific price series used as reference prices are shown in Appendix B.

[7] A bilateral trade version of the CCLS was developed in the 1990s for analysis of free-trade agreements, but it has not been used since and has not been updated.

Agricultural and Trade Policies

Producers are assumed to maximize profits in a perfectly competitive environment, subject to domestic agricultural and trade policy interventions and land constraints. Agricultural policy instruments commonly include producer support prices, input subsidies, direct producer subsidies, taxes, tax exemptions, domestic consumer subsidies, and so on. Modelers update and project these policy variables. While typically assumed to be exogenous, in some country models policy price[8] projections are endogenous, depending primarily on domestic market conditions. For example, in some countries, support prices reflect both world market prices and domestic market factors such as production costs.

The models accommodate several trade policy parameters, including import and export tariffs and tariff-rate quotas[9] (TRQs). Trade policy data (e.g., most-favored-nation applied tariffs) are obtained from the tariff database of the World Trade Organization (WTO) or from country sources. Typically, such parameters and policies are held constant over the projection period. However, expected tariff changes, such as when a country accedes to the WTO, are usually accounted for in the models. In regional models, tariffs of a representative country are used.

Historical Supply and Demand Quantity Data

The primary source of historical supply and demand data is the USDA, Foreign Agricultural Service (FAS) Production, Supply and Distribution (PSD) database (USDA, FAS, 2018). The database includes most grains, oilseeds and products, cotton, sugar, livestock, and livestock products. Supply-side variables are beginning stocks or animal inventory, area harvested or slaughter, yield, production, and imports. Demand-side variables include food, feed, industrial use, other use, ending stocks, and exports.

Some livestock product data are not available for one or more countries in the PSD dataset. To include more market participants, missing data are culled from FAOSTAT, the agriculture database of the Food and Agriculture Organization of the United Nations (FAO) (FAO, 2018). The commodities for which data from FAOSTAT are used include beef and veal, pork, poultry (chicken and turkey) meat, eggs, and lamb and mutton.

[8] A policy price is a government-legislated or -announced support price, such as a loan rate, procurement price, target price, minimum price, or similar.

[9] A tariff-rate quota is a trade barrier that applies two levels of tariffs—one level on quantities at and below the quota and another higher level on quantities above the quota.

General Model Structure

Individual country models are composed of a system of behavioral equations and identities. Within a single country model, projections are based on supply-use equations for every included commodity and time period. In a model that spans multiple commodities, subscripts are included to indicate specific country-commodity pairings. To limit equation complexity, the following equations are for a single country and commodity subscripted by time (t).

The fundamental identity that each commodity market within a country must satisfy is the supply and use balance:

$$QP_t + IM_t + ES_{t-1} \equiv QC_t + EX_t + ES_t. \quad (1)$$

Equation 1 is a simple, but powerful, accounting identity. The left side of the equation represents the supply of a commodity each year, which is equal to the quantity produced (QP_t) plus imports (IM_t) plus ending stocks from the previous year (ES_{t-1}). The right side of the equation is equal to the quantity consumed (QC_t) plus the quantity exported (EX_t) plus the quantity to be carried over into the next marketing year (ES_t). The historical data that populate the country models are constructed such that this supply and use balance is met.

To find the quantity levels for each variable needed to satisfy the equilibrium supply and use balance, a behavioral relationship between quantity and price must be specified. As noted previously, the domestic prices that yield quantities are primarily derived from reference prices. For example, for an integrated market such as that of soybeans from Brazil, the prices used to find domestic supply and demand equilibrium are linked directly to world prices. However, for a commodity that is largely protected from world prices in a country due to domestic and/or trade policies or limited or no foreign trade (e.g., fluid milk), the prices that equate supply and demand would usually be internal market equilibrium prices. This does not preclude world market price transmission for other commodities or for inputs to a commodity isolated from the world market. For example, corn imported to feed dairy cows may be linked directly to world market prices.

Each of the country models is based on standard conceptual specifications. Derivation of the supply of crops and animal products is conceptually identical. In both cases, output is assumed to occur under perfectly normal weather and other agronomic conditions in all future years. In addition, producers are assumed to be maximizing profit, subject to policy incentives and constraints.

Price Determination

As shown in figure 1, reference prices, domestic macroeconomic policies, plus foreign trade and agricultural policies determine a country's domestic commodity prices. The trade prices faced by all importing countries and all exporting countries are computed in the same way. The border price (BP_t) for an importing country is defined in equation 2 with the reference price (RP_t) and international transportation costs (TC_t) from the reference point (e.g., U.S. Gulf) to the import port summed, then converted into local currency units via the exchange rate (XR_t). Note that in the case of an exporter, the transportation cost in equation 2 is the difference between the cost of delivering the commodity from the reference point and from the exporter's port. The import price (MP_t), shown in equation 3, is the product of the border price and in-quota (MX_t^{IQ}) and over-quota (MX_t^{OQ}) tariffs weighted, respectively, by the quota (TQ_t) and over-quota quantities ($IM_t - TQ_t$). Note that when no tariff quota applies, TQ_t is zero and MX_t^{IQ} and MX_t^{OQ} are identical, so the import price is equal to the border price plus the tariff. The price at which a commodity may be exported (XP_t) is the border price plus applicable export taxes (XX_t), as shown in equation 4.

$$BP_t = XR_t \cdot (RP_t + TC_t) \quad (2)$$

$$MP_t = BP_t \cdot [1 + MX_t^{IQ} \cdot TQ_t + MX_t^{OQ} \cdot (IM_t - TQ_t)] \quad (3)$$

$$XP_t = BP_t \cdot (1 + XX_t) \quad (4)$$

Producer and consumer prices may be determined in several ways, depending on the magnitude of international trade and agricultural and consumer policies. When a policy-driven support price (e.g., target, guaranteed, procurement, or similar) is applicable, the producer price will be determined, in part, by the policy price. Producer support (policy) prices may be linked to expected input costs (PI_{t-1}, $\boldsymbol{E}[PI_t]$)[10], import prices, and similar variables, or be legislated (GP_t^l)(equation 5)[11]. If a locally produced product is being imported or exported, import and/or export prices will also be a determinant of the producer price.[12] Therefore, the producer price (PP_t) may then be broadly defined as shown in equation 6.

$$GP_t = f(PI_{t-1}, \boldsymbol{E}[PI_t], MP_t, GP_t^l) \quad (5)$$

$$PP_t = f(MP_t, XP_t, GP_t) \quad (6)$$

Some governments subsidize consumer prices (GC_t). While the specific determinants of a subsidized consumer price are country-specific, they may, for example, be derived based on expected per capita income ($\boldsymbol{E}[pcGDP_t]$), be relative to a government producer price, be legislated (GC_t^l), or they may vary with nonsubsidized consumer prices (CP_t) (equation 7). Nonsubsidized consumer prices may be derived from factors such as producer prices, import prices, or subsidized consumer prices (equation 8). Note that only those variables relevant to the country and specific commodity being modeled are included in the producer and consumer price equations.

$$GC_t = f(\boldsymbol{E}[pcGDP_t], GP_t, GC_t^l, CP_t) \quad (7)$$

$$CP_t = f(PP_t, MP_t, GC_t) \quad (8)$$

When there is no trade in a commodity, or border measures are such that transmission of world market prices is limited, domestic market-clearing (equilibrium) prices prevail. In such case, producer or consumer prices are obtained by successive iterations that ensure that the accounting identity in equation 1 is satisfied for the commodity in question. In the special case where imports are the market-clearing variable and are subject to a TRQ, the producer price is a function of the producer price that would result in imports at the TRQ level (PP_t^{TRQ}), bounded by the within-quota (MP_t^{IQ}) and over-quota (MP_t^{OQ}) import prices:

$$PP_t = max(MP_t^{IQ}, min[MP_t^{OQ}, PP_t^{TRQ}]). \quad (9)$$

The consumer price is then computed from the producer price and other applicable variables as shown in equation 8.

[10] The symbol $\boldsymbol{E}[\ ]$ denotes an expected value.

[11] See the Functional Forms section for descriptions of the specific functional forms that may be used in the models.

[12] The degree to which international market prices influence domestic prices will vary with domestic and trade policies.

Crop Production

When deciding how much of each crop to plant, farmers are assumed to calculate net returns per hectare[13] to each possible crop, shifting some area toward higher return crops, subject to agronomic and policy constraints. It is further assumed that this individual behavior can be aggregated across all producers in a country to derive changes in crop area. Since the PSD and FAOSTAT databases do not report area planted, it is also assumed that area harvested is an adequate representation of producers' planting intentions. Thus, crop production (QP_t^{cr}) is defined as the product of area harvested (AH_t) and yield (YL_t) (equation 10).

$$QP_t^{cr} = AH_t \cdot YL_t \quad (10)$$

Area harvested of crop *j* (AH_t^j) is defined as a function of expected returns to crop *j* and *n-1* alternative crops, plus the stock of land (equation 11). The symbol $\boldsymbol{E}[NR_t^j]$ in equation 11 and subsequent equations denotes the expected net return to crop *j*, while LA_t represents the land base in year *t*. The stock of land—the area that may be used to produce annual crops—is included as a determinant of area harvested to limit the aggregate use of land to a plausible level. (See box, "Land Use.")

$$AH_t^j = f(\boldsymbol{E}[NR_t^1], \dots, \boldsymbol{E}[NR_t^j], \dots, \boldsymbol{E}[NR_t^n], LA_t) \quad (11)$$

Land Use

The aggregate stock of land within a country is fixed. Globally, the land used for agriculture has been declining for decades because of population growth and other factors (FAO, 2018).[14] However, within a country or region, the distribution of land to agricultural and nonagricultural uses, as well as whether agricultural land is used for crops or animals, varies depending on market and other conditions. Arable land can be cropped, used temporarily for pasture, be fallowed, or be used for noncommercial purposes. The use of land for crops or temporary pasture may depend on the expected profitability or return to producers from the two activities. Leaving the land fallow or putting it to other non-cropped uses is often a function of physical characteristics of the land. Some arable land can be cropped more than once a year, given sufficient water, appropriate soil characteristics, and other favorable agronomic factors.

When projecting area harvested of crops within a country model, the sum of the total area harvested within a production season (e.g., winter crops, summer crops) should not exceed the stock of arable land allocated to crop production multiplied by the cropping intensity or multiple cropping index (MCI). The MCI measures the number of times a plot of land is used to produce a crop within a given year (FAO, 1995). A historical MCI series can be approximated by tabulating total area planted within a country and comparing that to FAOSTAT's land used for temporary crops (crops that must be replanted after each harvesting, as opposed to permanent crops such as fruit grown on trees).

