

A Conceptual Model of the Agricultural Sector

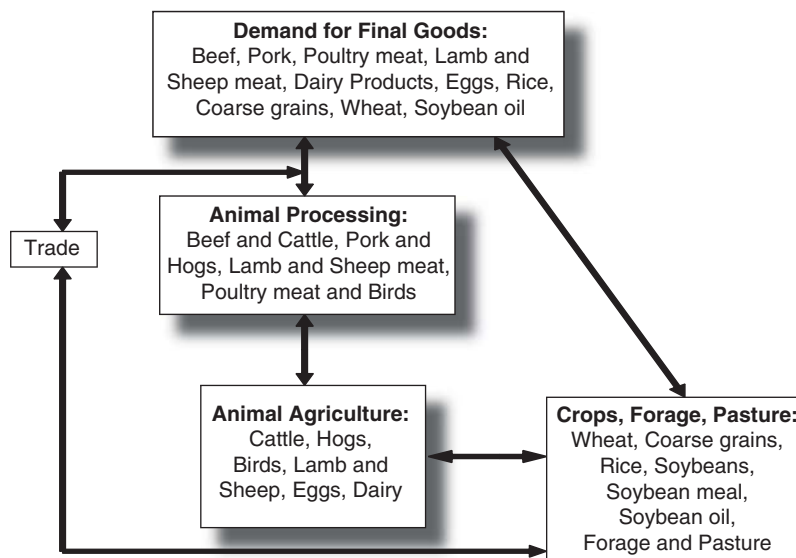
Efficient modeling of the impacts of FMD in the United States is enhanced by integrating a disease-spread model with an economic model. For building a quarterly agricultural model, a general plan is required for the model's structure and for how the pieces fit together (fig. 1). A detailed presentation of the model is found in appendix A. The general approach follows that of Jones (1981) and Sanyal and Jones (1982).

The model and application assume price-taking economic decisionmakers who maximize well-defined objective functions. Utility maximization for consumers gives a set of per capita demand functions. Producers (firms or farms) choose inputs and products that maximize profits using four types of inputs. One type, which includes fuel and electricity, is mobile among production activities and is in perfectly elastic supply. A second set of inputs consists of sector-specific intermediate goods. A third input type consists of sector-specific physical and human capital, and the final input is land, which is mobile across crop production.

Total consumption of final goods (beef, pork, poultry meat, lamb and sheep meat, eggs, milk, wheat, coarse grains, rice, and soybean oil) in the U.S. economy in the current quarter depends on population and per capita consumption during the quarter. Wheat and coarse grains are included, since they are also used for feed. Soybean oil is included because its joint product, soybean meal, is a major feedstuff. Rice is modeled because its area interacts with crops used for animal feed. Health-shock parameters are incorporated that allow variations in the level of consumer perception of health risks.

Figure 1

Economic modeling component for analyzing effects of foreign animal diseases on U.S. agricultural sectors



Source: Compiled by the authors.

These parameters indicate the share of the population unafraid of a health risk associated with each final good and provide a policy instrument by which to manage policy impacts on final demand.

Goods (meats, eggs, milk, animals, and crops) are produced by separate industries (sectors). Firms producing individual meats do not earn super-normal profits, so a zero-profit condition holds for each meat, as well as for milk and eggs. Production of meats, eggs, and milk is assumed to occur during the current quarter, while production of animals and crops are lagged according to biological limitations. Three types of production factors are used: factors in perfectly elastic supply, animal intermediate inputs (live-stock and poultry), and sector-specific primary factors (physical and human capital). Markets clear at market prices, determined by market-clearing identities that are consistent across time, with biological lags.

Livestock

Livestock are described here as a primary output, but also act as intermediate inputs into meat production. From this point, poultry may be included as livestock or animals and will only be listed or mentioned separately when it is necessary to discuss it separately. Breeding and replacement decisions reflect previous livestock inventories, salvage values, and the expected relative profitability of producing animals or products for future sale. During a disease outbreak, these inventories (and values) are adjusted to reflect disease-induced losses.

Four types of feed are available in the model: wheat, coarse grains, soybean meal, and forage and pasture. Not all livestock use all feeds, and each growth stage has unique derived (input) demands for feed. Use of a feed ingredient is a function of the feed prices and the number of animals consuming feed in each stage. The model reflects the fact that cattle, hogs, sheep, and lambs have production cycles spanning more than one quarter.

The structure of the dairy sector and its feed allocation differ from sectors with other livestock species because the model determines milk production using the zero-profit and specific factor-market-clearing conditions. Milk output and dairy cattle being milked are determined simultaneously. The decision to determine milk output directly and convert that output into dairy cows reflects the way cost data are reported: Production costs for milk include the feed costs, but not the cost of replacement heifers, whereas meat cost data include the animal, but not the feed. Disease outbreaks are reflected in reduced milk output, which translates into reduced dairy cattle inventory. Thus, the size of the dairy herd in the quarter is determined by milk output in the current quarter and, because inventories of dairy cattle are slow to adjust, by lagged dairy cow inventory.