—continued

[13] A hectare is a measure of land equal to 2.471 acres.

[14] Land use data are available in the Inputs domain of FAOSTAT.

Land Use—continued

Given a historical MCI series, land harvested to crops may be projected exogenously or endogenously. If a country's historical MCI is fairly constant or displays a distinct trend, it can be exogenously determined. However, if the MCI is variable, it can be projected from a combination of country-specific factors. For example, in Brazil, corn is planted after soybeans in the Center-West region, so total corn area depends in part on soybean area and in part on the relative returns to alternative crops. In this example, an MCI can be projected based on soybean area and expected returns to corn and competing crops.

In general, there are limits on the MCI. While an MCI in the range of 2 to 3 is agronomically possible under very specific circumstances, it is highly unlikely that such a value would apply to an individual country's entire agricultural land base. Therefore, any one country's aggregate MCI should be less than 3, and often less than 2, which serves to set a limit on total area harvested in any 1 year.

The land constraint is modeled in one of two ways. The first option is to project land available for temporary crops by eliminating land used for other purposes. For example, deduction of trend values for forests and woodlands, land for nonagricultural uses, pasture, permanent crops, and fallowed land from the total land area yields land available for temporary crops. The sum of area harvested for all modeled crops is then divided by this value, yielding an MCI. The modeler judges whether the resulting MCI value is reasonable, adjusting area harvested projections as necessary to maintain an appropriate MCI.

The other option for limiting temporary crop land use to a reasonable level is to project an MCI directly in response to economic incentives. Increases in the MCI will be positively correlated with increasing expected returns for crops commonly multi-cropped, such as rice, soybeans, and corn. Therefore, a 5-year Olympic average (in which the highest and lowest values are removed and the average is calculated from the remaining values) of expected returns to alternative crops may be a good indicator of incentives to multiple cropping. When the MCI is projected directly, the modeler multiplies the land available for temporary crops by the MCI and then deducts the sum of area harvested for modeled crops, yielding a residual amount of land available for other crops such as pulses, vegetables, and so on. The modeler must then judge whether the residual area is reasonable and, when necessary, make adjustments to the area of modeled crops.

Yields are defined as a function of expected producer prices, expected input costs ($\boldsymbol{E}[IC_t]$), and a trend, which is most frequently a time trend (equation 12).

$$YL_t = f(trend, \boldsymbol{E}[PP_t], \boldsymbol{E}[IC_t]) \quad (12)$$

The expected net return to a crop ($\boldsymbol{E}[NR_t]$) is equal to expected gross revenue ($\boldsymbol{E}[RV_t]$) less expected input costs or:

$$\boldsymbol{E}[NR_t] = \boldsymbol{E}[RV_t] - \boldsymbol{E}[IC_t]. \quad (13)$$

The general specification of expected revenue for a single commodity is the product of the expected producer price and the expected yield:

$$\boldsymbol{E}[RV_t] = \boldsymbol{E}[PP_t] \cdot \boldsymbol{E}[YL_t]. \qquad (14)$$

The expected producer price can be projected by a number of means, depending on whether policies play a significant role in establishing producer price expectations. If policy prices apply to a majority of the crop or if they are viewed as indicative of the current-year market price, the expected price may simply be the policy price (e.g., a government support price). If producers are guaranteed a minimum price, expected prices are bounded below at the minimum price. Government support payments and other policy-related, lump-sum receipts may also be a component of expected returns. In such cases, the expected policy-related per hectare payment would be added to expected revenue as shown in equation 15.

$$\boldsymbol{E}[RV_t] = \boldsymbol{E}[PP_t] \cdot \boldsymbol{E}[YL_t] + \boldsymbol{E}[PolicyPymt_t] \qquad (15)$$

In the absence of policy prices or when policy prices are received on a small portion of the crop, the expected price will depend on expected market prices. In a shortrun model, futures prices would be the best indicator of price expectations, as demonstrated in a wide variety of research (e.g., Gardner, 1976; Hendricks et al., 2014). Since futures prices are not available 10 years into the future, expected market prices are often used instead, typically specified as a function of previous producer prices. The precise specification is determined by the modeler, and it depends, in part, on whether market prices are in general rising, constant, or falling. If real market prices are generally constant, an average of past market prices may be used. When prices are rising or falling, a 3- to 5-year moving average or 5- to 7-year Olympic average[15] with an intercept adjustment may be required. To ensure like responses when a model is used to produce a baseline and, subsequently, for scenario analysis, an intercept adjustment must be based on information contained within the country model. One way to update a price trend is to add a specific percentage of the difference between the average market price in some recent previous period and the moving average price in the same period, such as:

$$\boldsymbol{E}[PP_t] = 5yrOlympicAveragePP_{t-1} + [Average(PP_{t-1}, PP_{t-2}, PP_{t-3}) - 5yrOlympicAveragePP_{t-1}] \cdot \varphi. \qquad (16)$$

In this equation, φ is the percent of the difference that is applied to adjust the intercept.

Expected yield as used here is a measure of how much output per hectare a farmer expects from a crop. Such yields are usually specified as a function of expected prices, expected input costs ($\boldsymbol{E}[IC_t]$), and technology (equation 17).

$$\boldsymbol{E}[YL_t] = f(\boldsymbol{E}[PP_t], \boldsymbol{E}[IC_t], technology) \qquad (17)$$

An empirical formulation for *technology* that is used in some models is a growth rate computed as the ratio of the 7-year Olympic average for the previous year (t-1) and for year t-2 applied to a 5-year Olympic average yield for the previous year (t-1):

$$technology = \left(\frac{7yrOlympicAverageYield_{t-1}}{7yrOlympicAverageYield_{t-2}}\right) \cdot 5yrOlympicAverageYield_{t-1}$$

[15] In an Olympic average, the highest and lowest values are removed and the average is calculated from the remaining values.

Even in those cases where yields are highly variable (e.g., non-irrigated crops), this formulation produces relatively smooth projections of expected yields because the Olympic averages reduce the impact of weather disturbances on yields. It also updates the trend yield projection, albeit with a lag, and therefore includes expectations based on actual, recent performance. Alternatively, a formula such as that for expected price as shown in equation 16 has also been used.

Expected input costs for a single crop, in a single year, are the sum of expected input prices multiplied by the per hectare application or use rates of each input *i*:

$$\boldsymbol{E}[IC] = \sum_i (\boldsymbol{E}[PI_i] \cdot \boldsymbol{E}[UR_i]). \qquad (18)$$

In this equation, PI_i and UR_i denote, respectively, the price and the use rate of input *i*. As in the case of expected market prices, expectations of input prices can be formulated many different ways. If policy prices are relevant (e.g., the government provides subsidies for input purchases), then a combination of past market prices and current and/or past policy prices could be used to project expected input prices. The use rates are recommended or actual application rates, such as those reported in crop budgets or cost of production tabulations.

In many cases, information on input use rates and input prices is limited. When such data are not available, input costs may be omitted in the expected revenue calculation. This essentially imposes the assumption that input costs remain constant in relative terms to gross revenue. This assumption is, however, violated if input use rates and/or input prices are changing over time.

The cost of fuel and fertilizers, two major inputs to crop and livestock production, is linked to petroleum prices. In periods of high energy prices, Beckman et al. (2013) found that farmers adjust their fuel use by keeping machinery serviced and reducing trips over the fields. They also found that higher fertilizer prices resulted in, among other things, lower application rates and greater reliance on precision technologies. Given this linkage, rather than omit input costs entirely, they can be approximated by assuming there are two inputs to production—energy related and all other costs (see box, "Energy-Related Crop Production Costs"). Country-specific consumer price indices and the world petroleum price are included in the macroeconomic assumptions, while fertilizer nutrient prices (urea, triple super phosphate, and potassium chloride) are included in the reference price projections. Depending on the nature of country-specific energy and fertilizer industries, the petroleum price and/or nutrient prices and any relevant domestic market determinants (e.g., input subsidies) may be used to project costs of energy-related inputs, while other costs may be projected from the general rate of inflation.

Energy-Related Crop Production Costs

Energy-related input costs for grains, cotton, and sugarcane in five major producing countries/regions are shown in the following table. As a share of total variable costs, energy-related costs range from a high of 84 percent for Brazilian soybeans to a low of 27 percent for soybeans in India. The variation in the use of energy-related inputs is due to the technology used to produce different crops. For example, the majority of rice and wheat produced in Brazil is irrigated with electric- or fuel-powered pumps, and planting and harvesting machinery is used on large tracts of land devoted to soybeans. China's high energy-related input use is principally in the form of fertilizer, where nutrient application rates per hectare of arable land have, on average, exceeded 500 kilograms since 2008 (FAO, 2018). Nearly all of the wheat and 60 percent of the rice produced in India is irrigated, which pushes energy-related costs for those crops up relative to others.

Table 1

Energy-related input costs as a percent of total variable costs, average 2002-12

Country	Corn	Cotton	Rice	Soybeans	Sugarcane	Wheat
Brazil	74.7	73.1	80.6	84.1	46.4	80.2
China	65.3	65.4	65.4	57.6	56.5	73.2
EU	40.5	--	--	--	--	44.2
India	36.2	37.5	42.8	26.5	34.0	53.7
United States	56.2	41.3	57.7	42.7	--	58.9

Note: -- denotes not available or applicable. EU denotes European Union. Energy-related costs include one or more of fuel, lubricants, electricity, fertilizer, agrochemicals, and plastic film and similar weed-control agents. Variable costs include seed, fertilizer, soil conditioners, agrochemicals, fuel, lubricants, electricity, energy-based supply of irrigation water, interest paid on inputs, rented land, and hired labor. To ensure comparability of costs across countries, variable costs for cotton and rice in the United States exclude ginning and commercial drying.

Source: USDA, Economic Research Service (ERS) calculations using data from USDA, ERS (2014); CONAB (2014); European Commission (2014); Government of China (2015); and Government of India (2015).

With sufficient knowledge about a country's crop production technologies, the energy-related cost shares shown in the above table, and other information that can be gleaned from international (e.g., FAO) and country sources, input costs can be projected. When data are available, such costs can be projected from base levels. When not available, a cost index set equal to 100 in an initialization year may be used to offset expected revenue.

To generate projections of area for each crop, own- and cross-return elasticities are needed. When sufficient data are available to calculate returns to competing crops, the necessary elasticities may be econometrically estimated with theoretical restrictions imposed. This challenging task is not possible for many countries due to data limitations. In countries such as the United States and others with well-developed market reporting systems, the necessary data are more readily available. However, in the case of most countries, it is extremely difficult to obtain a reasonable time series of sufficient quality of historical producer, input, and other prices for a number of competing commodities.

When necessary data are not available, the modeler chooses parameter values for production decisions based on the theory of supply detailed by Sadoulet and de Janvry (1995). Thus, production of a crop with relatively larger increasing returns will result in greater production of that crop. When choosing values for own- and cross-return elasticities, the sum of cross-return effects will generally be no larger in absolute value than the own-return effects. Cross-return elasticities are positive for crops that are complements, such as double-cropped soybeans and corn, and negative otherwise. These conditions are imposed with the aid of an algorithm that uses the assumption that the ratio of any two cross-return elasticities for a single commodity is proportional to their relative base area shares (see Appendix D).

Livestock Product Production

Output of livestock products (QP_t^{ls}) is derived in the same manner as for crops, with slaughter (SL_t) substituting for area. Note that due to data and time limitations, in most models, slaughter or production is estimated directly rather than from an inventory flow model.[16] Following the PSD database convention, animal product production is equal to the number of animals slaughtered (milked, laying) multiplied by the average meat (milk, eggs) yield (YL_t^{ls}):

$$QP_t^{ls} = SL_t \cdot YL_t^{ls} \qquad (19)$$

Similar to crop production, separating total livestock production into specific components allows greater flexibility in capturing producer response to prices. Slaughter yields are principally a function of a trend variable with some role allocated to current year (poultry meat, eggs, milk) or expected (cattle, hogs) output prices and input (feed) prices (CP_t^{fe}):

$$YL_t^{ls} = f(trend, PP_t, \boldsymbol{E}[PP_t], CP_t^{fe}). \qquad (20)$$

Slaughter is typically specified as a function of current and lagged expected returns as shown in equation 21.

$$SL_t = f(\boldsymbol{E}[NR_t], \boldsymbol{E}[NR_{t-1}], \boldsymbol{E}[NR_{t-2}]) \qquad (21)$$

As is the case with crops, expected net returns are computed as the difference between expected revenue and expected costs (see equation 13). Expected gross revenue is computed as the product of the expected price and expected yield. Expected market prices are typically specified as a function of previous producer prices (e.g., equation 16). For fed livestock, the bulk of expected costs are those for feed, while grazed livestock costs are more heavily weighted toward inputs such as fertilizer that are necessary to maintain or improve pasture. As shown in equation 22, expected yields are principally a function of lagged yields and/or a trend and may also depend on expected output prices and feed costs.

$$\boldsymbol{E}[YL_t^{ls}] = f(YL_{t-1}^{ls}, trend, \boldsymbol{E}[PP_t], \boldsymbol{E}[CP_t^{fe}]) \qquad (22)$$

Consumption

Total consumption of each commodity (QD_t) is the sum of individual demands, as applicable, for feed (FE_t), food (FD_t), crush (CS_t), and other uses (equation 23). Feedstock use for biofuel produc-

[16] The U.S. and Canada models include inventory flows for cattle and hogs, while total cattle inventories are included in the Australia and Brazil models.

tion and cotton demand for milling are considered industrial uses, which, when combined with seed, losses, and other incidental disappearance, make up other demand (OD_t).

$$QD_t \equiv FE_t + FD_t + CS_t + OD_t \tag{23}$$

Food use is the product of per capita food consumption (FD_t^{pc}) and population:

$$FD_t = FD_t^{pc} \cdot pop_t. \tag{24}$$

Per capita consumption of food i ($FD_{i,t}^{pc}$) in year t depends on own- and cross-price relationships as well as per capita income (Y_t^{pc}) (equation 25).

$$FD_{i,t}^{pc} = f(CP_t^1, CP_t^2, CP_t^i, \ldots, CP_t^n, Y_t^{pc}) \tag{25}$$

Given the number of models within the CCLS, the stability and robustness of food use projections require a complete demand system approach. The parameter values for the models conform to the principles of demand theory (e.g., Deaton and Muellbauer, 2006). Thus, the own-price demand elasticities are negative; substitute commodities have positive cross-price elasticities; the sum of the cross- and own-price elasticities for each product is zero (homogeneity of degree 0); and the cross-price elasticities fulfill symmetry restrictions. These theoretical restrictions are used to derive a complete set of food demand elasticities from modeler-supplied own-price and income elasticities and base period expenditure shares (for a more detailed discussion, see the section, "Supply, Demand, and Other Elasticities" in Appendix D).

Feed demand

Within each model, energy (e.g., grain) and protein (e.g., oilseed meal) feed demand is linked to the production of animal products. The approach determines the quantity of feed needed to yield projected production of meat, milk, and eggs (Hjort and Van Peteghem, 1991). The starting point in this process is identifying the share of animal product production that is derived from fed animals. The proportion of animals fed depends on the structure of the livestock industry in the country being modeled. If feeding is used in conjunction with range production, the decision to feed animals depends on variables such as relative feed/meat prices and technology. Therefore, the proportion of fed animals may be modeled by using an economic function or may be assumed. Once the proportion fed is projected, the percentage fed is applied to total animal product production to derive the quantity of meat, milk, and eggs produced by fed animals.

The second step in the process requires the specification of feed conversion coefficients. Feed conversion coefficients are the tons of energy (grain) or protein (meal) required to produce a ton of meat, milk, or eggs (Hou et al., 2016; FAO, 2012).[17] These coefficients are assumed to be exogenous, varying only with genetic advances in feeding efficiency. The coefficients are multiplied by the production of meat, milk, and eggs from fed animals to derive the total amount of grain and protein required to support the projections of animal product production. The total requirement for grain and meal can then be distributed among the individual grains and meals with user-specified economic functions.

[17] Note that since cattle and hog inventories are not included in most models, the feed-conversion coefficients for beef and veal and for pork may be inflated to account for breeding animals. Feed-conversion coefficients on a live-weight basis are converted to meat, milk, and egg equivalents by dividing by the dressed weight.

The standard derivations of energy and protein feed demand are shown in equations 26 and 27. Demand for each energy feed (FE_t^e) and protein feed (FE_t^p) is a function of the consumer price of alternative energy (CP_t^{ei}) and protein (CP_t^{pi}) sources, plus the aggregate energy ($EnReq_t$) and protein ($PtReq_t$) requirements computed as described above.

$$FE_t^e = f(CP_t^{e1}, CP_t^{e2}, \dots, CP_t^{em}, EnReq_t) \tag{26}$$

$$FE_t^p = f(CP_t^{p1}, CP_t^{p2}, \dots, CP_t^{pm}, PtReq_t) \tag{27}$$

Note that because energy and protein feeds are estimated individually, substitution of a predominantly energy-based feedstuff for a predominantly protein-based feedstuff and vice versa is not taken into account. In the event there is potential for significant cross substitution of energy and protein feeds, the standard demand equations must be amended by inclusion of prices of substitutable feedstuffs.

As in the case of food demand, consistency in own- and cross-price demand elasticities is necessary to ensure stability of the CCLS. Such stability is created with use of energy and protein demand matrices similar to that for food consumption. The algorithm used to derive cross-price elasticities for food demand is likewise applied to feed demand (see Appendix D for more information).

Oilseed crush

The quantity of oilseed that is crushed depends on the crush-return ratio. As shown in equation 28, the crush-return ratio (CR_t) for a single oilseed is equal to the sales value of the oilseed products divided by the cost of the oilseed. Specifically, the crushing yields of meal (μ_t^m) and oil (μ_t^o) are each multiplied by their respective producer prices (PP_t^m and PP_t^o), and then the sum is divided by the consumer (wholesale) price of the oilseed (CP_t^s) (equation 28).

$$CR_t = (\mu_t^m \cdot PP_t^m + \mu_t^o \cdot PP_t^o)/CP_t^s \tag{28}$$

In the European Union, Brazil, and many other countries, market- and/or policy-driven demand for vegetable oils for biodiesel production is also an important determinant of oilseed crush. In such cases, crush (CS_t) will also depend on an exogenously determined level of biodiesel production (QP_t^{bd}). In addition, or instead of explicit biodiesel production, a trend may be used to capture other forces driving crush demand, yielding the standardized crush demand specification for a single oilseed as shown in equation 29.

$$CS_t = f(CR_t, QP_t^{bd}, trend) \tag{29}$$

Other demand

Demand for ethanol (non-oilseed) feedstocks, cotton mill demand, seed use, losses, and other disappearance fall within other demand. A general specification for a single commodity, which encompasses all of these uses, is:

$$OD_t = f(QP_t^{et}, pOil_t, CPI_t, AH_t, trend). \tag{30}$$

In this equation, QP_t^{et} denotes ethanol production; $pOil_t$ is the price of petroleum, which impacts cotton mill demand and/or demand for ethanol feedstocks; CPI_t is the consumer price index, which is a proxy for general manufacturing or labor costs; seed demand depends on area harvested (AH_t);

and *trend* is a catch-all trend growth rate. Note that only those explanatory variables that are relevant to a specific commodity will appear in the projection equation. In addition, country-specific market structure, policies, and other circumstances may dictate inclusion of additional variables in the other demand equation.

Stocks

Demand for stockholding is treated as a function of prices and trends (either time or lagged dependent variable). Modeled as a downward sloping demand curve, this behavioral equation is what links quantities across time, thus also playing an important role for determining prices in each period. While there is a large amount of theoretical literature about the demand for stocks (e.g., Williams and Wright, 1991), the stocks equation has been simplified here to provide a tractable model that solves for quantity and prices domestically and globally. Accordingly, many of the theoretical considerations of those rational expectations models are assumed to be captured within the trend and lagged dependent variables.

Market interventions in the name of food security frequently affect stockholding. For example, in India, the National Food Security Act of 2013 guarantees a minimum quantity of food grains to 813 million people each year (Kishore et al., 2014). To fulfill that obligation, the Government procures food grains from producers at announced prices. Farmers will sell their grain to state buyers if the procurement price (GP_t) exceeds the prevailing producer price at harvest time. This has resulted in the Government holding as much as 66 million metric tons (mmt) and as little as 12 mmt of food grains over the past 10 years (Government of India, 2016) .[18] Once the stocks are held, withdrawals depend on the size of the population guaranteed minimum rations and, for other eligible recipients, the difference between Government-subsidized consumer prices (GC_t) and free-market consumer prices (CP_t).