Due to their short production cycle, poultry stocks are relatively simple to model, with the number killed determined in the current quarter using zero-profit and specific factor-market-clearing conditions, but also influenced by output lagged by one quarter. The model determines egg production, using the zero-profit and specific factor-market-clearing conditions. The number of layers and the feed use is known from egg production. Disease affects egg

production (and thus layer numbers). Layer stocks respond more slowly than broilers, so lagged production is included with a stronger effect.

Trade is linked to U.S. market prices, trade policy, and disease outbreaks. Trade policy intervention is modeled as a specific trade intervention during the current quarter, with trade determined by the U.S. domestic price less the specific trade intervention. Because an animal disease outbreak can disrupt trade, parameters are used to indicate the severity of trade restrictions.

Crops

The foregoing discussion identified intermediate demands for crops as feed-stuffs. In addition, there are final (retail) demands for crops. Crops included in the model are wheat, coarse grains, soybeans, rice, and forage and pasture. Focusing on the supply side, crop production occurs at set times and then becomes carryin stocks in subsequent quarters until a new crop is harvested. Crop supplies in a given quarter are any crops produced in that quarter, plus any carryin stocks. Another key feature is that production decisions are made well before harvest, based on expectations of crop returns. Finally, except for forage and pasture, all of the crops included in the model are program crops. This means the influence of the various U.S. Government price and income supports must be incorporated. Acreage allocations are based on expected net returns for each crop at harvest, with expected returns being the previous harvest prices plus appropriate government payments. The computations are done in quarter 1 so that acreage allocations consistent with one crop cycle can be imposed. Since there are both winter and spring crops in the model, this is a simplification of the actual decision process. Soybeans and rice are spring crops (planted in the second quarter of the current year and harvested in quarters 3 (rice) or 4 (soybeans)). Coarse grains (corn, sorghum, millet, barley, rye, and oats) are planted in quarter 2 and harvested in quarters 3 and 4. Barley is planted in both winter and spring and is assumed to be harvested in quarters 2 and 3.

Wheat pose a larger problem because it is a major crop, like corn and sorghum, but with both spring and winter crops. Spring wheat is planted in quarter 2 and harvested in quarter 3. Winter wheat is planted in the fourth quarter of the previous year and is assumed to be harvested in quarter 2. The acreage (production) decision for that second-quarter harvest is assumed to be made in the first quarter of the year and is based on returns to second-quarter wheat in the previous year. This is done to create a consistent use of land, because it requires arranging inputs earlier in the year and constrains cropping decisions in the spring.

Forage and pasture pose problems similar to those of wheat. Production occurs in quarters 2 and 3. Forage and pasture acreage is assumed to be determined in quarter 1, based on the prices in quarters 2 and 3 of the previous year.

The economic return to land captures the negotiation process between farmer and landlord for land rent for the upcoming crop season. Land is mobile among crops. The expected return to land is determined by the land-market-clearing condition and the expected zero-profit conditions for each crop, which include the costs of exogenous factors and the expected return to phys-

ical and human capital for each crop, as determined by the expected return for the crop. Expected returns for crops vary with market conditions. The price expected in quarter 1 is the price prevailing in the harvest quarter of the previous year. The returns also reflect U.S. Government payments, of which there are several. There is some debate about how they affect production, for example, because of the decoupling issue (Goodwin and Mishra, 2006).

In our model, the farmer is assumed to receive loan deficiency payments (LDPs) equal to the difference between the loan rate (LR) and market price when the LR exceeds the quarterly market price. Payments are made on the full amount of production. Direct payment rates (DPs) are established in law. Total payments are the rate multiplied by 85 percent multiplied by program yield and base area. Additionally, the 2002 Farm Act provides for counter-cyclical payments (CCPs) calculated from an announced target price (TP). The payment rate is the difference between the target price, less any direct payment, and the market price when the market price is above the loan rate. If LDPs are paid, they are not adjusted by the 85 percent used in the CCP adjustment, but instead, the full LDP is added to the market price. The CCP payments are 85 percent of the crop base acreage times program yield times the payment rate. The expected return is the expected price on the previous crop plus CCP payments, LDPs, and direct payments.

Loan deficiency payments are coupled payments. A critical issue is whether direct payments and CCPs are decoupled or not. Returns to human and physical capital and to land cannot be adequately modeled without including these payments, so they are reflected in the model and affect the dynamics of the model solutions. The payments are modeled to affect relative per acre returns among program crops. Since forage and pasture are not program crops, there is no direct price adjustment, but there is a relative price effect.