In general, stocks are drawn down when weather-induced supply shortfalls result in rising prices. The incidence of weather-induced movement in stocks is more prevalent in countries with highly variable precipitation (monsoons) and/or no or limited irrigation capacity (e.g., North Africa). When such countries are being modeled, the best predictor of stocks may be the yield.

In combination, the traditional determinants of stocks plus food security and supply shocks give the generalized ending stock equation as:

$$ES_t = f(PP_t, GP_t, CP_t, GC_t, YL_t, ES_{t-1}, trend). \quad (31)$$

Note that only those variables relevant to the country being modeled will appear in the projection equation.

Foreign Trade

To accommodate commodity analysis, imports and exports are modeled separately in most models. As noted previously, all commodities are assumed to be homogenous in international trade. Thus, each country has a single reference price for each commodity. Specification of import demand and export supply depends on trade policy, the magnitude of trade, and choice of market-clearing vari-

[18] The 66 mmt of wheat and rice held in stocks on January 1, 2013, represented about 23 percent of world wheat and rice stocks (USDA, OCE, 2015).

able. The simplest formulation is when imports and exports are not market-clearing variables and imports are not subject to TRQs. In that case, since import and export prices embody trade policy parameters (see equations 3-4), export supply (quantity exported) depends on domestic producer and export prices (equation 32), while import demand may vary with consumer and import prices (equation 33).

$$EX_t = f(PP_t, XP_t) \quad (32)$$

$$IM_t = f(CP_t, MP_t) \quad (33)$$

If either exports or imports are selected as the market-clearing variable, a large change in one or more of the supply or demand variables could, with relatively small trade values, result in negative exports or imports. In such cases, a dual-residual trade formulation prevents exports and imports from falling below their respective floors, while continuing to clear the domestic market. In this formulation, exports and imports can be found via equations 34 and 35, where the import and export floors (IM_t^{floor} and EX_t^{floor}) may be constants or functions.

$$EX_t = max\ (QP_t + ES_{t-1} - QD_t - ES_t + IM_t^{floor}, EX_t^{floor}) \quad (34)$$

$$IM_t = max\ (QD_t + ES_t - QP_t - ES_{t-1} + EX_t^{floor}, IM_t^{floor}) \quad (35)$$

If imports are subject to a TRQ with a domestic price adjusting to clear the domestic market, exports would be specified as in equation 32, while total imports (equation 36) would be the sum of (a) the lesser of the TRQ and a behavioral import equation facing the within-quota import price (equation 37), and (b) the greater of zero and a behavioral import equation facing the over-quota import price less the TRQ (equation 38).

$$IM_t = IM_t^{IQ} + IM_t^{OQ} \quad (36)$$

$$IM_t^{IQ} = min\ (\ f(PP_t, MP_t^{IQ}), TRQ_t) \quad (37)$$

$$IM_t^{OQ} = max\ (f(PP_t, MP_t^{OQ}) - TRQ^t, 0) \quad (38)$$

Market-Clearing Mechanism

Each commodity market is cleared—that is, equation 1 is satisfied—either with an equilibrium price or a residual quantity by initiating full iterative calculation of the Excel-based model file. The choice of a market-clearing variable depends on the nature of a commodity market and its relation to international markets. Commodity markets where there is little or no international trade, such as milk or eggs, are most appropriately cleared with an equilibrium domestic market price. Among major international market players, imports or exports are most often the market-clearing variables.

When trade policies used by a country preclude use of imports or exports as the market-clearing variable, the domestic price or a demand variable usually clears the market. In the latter case, the choice of variable depends on the type of commodity under consideration and is almost always for a large demand component (e.g., food consumption instead of industrial use). For an oilseed, crush may be an appropriate market-clearing variable. Ending stocks are less likely to be used to equilibrate supply and demand since they are typically a much smaller share of total disappearance than food, feed, or crush demand.

In some cases, an equilibrium producer or consumer price may be the most appropriate means of clearing a market. As noted previously, an equilibrium domestic market price may be best when there is no trade in a commodity or border measures are such that transmission of world market prices is limited. In such cases, there may be little linkage between domestic and world market prices. When a price clears a commodity market, all supply and demand variables are projected from behavioral relationships. If the producer price, for example, is the market-clearing variable, it is computed as shown in equation 39 by initiating a full calculation of the model.

$$PP_t^{cc} = PP_t^{cc} \cdot \left[1 - \left(\frac{QP_t^{cc} + ES_{t-1}^{cc} + IM_t^{cc} - EX_t^{cc} - FD_t^{cc} - FE_t^{cc} - OD_t^{cc} - ES_t^{cc}}{Abs\left(QP_t^{cc}\right) + Abs\left(FD_t^{cc}\right) + Abs\left(FE_t^{cc}\right)}\right) \cdot \rho\right] \qquad (39) \qquad (39)$$

In this equation, *cc* denotes the commodity, Abs(.) denotes an absolute value, and ρ is an adjustment parameter, which in general is less than or equal to 0.5. In each iteration, the specified portion of the ratio (ρ) of the supply-demand balance (the numerator in the ratio) and the absolute value of the sum of production, food demand, and feed demand is subtracted from 1, which in turn is applied to the current value of the producer price. As the supply-demand balance falls to zero, the producer price stabilizes at a market-clearing level.

The solution process in the CCLS is similar. All reference prices are endogenous, and a solution is found that balances world supply and demand. This solution takes into account how world prices are translated to domestic market outcomes in each linked country according to its integration with each world commodity market. In addition to the country models, the CCLS includes a world residual region that ensures world imports equal world exports for each commodity. The residual region absorbs reporting discrepancies in world trade flows due to shipping times and other factors that result in world import totals differing from world export totals.

Supply, Demand, and Other Elasticities

There is an abundance of literature on the theoretical aspects of production economics (e.g., Beattie et al., 2009; Debertin, 2012), consumer demand (e.g., Deaton and Muellbauer, 2006; Pollak and Wales, 1992), international trade (e.g., Helpman and Krugman, 1999; Houck, 1986), and agricultural policy analysis (e.g., Gardner, 1987; Taylor et al., 1993). While these theoretical models have received extensive empirical application in analysis of the U.S. and other developed economy domestic markets (e.g., Hendricks et al., 2014; Orazem and Miranowski, 1994; Okrent and Alston, 2012; Andreyeva et al., 2010; Tiffin et al., 2012), empirical analysis of other markets tends to be relatively sparse. When relevant elasticities are found in the literature, they frequently are dated, or limited to a few commodities or countries, or apply to a higher level of aggregation than required for the CCLS (e.g., Muhammad et al., 2011; Seale et al., 2003). Some country studies provide good guidance to the modelers, including, for example, Kumar et al. (2011) for India and Ulubasoglu et al. (2015) for Australia. For many countries and regions, the lack of empirical analysis is constraining. Elasticities culled from disconnected literature (different approaches, different levels of aggregation, etc.) can often only be considered a rough guide to the relative magnitudes of elasticities for a partial equilibrium multicommodity model.

Elasticities may be estimated instead of culled from published research. Such estimation requires supply and demand quantity and price data of sufficient quality and quantity for a specific commodity. Basic market-relevant data such as commodity prices may be available for major agricultural-producing countries but less so for other countries. Even when relevant data are available, mismatches in data pairs (e.g., monthly prices and annual demand) and a limited consistent time series often preclude use of econometrics or other statistical methods of estimating elasticities.

Given these constraints, the majority of the elasticities and other parameters in the analytical agricultural sector models are synthetic. The criteria used to decide on elasticities are generally based on five factors:

- Are they theoretically consistent?
- Are they reasonable in terms of known supply and demand elasticities in like economies?
- Are they reasonable in terms of cross-commodity comparisons?
- Are they representative of historical behavior?
- Do they generate results that country and commodity experts believe?

This approach means there is considerable room for disagreement on the particular elasticities employed in any one of the country baseline models. And, because most of the elasticities and technical parameters are based on expert knowledge, they are almost continually revised as new information becomes available. Since the projections produced with the models are vetted each year by the Interagency Agricultural Projections Committee, the underlying elasticities may be considered, in aggregate, consensus values.[19]

[19] The CCLS includes diagnostics that generate implied elasticities with respect to changes in (a) world prices, (b) producer prices, (c) consumer prices, (d) government producer prices, and (e) government consumer prices. The diagnostic results are periodically reviewed by the ERS country modelers.

The parameter values for the models conform to the principles of demand theory. Specifically, for food demand:

- own-price elasticities are negative;
- substitute commodities have positive cross-price elasticities;
- the sum of the cross- and own-price elasticities for each product is zero (homogeneous of degree 0); and
- cross-price elasticities fulfill symmetry restrictions.

These conditions are imposed with the aid of an algorithm that computes theoretically consistent cross-price elasticities from expenditure shares computed in the model and an own-price and income elasticity supplied by the modeler. The algorithm uses the standard demand theory conditions (homogeneity, symmetry, and Cournot aggregation) plus the assumption that the ratio of any two cross-price elasticities for a single commodity is proportional to their expenditure shares. The latter means that in practical terms, a commodity that has a relatively large expenditure share will also have a relatively large cross-price elasticity. This makes intuitive sense in that a change in the price of a commodity on which a large percentage of income is spent is likely to have a relatively large impact on the consumption of other commodities. See Appendix D for more information on food and feed demand and area elasticities.

Functional Forms

Based on the foundation of the general theory presented above, each country modeler is responsible for specifying the behavioral equations within their respective models. In the absence of particular market knowledge, as is likely to be the case with regional models, simple versions of the above standard equations may be used. In contrast, in models for major commodity producers such as Brazil, Argentina, or the EU, closer adherence to the standardized equations is common. The same applies to the U.S. model, which also includes greater detail in some commodity markets.

The modeler may choose from three functional forms, with the choice depending on the nature of the equation being specified and on the expected level of market responsiveness. The first form is a linear equation, which is most typically used for identities such as the definition of a border price, and may also be used for behavioral equations. Many U.S. model equations are linear. For example, the national yield of barley in the United States is projected with a simple linear trend ($YL_t^{BA} = \beta_0 + \beta_1 \cdot time$) with the values of β_0 and β_1 estimated econometrically.

The second, and most frequently used functional form, is the linearized exponential or Cobb-Douglas equation. Using a three-commodity, area-harvested equation as an example, the Cobb-Douglas projection equation takes the form:

$$AH_t^{wh} = AH_{t-1}^{wh} \cdot (1 + \%\Delta ER_t^{ba} \cdot \epsilon_{ba}^{wh} + \%\Delta ER_t^{ra} \cdot \epsilon_{ra}^{wh} + \%\Delta ER_t^{wh} \cdot \epsilon_{wh}^{wh}).$$

In the above equation, $\%\Delta$ denotes percent change, and ϵ_x^{wh} is the elasticity of wheat area with respect to a change in the expected return of x (i.e., barley (ba), rapeseed (ra), and wheat (wh)). The above linearization applies in general to small changes in explanatory variables. Therefore, the Cobb-Douglas formulation is typically used when the elasticities used to compute the dependent variable are small. This makes the Cobb-Douglas a preferred form for variables such as food demand and area harvested where cross-price elasticities are likely to be small.

The third functional form is the exponential projection equation. With the variables as previously defined, it takes the following form:

$$AH_t^{wh} = AH_{t-1}^{wh} \left(\frac{ER_t^{ba}}{ER_{t-1}^{ba}}\right)^{\epsilon_{ba}^{wh}} \left(\frac{ER_t^{ra}}{ER_{t-1}^{ra}}\right)^{\epsilon_{ra}^{wh}} \left(\frac{ER_t^{wh}}{ER_{t-1}^{wh}}\right)^{\epsilon_{wh}^{wh}}.$$

This exponential formulation is suitable for any elasticity value and is preferred when economic responses are more elastic and explanatory variable adjustments may be large. For example, stocks and trade levels are most likely to change sharply when prices rise or fall. Therefore, these equations may best be represented with an exponential equation.

The linearized Cobb-Douglas formulation approximates the results of the exponential formulation. If the elasticities are large and the explanatory variables (e.g., expected returns) cause the level of area harvested to oscillate—to rise and fall, or to fall and rise—the final Cobb-Douglas linear approximation can sag significantly below the exponential level. Suppose that there is one explanatory variable, which in period 1 causes the dependent variable level to drop significantly from its period-0 level. In period 2, if the explanatory variable is restored to its period-0 level, the exponential form will result in the period-0 level of the dependent variable. However, the period-2 level of the linearized Cobb-Douglas approximation will be below the period-0 level because growing linearly from the low period-1 level up to the period-0 level would require a larger relative change in the explanatory variable than merely restoring the period-0 level of the explanatory variable. Problematic changes in levels may occur for those variables where elasticities tend to be large. In those cases, the exponential formulation may be preferred.

An important feature of the functional forms is that each elasticity or other parameter can vary over time via specification of a growth rate for the coefficient. This is necessary when modeling food demand in developing countries since consumption preferences change as incomes rise. For example, the income elasticity on animal products can decline over the projection period. It also enables, for example, incorporating slowing technological growth in yields, declining or rising influence of world prices on domestic market prices, and numerous other factors that may vary over time.

Initial Projection Values and Add Factors

The country models must conform to the latest official production, supply, and disappearance data. That is, for the initialization year through the last year of historical data,[20] each projected variable, such as area, yield, food demand, and so on, must be the same as that in the last version of the FAS' PSD database loaded into the models.[21] The estimated values from behavioral equations after the initialization year through the last year of PSD data (e.g., 2015/16 and 2017/18, respectively) are rarely the same as published values since the latter reflect year-to-year anomalies and market disturbances. To ensure that the PSD and model data are the same, add factors are used to calibrate the behavioral relationships to the PSD data. This process, which is referred to as the "truing up" of a model, is completed using an automated routine that shifts the intercept of each supply or demand equation that differs from a PSD value. This is accomplished by applying an add factor equivalent to the difference between the value estimated from the behavioral relationship and the published PSD value, thus yielding the published value.

Add factoring is also used to true a projection equation to a known price, cost, or other variable used in a model. For example, in the Brazil model, corn production costs are projected to compute expected returns to producing corn vis-à-vis other crops. Actual production costs and domestic market prices are usually known for the base and subsequent years through the last historical data year (e.g., 2017/18). Similarly, policy (procurement) prices in India are announced in advance of a marketing season. To incorporate this information in a model, equations projecting such variables are trued to the announced or known values.

Add factors are also used to adjust values of supply-demand variables in the first projection year. These manual adjustments, which are made by the modelers, may be necessary when an initialization year value—such as a yield—is abnormally high or low. Thus, a yield reduced by drought in the last year of historical data can recover to a normal growth level by addition of a positive add factor to the first projection year. This is essential in the case of a variable being projected with a linearized Cobb-Douglas or exponential equation, as large changes in a single year can have rippling effects across future years.

Add factors are also used to calibrate supply and demand elements as necessary to yield the Interagency Agricultural Projections Committee consensus import and export projections. Calibration add factors are applied in an automated routine to one or more variables chosen by the modeler within a commodity supply-demand balance. The calibration add factors provide important information to the modeler. When the add factors are large, the modelers examine the behavioral equation specifications to determine whether a structural shift or other external factor is not adequately captured by the specification. This process ensures the continued validity of behavioral responses.

Note that when the model is used for policy analysis, the truing and calibration add factors are fixed. This means that all scenario-related changes are derived exclusively from the behavioral responses in the models. This is the case even when add factors are used to adjust first projection year values. Those add factors have no effect on measurement of the behavioral responses.

[20] For example, 2015/16 is the initialization year, 2017/18 is the last year of historical data, and 2018/19 is the first projection year for the 2018 USDA baseline projections to 2027/28 that were released in February 2018.

[21] The last version of the PSD loaded into the models is one of the underlying assumptions upon which the baseline projections are predicated.

Conclusion

The preceding presents the framework within which longrun commodity-country projections are developed within USDA and global scenarios analyses are implemented within ERS. At the heart of the international projections and scenarios is a multi-country partial equilibrium model that has been developed specifically, and made unique, for each country. The country models and the CCLS program, which were initially built in the early 1990s, have been further developed, used, and improved by numerous former and current ERS economists. The CCLS is constantly enhanced and the country models are revised in response to new market information and research findings.

The CCLS is unique among other prominent multi-country partial equilibrium agricultural sector models in the need to produce rigorous economic projections while integrating with USDA's consensus-based, short- to medium-term forecasting process. The effort put forth over a quarter century has yielded a tool for analysis of contemporary issues facing U.S. and global agricultural market participants. Together, the combination of all country models allows an analyst to study and project changes to country-specific factors, while simultaneously considering commodity markets globally. By measuring the impacts of global or country-specific changes on the entire linked system, the CCLS provides a useful approach, rooted in the principles of supply and demand, to better understanding world agricultural markets. While detailing and specifying each country-commodity model is not practical here, this document serves as a general reference for understanding the approach taken at ERS to build and maintain country- and region-based analytical agriculture sector models.

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Appendix A: Regional Models

Table A
Country content of regional models

Region code	Region and member countries
CAC	***Central America and Caribbean (excluding Cuba)***
	Bahamas
	Barbados
	Belize
	Bermuda
	Costa Rica
	Dominica
	Dominican Republic
	El Salvador
	French West Indies
	Greenland
	Grenada
	Guadeloupe
	Guatemala
	Haiti
	Honduras
	Jamaica and Dependencies
	Netherlands Antilles
	Nicaragua
	Panama
	Puerto Rico
	St. Kitts and Nevis
	St. Lucia
	St. Vincent and Grenadines
	Trinidad and Tobago
	United States Virgin Islands
ECO	***ECOWAS (Economic Community of West African States)***
	Benin
	Burkina Faso
	Cape Verde Islands
	Cote D'Ivoire
	Gambia
	Ghana
	Guinea

—continued

Table A
Country content of regional models—continued

Region code	Region and member countries
	Guinea Bissau
	Liberia
	Mali
	Niger
	Nigeria (oilseeds, meals and oil other than soy, milk, lamb and mutton, eggs only)
	Senegal
	Sierra Leone
	Togo
EUN	***European Union***
	Austria
	Belgium
	Bulgaria
	Croatia
	Cyprus
	Czech Republic
	Denmark
	Estonia
	Finland
	France
	Germany
	Greece
	Hungary
	Ireland
	Italy
	Latvia
	Lithuania
	Luxembourg
	Malta
	Netherlands
	Poland
	Portugal
	Romania
	Slovakia
	Slovenia
	Spain
	Sweden
	United Kingdom

—continued

Table A
Country content of regional models—continued

Region code	Region and member countries
OAO	***Other Asia and Oceania***
	Afghanistan
	Australia (eggs only)
	Bhutan
	Brunei
	Burma (excluding rice)
	Cambodia (excluding rice)
	Fiji
	French Polynesia
	Hong Kong (excluding wheat, rice)
	India (pork and lamb and mutton only)
	Indonesia (other coarse grains, beef, eggs, milk, lamb and mutton only)
	Kiribati and Tuvalu Gilbert
	Korea, North
	Laos
	Macau
	Malaysia (other coarse grains, sugar, beef, lamb and mutton, milk, eggs only)
	Maldives
	Mongolia
	Nepal
	New Caledonia
	New Zealand (excluding beef, lamb and mutton, milk)
	Pakistan (only sugar, pork, lamb and mutton)
	Papua New Guinea
	Singapore
	Solomon Islands
	Sri Lanka
	Taiwan (only sugar, oilseeds and meals other than soy)
	Thailand (only other coarse grains, milk, lamb and mutton)
	Tonga
	Vanuatu
	Vietnam (only other coarse grains, animals products except poultry)
	Western Samoa
OEU	***Other Europe***
	Albania
	Bosnia Herzegovina

—continued

Table A
Country content of regional models—continued

Region code	Region and member countries
	Faroe Islands
	Gibraltar
	Iceland
	Macedonia
	Montenegro
	Norway
	Serbia
	Switzerland
OFS	***Other Former Soviet Union***
	Armenia
	Azerbaijan
	Belarus
	Georgia
	Kazakhstan
	Kyrgyzstan
	Moldova
	Tajikistan
	Turkmenistan
	Uzbekistan
OME	***Other Middle East***
	Bahrain
	Former Yemen North Sanaa
	Former Yemen South Aden
	Iran (other coarse grains, cotton, sugar, and livestock products only)
	Iraq (excluding grains)
	Israel
	Jordan
	Kuwait
	Lebanon
	Oman
	Qatar
	Saudi Arabia (other coarse grains, cotton, sugar, pork, eggs, and milk only)
	Syria
	Turkey (sugar, pork, eggs, and milk only)
	United Arab Emirates
	Yemen