Sector-specific, factor-market-clearing conditions, using expected rent and factor prices in quarter 1, determine crop output for the harvest quarter. Land is mobile among the crops. Its return is determined in quarter 1 by the demand and supply for land for the upcoming crops in period t . While crop output is determined based on the expected returns to sector-specific factors, actual returns to the sector-specific factors can differ from expected returns because actual returns to crop production differ from expected returns. The actual market prices are determined in market-clearing identity equations. Once the crop-market prices are known, the LDP and CCP payment rates and total payments can be calculated for the crop produced at time t . The actual return to the program crop is arrived at with the addition of the payments. The return to forage and pasture is the market price, since there is no program.

The soybean complex is included because soybean meal is a major feedstuff whose use is affected by any disease outbreak, and soybeans compete with other crops for acreage. In addition to soybeans as a crop, there are demands for soybean meal in animal feed and soybean oil for human food. Thus, soybean processing, or crushing, into the joint products of meal and oil, must be modeled. This is done by specifying a derived demand for soybeans for crushing as a function of the current-period crushing margin. The crushing margin is the value of the joint-product yields multiplied by their prices and adjusted for the price of soybeans.

Closure

Model closure requires domestic and international market-clearing relationships for quantities and prices. Exports depend on prices and trade interventions and, in some cases, on the disease outbreak. For many agricultural goods, the United States is an exporter and does not intervene in the market. While many agricultural goods are imported into the United States without restriction, beef and dairy products are subject to tariff-rate quotas, TRQs. A TRQ is a stepped tariff, with import volumes below the quota requiring payment of a lower tariff than volumes above the quota. To facilitate a model solution, it is assumed that the quotas are not filled and that the below-quota interventions apply. Quota underfill seems to be more common for U.S. beef imports than quota overfill. When an intervention is applied, it is deducted from the U.S. domestic price, so that trade reacts to the “world” or border price. The remaining imports are explained by an excess supply to the United States.

Completing the model requires vertically linking farm prices for crops and livestock, wholesale prices for meats, milk, and eggs, and retail prices for all final goods. These three levels are linked by calculated marketing margins. This vertical linkage improves the numerical accounting of the impacts, but does not affect the model response to shocks.

Differential Transformation of the Conceptual Model

A numerical solution of the integrated economic agricultural sector model is facilitated by a total logarithmic differential version of the model described above, for which the details are presented in appendix A. The logarithmic-differential version has several advantages: (1) the differential version is driven by elasticities, which are easier to obtain than specific functional forms and are also more intuitive than partial derivatives; (2) the elasticity version can be applied to observed historical data, which avoids the need to forecast future exogenous variable values; and (3) the base data can be updated quickly as new values become available. While we give a brief description in the following paragraphs, details of the conversion of the conceptual model to the total logarithmic differential version are found in appendix A.

Meat, milk, and egg production are described by the zero-profit equations and the sector-specific, factor-market-clearing conditions. After totally differentiating the zero-profit conditions at time t , applying the envelope property, and normalizing quantity on the unit isoquant, the percentage change in the wholesale price becomes a linear combination of the factor-price changes. With the mobile factor price exogenous, the mobile factor-market-clearing identity is dropped so the sector-specific, factor-market-clearing conditions can be partitioned into two sets of equations: (1) the per unit use of physical and human capital and (2) the derived demand for animals for beef cattle, swine, lambs, sheep, and poultry slaughter and for dairy-cow and poultry-layer production inventories.

Completing this part of the model requires specifying the changes in per unit factor uses. This is accomplished with a matrix of Morishima elasticities of substitution (e.g., Chambers, 1988, p. 96) between mobile factors and capital, and between animals and capital, under constant returns to scale. Logarithmic

differentiation links changes in the ratio of per unit factor use to changes in factor prices, via the Morishima elasticities of substitution.

The feed demands reflect the age distribution and flow of animals. Because the per unit feed demands are responsive to changes in relative feed prices, the percentage changes in the derived demands for feeds also use Morishima elasticities of substitution between each feedstuff and each category of each species of feed-consuming livestock. Changes in relative prices alter the per animal mix of feedstuffs according to the Morishima elasticities of substitution.

The next component of the model consists of logarithmic differentiation of the crop production structure to determine changes in expected net returns for each crop and changes in production of each crop, including changes in land allocations. Changes in production of each crop, including changes in land allocations, determine land rent. Soybean crushing depends on the margin, which, in turn, depends on the prices of soybean meal, soybean oil, and soybeans. With assumed constant meal and oil yields, differentiating the crush demand and the margin identity gives changes in supplies of meal and oil.

Closure requires logarithmically differentiating excess demand, excess supply, and commodity-market-clearing conditions. The excess-demand and excess-supply equations include trade policy interventions. Since several commodities do not have trade interventions, the logarithmic change is not defined. Thus, trade policy interventions are treated as specific (per unit) policies, and the differential form differs from the other equations. In addition, each commodity has a market-clearing condition in which the total differential includes derived demands for animals and feed ingredients and maintains the linkages through the total differentials of the margin-markup equations.