—continued

Table A
Country content of regional models—continued

Region code	Region and member countries
ONA	***Other North Africa***
	Algeria
	Egypt (other coarse grains, sugar, pork, eggs, and milk only)
	Libya
	Morocco (except wheat, rice, corn, barley, and sorghum)
	Tunisia
OSA	***Other South America***
	Argentina (lamb and mutton only)
	Brazil (lamb and mutton only)
	Bolivia
	Chile
	Colombia
	Ecuador
	Guyana
	Paraguay
	Peru
	Suriname
	Uruguay
	Venezuela
OSS	***Other Sub-Saharan Africa***
	Angola
	Botswana
	Burundi
	Cameroon
	Central African Republic
	Chad
	Comoros Islands
	Congo (Brazzaville)
	Congo (Kinshasa, formerly Zaire)
	Djibouti
	ECOWAS (livestock products only)
	Equatorial Guinea
	Eritrea
	Ethiopia
	Gabon
	Kenya
	Lesotho

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Table A
Country content of regional models—continued

Region code	Region and member countries
	Madagascar
	Malawi
	Mauritania
	Mauritius
	Mozambique
	Namibia
	Reunion
	Rwanda
	Sao Tome and Principe
	Seychelles
	Somalia
	South Sudan
	Sudan
	Swaziland
	Tanzania
	Uganda
	Zambia
	Zimbabwe
ROW	***Rest-of-world (grouped by commodity)***
	Soybeans and products: OSS
	Rapeseed and products: OSS, RSA, USA
	Sunflowerseed and products: OSS, USA
	Other oilseeds and products: OSS, RSA, UKR, USA
	Cotton: RSA
	Sugar: EUN, MEX, OSA, OSS, RSA, USA
	Beef and veal: OSS
	Pork: OME, ONA, OSS
	Eggs: CAN, MEX, OSS, RSA
	Milk: CAN, MEX, OSS, RSA
	Lamb and mutton: CAC, CAN, EUN, MEX, OAO, OEU, OFS, OSA, OSS, USA

MEX = Mexico. RSA = Republic of South Africa. UKR = Ukraine. USA = United States of America.
Source: USDA, Economic Research Service.

Appendix B: Reference Prices

Table B
Reference prices

Commodity	Description
Cattle	Steers, all grades, U.S. 5-Area (TX/OK/NM; KS; NE; CO; IA/MN)
Beef (grass fed, imported)	Beef, Australia/New Zealand, U.S. ports
Beef (U.S.)	Cows, cutter, 90% lean, 500 lbs. & up, U.S. national average
Milk (U.S. only)	Prices received by U.S. farmers, all milk
Butter (U.S. only)	Grade A, 80% butter fat
Cheese (U.S. only)	40-lb blocks, USDA Grade A, or better
Non-fat dry milk (U.S. only)	Central States, wholesale, extra grade
Hogs (U.S. only)	Hogs, national base, live equivalent, 51-52% lean
Pork (U.S.)	U.S. carcass cut-out value, 51-52% lean
Pork (international)	Japan unit import values, c.i.f.
Sheep	Composite of mutton (0.1) and wool (0.75)
Lamb/mutton	Lamb, New Zealand, London
Wool	Wool, coarse, Australia/New Zealand, 48's, London
Poultry meat	12-city composite wholesale price, ready to cook
Eggs	Grade A "large," wholesale, New York
Rice (long grain, U.S.)	Houston #2 long grain, 4% brokens, f.o.b. mill, adjusted to f.o.b. equivalent
Rice (long grain, Asia)	Thai B, f.o.b. Bangkok
Rice (medium grain, U.S.)	California medium grade #1, 4% brokens, sacked for export, Oakland
Corn	U.S. Gulf, #2 yellow, f.o.b.
Sorghum	U.S. Gulf, #2 yellow, f.o.b.
Wheat (U.S.)	U.S. Gulf, #2 HRW, f.o.b.
Wheat (Argentina)	Rosario, Trigo pan, f.o.b.
Barley (Canada)	Winnipeg, Canada, f.o.b.
Barley (EU)	French, Rouen, grade 1, nearest available shipment
Oats	U.S. farm
Cassava	Tapioca, hard pellets, f.o.b., Rotterdam
Cotton	"A" index
Sugar	United States only: New York #16
Sugar	World price: Sugar, New York #11, Caribbean
Soybeans	Rotterdam, c.i.f., U.S. origin (Oil World)
Groundnuts	Rotterdam, c.i.f., U.S. Runners 40/50%, shelled basis (Oil World)

—continued

Table B
Reference prices—continued

Commodity	Description
Sunflowerseed	Rotterdam/Amsterdam, c.i.f., (Oil World)
Rapeseed	Hamburg, c.i.f., Europe "00" (Oil World)
Cottonseed	Composite of cottonseed oil & meal extraction rates
Soybean meal	Hamburg, f.o.b., 44/45% protein, ex-mill (Oil World)
Groundnut meal	Derived from other meal prices
Sunflowerseed meal	Argentina/Uruguay, 37-38% protein, pellets, c.i.f., Rotterdam
Rapeseed meal	Hamburg, f.o.b., 34% protein, ex-mill
Cottonseed meal	Memphis, f.o.b., 41% protein, solvent extraction
Fishmeal	Any origin, c.i.f., Bremen, 64/65% protein
Copra meal	Philippine expeller pellets, 26% protein
Soybean oil	Rotterdam, crude, f.o.b. ex-mill (Oil World)
Groundnut oil	Rotterdam, c.i.f., any origin (Oil World)
Sunflowerseed oil	Northwest European ports, f.o.b. (Oil World)
Canola oil	Dutch, f.o.b., ex-mill Rotterdam (Oil World)
Cottonseed oil	Rotterdam, c.i.f., U.S. PBSY Greenwood, MS (USDA)
Coconut oil	Rotterdam, c.i.f., Philippines/Indonesia origin (Oil World)
Palm oil	Malaysia, RBD, f.o.b. (Oil World)
Urea	Eastern Europe, f.o.b., bulk, spot
Triple Super Phosphate	North Africa ports, f.o.b. (GEM, World Bank)
Potash	Potassium chloride, standard grade, spot, f.o.b., Vancouver
Petroleum	Petroleum, U.S. refiners acquisition cost

c.i.f. = cost, insurance, and freight. f.o.b. = free on board. HRW = hard red winter. PBSY = prime, bleachable, yellow, summer. RBD= refined, bleached, and deodorized.
Source: USDA, Economic Research Service.

Appendix C: Higher Soybean Yield Growth Scenario

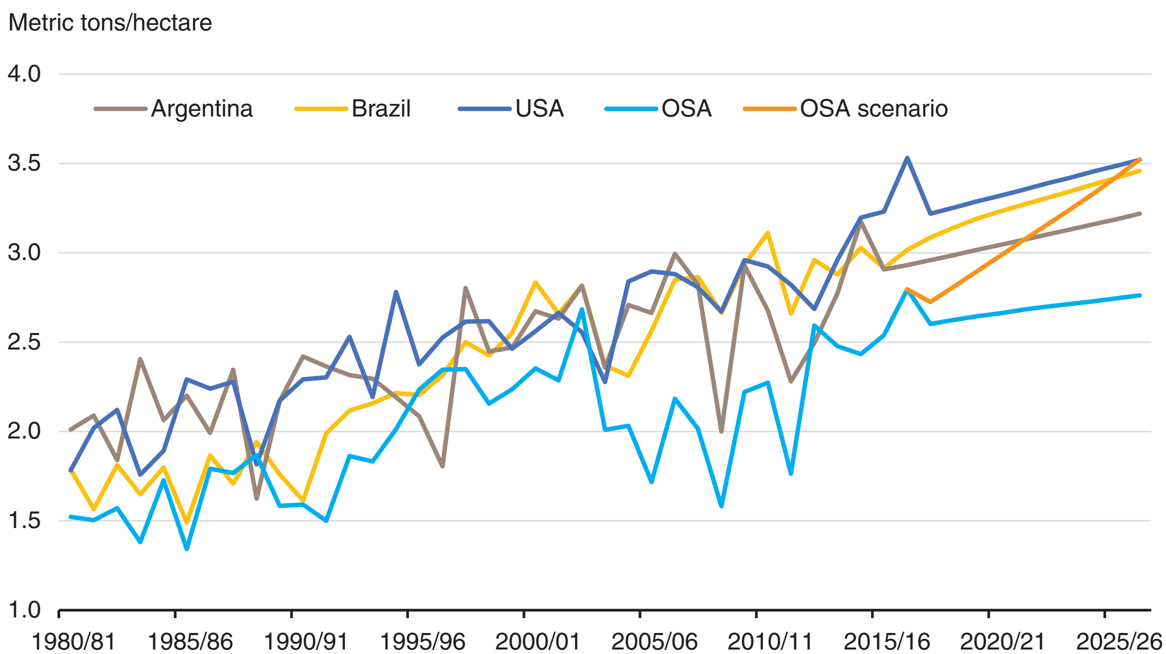
The following numerical illustration provides context to both the modeling and projection processes.

The ability of the Country-Commodity Linked System (CCLS) to incorporate alternative scenarios is demonstrated by introducing a higher rate of growth of soybean yields among South American countries other than Argentina and Brazil. This region, denoted Other South America (OSA), includes Bolivia, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay, and Venezuela. When combined, this group of countries is the third-largest exporter of soybeans after Brazil and the United States. Soybean yield growth in the OSA has been slower than that in Brazil and Argentina. There likely are many reasons for lower yields within the region, including geographical, political, and agricultural policy differences. In this scenario, we assume that existing constraints to soybean yield growth are removed such that the aggregate OSA yield rises to a level similar to that of the United States by 2026. This scenario, therefore, provides a counterfactual to the current projections by examining the impact of higher yields in Other South American countries.

A comparison of historical and projected soybean yields for the United States, Argentina, Brazil, and OSA from 1980/81 to 2025/26 is shown in figure C1. In addition, the figure includes the alternative or scenario projection of OSA soybean yields with a 2025/26 value similar to that of the United States. The scenario yield is 27 percent higher than the baseline by 2025/26, with an average annual growth rate of 2.9 percent compared to 0.7 percent in the baseline.

Appendix figure C1

Historical and projected soybean yields for United States, Argentina, Brazil, and Other South America, 1980/81-2025/26



Note: OSA = Other South America. USA = United States of America.
Source: USDA, Economic Research Service research results.

Table C1 presents percentage changes in world and OSA soybean prices and supply-demand quantities with higher yield growth. The higher yields influence both the supply and demand sides of the market. Producers' rising expected revenues (expected prices multiplied by expected yield) drive more area into production, increasing total harvested area. Producers are able to benefit from the higher yields due to only modest price declines as domestic consumption (largely through crushing) and exporters are able to make use of the extra production without significantly suppressing domestic prices. The 1- to 2-percent decline in domestic prices is due to the high integration of domestic and world markets via exports. Globally, we see only modest price declines—4 percent by the final projection year.

Table C1
Projected change in world soybean prices and Other South America (OSA) soybean supply, demand, and domestic prices with higher soybean yields

Crop year	World reference price	OSA producer price	Area harvested	Yield	Production	Imports	Exports	Total use	Crush	Ending stocks
	Percent change from base value									
2016/17	-0.4	-0.2	0.0	2.2	2.3	0.0	2.5	1.8	1.9	0.2
2017/18	-0.7	-0.4	0.1	4.6	4.7	0.0	5.0	3.6	3.9	0.3
2018/19	-1.0	-0.5	0.5	6.9	7.4	-0.1	8.0	5.6	6.1	0.4
2019/20	-1.4	-0.7	1.0	9.3	10.4	-0.1	11.3	7.9	8.5	0.6
2020/21	-1.7	-0.9	1.5	11.8	13.5	-0.1	14.6	10.2	11.0	0.7
2021/22	-2.1	-1.0	2.0	14.3	16.6	-0.2	17.9	12.5	13.5	0.8
2022/23	-2.4	-1.2	2.6	16.7	19.7	-0.2	21.3	14.8	16.0	0.9
2023/24	-2.7	-1.4	3.1	19.3	23.0	-0.2	24.9	17.2	18.6	1.0
2024/25	-3.0	-1.5	3.7	21.9	26.4	-0.3	28.5	19.8	21.4	1.1
2025/26	-3.3	-1.7	4.2	24.6	29.9	-0.3	32.2	22.4	24.2	1.2
2026/27	-3.7	-1.9	4.8	27.3	33.4	-0.3	36.0	25.1	27.1	1.3

Source: USDA, Economic Research Service research results.

As shown, the models and CCLS can project the impact of rising soybean yields on OSA, but they also can analyze the impact on markets across the globe. Table C2 presents the impact of the yield growth in OSA on harvested area and exports of soybeans in the United States, Argentina, and Brazil. There are slight decreases in harvested area across the three countries due to lower prices. Argentina sees the largest percentage decline in exports at 7 percent by 2026/27. Brazil and U.S. exports also decrease, but in smaller percentage terms. The decrease in exports from the United States is due to lower production.

Table C2
Projected impact of Other South America (OSA) soybean yield growth on soybean area and exports in the United States, Argentina, and Brazil

Crop year	USA		Argentina		Brazil	
	Area harvested	Exports	Area harvested	Exports	Area harvested	Exports
	Percent change from base value					
2016/17	0.0	-0.1	0.0	-0.7	0.0	-0.1
2017/18	-0.1	-0.3	-0.1	-1.2	0.0	-0.1
2018/19	-0.2	-0.5	-0.2	-1.7	-0.1	-0.2
2019/20	-0.3	-0.8	-0.2	-2.3	-0.1	-0.3
2020/21	-0.4	-1.0	-0.3	-3.0	-0.2	-0.4
2021/22	-0.6	-1.3	-0.4	-3.5	-0.3	-0.5
2022/23	-0.7	-1.5	-0.5	-4.2	-0.3	-0.7
2023/24	-0.8	-1.8	-0.6	-4.8	-0.4	-0.8
2024/25	-1.0	-2.1	-0.6	-5.5	-0.5	-1.0
2025/26	-1.1	-2.3	-0.7	-6.3	-0.6	-1.1
2026/27	-1.2	-2.6	-0.8	-7.0	-0.6	-1.3

USA = United States of America.
Source: USDA, Economic Research Service research results.

The scenario impacts reported in tables C1 and C2 are just a sampling of the results from the scenario. Additional country outcomes are available, including cross-commodity effects. While the productivity growth substantially changes soybean output in OSA, the global impacts are more limited. Other published scenarios, such as those in the recent research reports identified in the Introduction of this report (Valdes et al., 2016; Motamed et al., 2013) further testify to the models' capabilities and analytical potential.

Appendix D: Estimating Theoretically Consistent Food and Feed Demand and Area Elasticities

Estimation of food demand elasticities for the CCLS countries and regions in general is not possible due principally to data constraints. This means elasticities must be obtained from published studies or other means. The availability of published estimates of demand elasticities is greater for developed market economies (e.g., Okrent and Alston, 2012; Tiffin et al., 2012). However, such studies frequently report elasticities for broad aggregates, such as cereals and bakery products, as opposed to primary food ingredients, such as wheat, rice, and vegetable oils. Despite these limitations, food demand in an agricultural sector model system made up of 44 individual country and regional models must conform to classical demand theory and exhibit properties associated with that theory.

Given this constraint, another method of imposing theoretical demand properties on food demand projections is needed. Such a method was developed by former ERS economist Mark Giordano[22] to ensure that projections of food demand conform to theory. With modeler-supplied own-price and income elasticities, base expenditures shares, imposition of the demand theory properties of homogeneity, symmetry, and Engel aggregation, and an assumption relating cross-price elasticities, a matrix of theoretically consistent own- and cross-price elasticities may be derived. The assumption, subsequently referred to as the base assumption, is that the magnitude of any two cross-price elasticities for a single commodity is proportional to their expenditure shares. In practical terms, this means that a commodity that has a relatively large expenditure share will also have a relatively large cross-price elasticity. This makes intuitive sense in that a change in the price of a commodity on which a large percentage of income is spent is likely to have a relatively large impact on the consumption of other commodities.

The approach is similar to that used by Beghin et al. (2003) to calibrate an incomplete demand system. However, it does not require specification of a functional form. The demand matrix contains up to 28 foods (commodities) and one nonfood good. Each column in the matrix refers to a single commodity, and each row represents a price (fig. D1). The modeler supplies an own-price (on the diagonal) and expenditure elasticity for each commodity.

Homogeneity requires that the sum of the cross-price elasticities (ε_{ij}) equals the negative sum of the own-price (ε_{ii}) and the income elasticity (γ_i) or:

$$\sum_{j=1}^{n\neq i} \varepsilon_{ij} = -(\varepsilon_{ii}+\gamma_i). \qquad \text{(D.1)}$$

Alternatively, equation D.2 can be stated in terms of a single cross-price elasticity (ε_{in}) as:

$$\varepsilon_{in} = -(\varepsilon_{ii}+\gamma_i) - \sum_{j=1}^{n-1} \varepsilon_{ij} \qquad \text{(D.2)}$$

Since the own-price and income elasticities are known (i.e., user supplied), the negative sum of the cross-price elasticities is also known. The algorithm allocates a share of that sum to each individual cross-price elasticity using the base assumption such that the homogeneity condition is met. After

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calculating all elasticities in the first column, the symmetry condition is used to calculate all elasticities in the first row. Symmetry requires:

$$\varepsilon_{ij}/\omega_j + \gamma_i = \varepsilon_{ji}/\omega_i + \gamma_j \,, \qquad \text{(D.3)}$$

(with the expenditure share of good *i* denoted ω_i), which can be rewritten as:

$$\varepsilon_{ij} = \left[\varepsilon_{ji}/\omega_i + \gamma_j - \gamma_i\right] \cdot \omega_j \qquad \text{(D.4)}$$

For the second and subsequent commodities in a column, not only are the own-price and income elasticities known, but one cross-price elasticity is also known. The sum of the remaining cross-price elasticities must now be equal to the negative sum of the own-price and income elasticities as well as the one predetermined cross-price elasticity. That sum is distributed to the remaining cross-price elasticities below the main diagonal, again using the base assumption, such that the homogeneity condition is met.

The general calculation rule is that the negative sum of the below-diagonal elasticities must be equal to the sum of the own-price elasticity and the sum of the cross-price elasticities above the main diagonal. The sum is distributed to each of the below-diagonal cross-price elasticities using the base assumption such that the homogeneity condition is met. As each column is calculated, the symmetry condition is used to determine the above-diagonal elasticities in its respective (inverse) row (fig. D1). Note that since the models are housed in Excel, initiating a full calculation of the model will result in iteration of all model equations such that the elasticity matrix fulfills all theoretical constraints simultaneously.

Modeler Supplied Own-Price and Income Elasticities

The cross-price elasticity system relies on modeler-supplied own-price and income elasticities. When supplying the necessary elasticities, the modeler reviews relevant literature (e.g., Kumar et al., 2011; Okrent and Alston, 2012) or published elasticities used in other partial equilibrium agricultural sector models (e.g., the FAPRI (Food and Agricultural Policy Research Institute) Elasticity Database). When elasticities are needed for a regional model or not available for a specific country, the modeler will choose values based on those reported for countries with similar consumption patterns and income levels.

Figure D1
Schematic of calculation rules for cross-price elasticities

	Demand for:				
Price of:	Poultry (p)	Rice (r)	Soy oil (o)	Other food (f)	Nonfood (n)
Poultry meat (p)	ε_{pp}	Symmetry: $\omega_p\left(\varepsilon_{pr}/\omega_r + \gamma_p - \gamma_r\right)$	Symmetry: $\omega_p\left(\varepsilon_{po}/\omega_o + \gamma_p - \gamma_o\right)$	Symmetry: $\omega_p\left(\varepsilon_{pf}/\omega_f + \gamma_p - \gamma_f\right)$	Symmetry: $\omega_p\left(\varepsilon_{pn}/\omega_n + \gamma_p - \gamma_n\right)$
Rice (r)	Homogeneity + base assumption	ε_{rr}	Symmetry: $\omega_r\left(\varepsilon_{ro}/\omega_o + \gamma_r - \gamma_o\right)$	Symmetry: $\omega_r\left(\varepsilon_{rf}/\omega_f + \gamma_r - \gamma_f\right)$	Symmetry: $\omega_r\left(\varepsilon_{rn}/\omega_n + \gamma_r - \gamma_n\right)$
Soy oil (o)	Homogeneity + base assumption	Homogeneity|(ε_{po}) + base assumption	ε_{oo}	Symmetry: $\omega_o\left(\varepsilon_{of}/\omega_f + \gamma_o - \gamma_f\right)$	Symmetry: $\omega_o\left(\varepsilon_{on}/\omega_n + \gamma_o - \gamma_n\right)$
Other food (f)	Homogeneity + base assumption	Homogeneity|(ε_{pf}) + base assumption	Homogeneity|$(\varepsilon_{pf}, \varepsilon_{rf})$ + base assumption	ε_{ff}	Symmetry: $\omega_f\left(\varepsilon_{fn}/\omega_n + \gamma_f - \gamma_n\right)$
Non-food (n)	Homogeneity + base assumption	Homogeneity|(ε_{pn}) + base assumption	Homogeneity|$(\varepsilon_{pn}, \varepsilon_{rn})$ + base assumption	Homogeneity|$(\varepsilon_{pn}, \varepsilon_{rn}, \varepsilon_{on})$ + base assumption	ε_{nn} from Homogeneity| $(\varepsilon_{pn}, \varepsilon_{rn}, \varepsilon_{on}, \varepsilon_{fn})$
Expenditure elasticity	γ_p	γ_r	γ_o	γ_f	Engel aggregation: $\gamma_n = \left[1 - \sum_1^{n-1} \omega_i \cdot \gamma_i\right] / \omega_n$
Expenditure share	ω_p	ω_r	ω_o	ω_f	ω_n

Notes:

- Symbols in red are values provided by the modeler or computed from data (e.g., consumer prices and per capita food quantities) in the model.
- ε_{ii} is commodity i's own price elasticity. ε_{ij} is the elasticity of demand for commodity i given a change in the price of commodity j. The expenditure share of good i is denoted by ω_i. The symbol γ_i represents the expenditure elasicity for good i.
- The elasticities listed after the symbol "|" in the soy oil, other food, and nonfood rows mean the homogeneity equation includes the calculated elasticities in all cells on the same row and to the left (listed in the parentheses).
- The base assumption is that the magnitude of any two cross-price elasticities for a single commodity is proportional to their expenditure shares.

Source: USDA, Economic Research Service.

Sometimes elasticities are available for a specific country but reported as broad aggregates—for example, "meat" or "cereals and bakery products" (e.g., Muhammad et al., 2011). In these cases, the modeler must decide how the commodity composition of the category relates to beef, pork, and poultry, or to wheat, rice, or other bakery product inputs such as vegetable oils. Clues to decomposition may be available in demand studies with two-stage budgeting. The first stage would normally provide elasticity estimates for broad aggregates and the second stage for those individual commodities (or subgroups) in the aggregate. In such cases, in addition to taking into account differences in country economic conditions, the modeler must be aware of the assumptions imposed on the second-stage estimation process and how they may impact the value of the second-stage elasticities.

When research-based guidance is not available, the modeler may survey the elasticities used in other CCLS models to develop a range of plausible values. Those values can be tested in the model for which elasticities are being chosen by backcasting. Backcasting involves specifying the demand function, selecting own-price and income elasticities, and then projecting back in time to see how well the elasticities perform relative to actual food consumption. This tedious and time-consuming task requires considerable patience, country knowledge, and economic expertise.

Feed Demand

The same procedures specified above are used to generate consistent cross-price elasticities for energy and protein feed demand. Instead of income, the aggregate demands for energy and for protein are used as proxies for income. The latter are derived as explained above in the Feed Demand section. While own- and cross-price elasticities for alternative feeds may be reported in published research, elasticities for aggregate protein or energy feed demand are unlikely to be available. Therefore, the modeler uses available own- and cross-price elasticities and chooses an aggregate demand elasticity that best replicates past feed demand patterns.

Area Harvested

The same algorithm that is used to derive cross-price food and feed demand elasticities is used to derive cross-return area elasticities. The income elasticity is replaced with an area expansion variable and associated elasticity. The area expansion variable is the stock of land available for temporary crops (see box, "Land Use"). As the total stock of land increases or decreases, a portion of that change is allocated to individual crops in proportion to the area expansion elasticity. Elasticities governing such decisions are not available, so once again the modeler examines past cross-commodity area patterns and chooses an elasticity that both reflects recent changes in land use patterns and yields reasonable projections of future land use patterns.

Appendix E: The USDA Baseline Projections Process

The task of producing the annual USDA baseline projections begins in mid-summer with ERS economists' presentation of their macroeconomic projections for modeled countries and regions. At about the same time, the ERS Domestic Baseline Coordinator updates U.S. commodity and fertilizer price projections from the previous year's baseline with the most recent U.S. price forecasts from the latest World Agricultural Supply and Demand Estimates (WASDE) report. Differences between the near-term prices and the U.S. prices projected in the previous baseline are smoothed out over the projection period, and the prices are extended 1 year. The ERS International Baseline Coordinator derives reference price projections from the U.S. price projections based on historical relationships between the series. The ERS Baseline Data Coordinator then loads the macroeconomic data and reference prices into the commodity models.

Production, supply, and distribution data from the USDA, Foreign Agricultural Service (FAS) Production, Supply and Distribution (PSD) database are also loaded into the models by the ERS Baseline Data Coordinator in mid-summer. The last year of PSD data (e.g., 2017/18 for the 2018 baseline projections to 2027) are projections. Data in the year preceding the last (e.g., 2016/17) are estimates. The last year of PSD data (e.g., 2017/18) defines the first projection year (e.g., 2018/19 for the 2018 baseline). The models endogenize domestic prices and quantities beginning in the year following the initialization year. For example, for the 2018 baseline projections to 2027, the initialization year is 2015/16. Since endogenous equations begin after the initialization year but before the first projection year, a programmed procedure is used to ensure that numbers in the models match PSD data (i.e., data in 2017/18 and 2016/17) by making year-by-year adjustments to equation intercepts.

The USDA baseline projections must reflect the most recent published PSD data, so quantity data are loaded into the models up to three more times, and each time the equation intercepts are adjusted via a programmed procedure such that the behavioral equations exactly yield PSD values. The reference price projections are also revised up to three times over the same time period as WASDE price projections change. Projections for biofuel supply and demand for major producing countries (Argentina, Brazil, Canada, China, Indonesia, the United States, and the European Union) are made in late summer with input from biofuel analysts from USDA's Foreign Agricultural Service (FAS), ERS country specialists, and representatives from the Office of the Chief Economist (OCE). The last PSD data update and reference price projections, along with the macroeconomic and biofuel projections and any policy assumptions, define the assumed conditions under which the supply and demand projections are made.

The ERS modelers begin their work for each country/region in mid- to late summer following loading of macroeconomic, PSD, and updated reference price data. The first step in preparing the models is identifying any important changes to agricultural, trade, or other country-specific policies and making necessary changes in the models. The modelers' next step is to update country-specific data such as domestic prices, land use, and crop or livestock production costs that affect the projections. This work is usually completed by early autumn.

When updating is completed, all projected variables are reviewed by the ERS modelers, with particular attention paid to the first projected year (i.e., 2018/19 for the 2018 baseline projections). Actual yields and area harvested mainly respond to prior-year prices and current-year agricultural policies, weather, and other agronomic conditions. Therefore, in unusual conditions, yields and area harvested in the final PSD year may not be in steady-state (longrun) balance with prices in that year. And, because each year's projected value depends on the previous year's value, it is critically important that single-year anomalies are not carried forward in the projections. This is usually handled by employing add factors—intercept shifters—to bring the first projected year yields, area harvested, and possibly other quantities into normal correspondence with prices in that year.

The ERS International Baseline Coordinator organizes six commodity workshops to develop expert consensus supply and demand projections for major commodities in the foreign countries and regions. The modelers and experts from USDA's ERS, FAS, Agricultural Marketing Service (AMS), and World Agricultural Outlook Board (WAOB) review the projections derived from the models. At these workshops, specific issues may be brought to the attention of the participants for discussion and evaluation. For example, a participant may question assumptions made with respect to a change in agricultural policies, or point out an apparent bias persisting across baselines (e.g., under- or over-estimated food demand). Once consensus export and import projections and specific trends for other supply or demand variables are agreed upon, the modeler makes necessary adjustments in the model.

After the adjustments agreed upon in the commodity workshops have been made by the modelers, the models are combined in the CCLS, which solves for simultaneous equilibrium in world grain, oilseed and product, livestock product, cotton, and sugar markets. The equilibrium prices from the CCLS are compared to the assumed reference prices to identify inconsistencies in cross-commodity relationships and global exports and imports for individual commodities, or other anomalies. Using the CCLS output and diagnostics tools, most inconsistencies can be identified, after which quantity intercepts are adjusted, and any equation or data errors are fixed. In the last case, revised data then are loaded into all affected models prior to the next commodity workshop to ensure consistent cross-commodity responses in subsequent workshops.

After the CCLS run following the last international commodity workshop, the ERS Domestic Baseline Coordinator organizes a round of six U.S. market commodity meetings to develop expert consensus projections for U.S. supply, use, and market prices. Inputs to the U.S. market deliberations include commodity models maintained by experts at ERS and the WAOB; the specialized knowledge of commodity and country analysts from ERS, FSA, FAS, WAOB, and other USDA agencies; and the CCLS output. Final U.S. price projections typically are made by consensus in late autumn. The final international reference prices are derived from the final U.S. prices, which subsequently are loaded into the country models. With final U.S. and international price projections in hand, the commodity analysts at ERS and WAOB produce final projections of exports and imports, which usually are those agreed upon in the commodity workshops. The final U.S. projections are presented at the annual USDA Agricultural Outlook Forum, typically held each year in February, with the foreign country projections reported in the annual USDA baseline projections publication (e.g., *USDA Agricultural Projections to 2027*, (USDA, OCE, 2018).

Since the trade values may be adjusted in the preceding process, the models' behavioral relationships that yield imports and exports, either directly or as residuals, may not produce the agreed-upon trade values. Therefore, prior to publication of the annual USDA baseline projections, to ensure that each model produces the agreed-upon trade values, ERS modelers use a programmed procedure that applies calibration intercept adjustments or add factors directly to imports or exports if they are projected from behavioral relationships. If imports or exports are projected as residuals, intercept shifters are applied to one or more modeler-specified supply or demand variables to ensure that the consensus trade values are attained. The intercept adjustments, which remain fixed until the next year's baseline is completed, ensure that the endogenous model generates the official trade levels. Once the trade calibration is completed, the international supply-demand balances for major countries and regions are published on the ERS website (USDA, ERS, 2018a).