Appendix B—Numerical Model Data and Numerical Form

This appendix describes the inputs to the numerical model. At a broad level, two sets of information, data and parameters, are required, but those broad categories disguise much detail.

Data

The majority of data required for the model consists of quarterly supply, use, and price data for the years 2001-04. These values set the baseline to which the percent changes are applied. With some exceptions, the data are reported in the Livestock Marketing Information Center (LMIC) database. Data not in the LMIC database consist of data for crops and some trade data. Quarterly supply, use, and price data for coarse grains, wheat, and rice come from situation reports prepared by the Economic Research Service of the U.S. Department of Agriculture (USDA/ERS). Quarterly supply and use tables for the soybean complex prepared by USDA/ERS cover the later years, but not 2001. The missing values for 2001 are generated using the newer data and assumptions about use patterns.

Forage and pasture data are difficult. Forage prices are reported by USDA/ERS in the *Livestock, Dairy, and Poultry Situation and Outlook* report. Total quarterly use is generated by feed balance spreadsheets, where data on animal numbers are combined with standard feeding practices to produce estimates of quarterly feeding of forage and pasture. Production numbers are limited. Production of hay, corn silage, and sorghum silage are reported by the National Agricultural Statistics Service, U.S. Department of Agriculture (USDA/NASS, *Crop Production*). No recent data exist for grazed pasture. While there is some early forage harvest, there is no way to know how much of the forage is harvested in the second quarter of the year. The assumption in this model is that forage harvest occurs in the third quarter. Given the quarterly use and third-quarter production, the residual is treated as grazed pasture. This residual is allocated equally to quarters 2 and 3, with no forage and pasture production in quarters 1 and 4. With this information, quarterly supply and use is calculated so that no quarter from the first quarter of 2001 to the fourth quarter of 2004 shows a negative carryover.

While LMIC and USDA/ERS report aggregate trade data for animals, the model requires decomposing those data into animals for slaughter and those to be fed. The data are obtained originally from U.S. Customs via the Foreign Agricultural Service, U.S. Department of Agriculture (USDA/FAS).

Policy information affecting crop variables comes from various sources. The policy data for 2001 and 2002 are reported by Nelson and Schertz (1996) in *Provisions of the Federal Agriculture Improvement and Reform Act of 1996*. Policy data for the 2002 Farm Act are taken from the Outlook reports prepared by USDA/ERS: *Rice, Wheat, Feed, Grains, and Oilseeds and Products*.

Parameters

Four sets of parameters drive the model: the livestock feed-balance calculator, the most complicated of the four; the revenue shares for all industries; elasticities used in model solution; and disease-related parameters used to manipulate disease scenarios. The numerical model is constructed so that the user can alter the parameter values, because for many values there is no consensus in the literature. The first three sets of parameters discussed here are the default values based on estimates in the literature, as well as on the authors' judgments in some cases. The animal disease parameters are discussed in the empirical section.

Livestock-Feed Balance

The livestock-feed balance calculators are critical because they relate the stocks and flows of animals for each quarter to the feed supplies available, forming the critical vertical linkage between the animal agriculture component and the crop component. Feed-use calculations, outlined in this section, incorporate information on foreign-born pigs, mortality rates, feed efficiency, and other factors.

Market Swine

The first step in determining swine feed consumption was formulating a typical swine diet for a market pig. Weight ranges (10-59 pounds, 60-119 pounds, 120-179 pounds, and 180-plus pounds) are consistent with those in the quarterly *Hogs and Pigs* (USDA/NASS), in which inventory numbers are reported for each weight category. However, in development of the model, the inventory numbers were not used to track pig flows. Instead, we used monthly farrowings, but the intervals were used to formulate diet specifications.

The next step was to determine weight gain and feed consumption in the weight categories. This information and all diet formulations are from the *Pork Industry Handbook* (PIH) (Purdue University, ongoing publication) and *The Kansas Swine Nutrition Guide* (Tokach et al.). From the beginning and ending weights in each phase, the model calculated the total weight gain and tracked how much feed is consumed for this weight gain. For example, a pig must consume a total of 92 lbs of feed in a quarter to go to 60 lbs. The calculations assumed an average feed efficiency of 3 pounds of feed consumed, on an as-fed basis, per pound of gain from 50 lbs to 250 lbs, and were scaled to account for the fact that lighter pigs have better feed-to-weight-gain efficiency than heavier pigs.

Average daily gain was used to calculate how many days each pig spends in each stage. Using these calculations, and assuming each pig starts consuming feed at a weight of 10 lbs, the model found that the total number of days for a pig to go from farrowing to market is 180 days, or two quarters. We combined this information with the percentages of feed ingredients—feed grains, wheat, soybean meal, and premixes/other—in the diet for each phase of production to calculate the daily and total feedstuffs consumed. Mortality rates in the nursery and grower/finisher portions of the production process were used to calculate deaths at each stage of production, since the only statistical input is the pig crop.

Monthly consumption patterns are produced by flow tracking of the monthly pig crop published in *Hogs and Pigs* (USDA/NASS). The intention is to take the monthly pig crop, track that crop for each month, and pinpoint how much feed the pigs are consuming in each month in order to calculate quarterly use.

This calculation starts with the number of days that pigs spend in each stage (e.g., 10-59 pounds, 60-119, etc.). Pigs take approximately 37 days to reach the first weight benchmark. We assumed that each month consists of 30.5 days; therefore, in their first month, the pigs spend all 30.5 days in this stage. Total monthly feed consumption is determined by multiplying 30.5 times the average daily feed consumption for the first stage of production. Continuing to the second month, since there are still 6.5 days left in stage 1, the pigs born in that first month spend 6.5 days in stage 1 and the remaining 24 days in stage 2. The amount of feed they consume is found by multiplying the number of days in each stage by the daily consumption for that stage. This pattern is carried out for the remainder of the months to give a schedule of total consumption for each pig crop.

To calculate total monthly feedstuff consumption by domestic pigs, multiply each monthly pig crop times its monthly consumption of each feedstuff. For example, for consumption in January, the total number of pigs born in December would be multiplied times feed grain consumption for the pigs' first month of production. Also added to January would be pigs born in November times their total consumption in the second month, and so on, back to pigs born in June times consumption in their sixth month of growth. Additionally, pig numbers are adjusted for death losses by multiplying the total number of pigs in their second month and higher by 97 percent (for nursery mortality rate), and pigs in their fourth month and higher times an additional 98 percent (or a compounded 95.06 percent) for mortality in the grow-finish section.

Consumption by foreign-born pigs must also be recognized. The U.S. International Trade Commission (USITC) changed its reporting procedure for import pigs in 2003. For years after 2003, the USITC breaks imports down into more subcategories; however, all can be aggregated into categories of less than 50 kilograms (kg), more than 50 kg not for immediate slaughter, and more than 50 kg for immediate slaughter.

Pigs imported at less than 50 kg are assumed to have entered the United States at the beginning of their second month of life, and those imported at weights greater than 50 kg are assumed to have arrived at the beginning of their fifth month of life.

Breeding Swine

Feed consumption for sows begins with an estimate of 1.9 litters/sow/year (*Pork Industry Handbook*). Additionally, an assumed average weaning age of 25 days is based on an average of several suggested weaning ages in the Pork Industry Handbook. Consequently, on average each sow is in lactation for 47.5 days and is in gestation 317.5 days (365-47.5). Average daily consumption listed for sows in lactation and gestation is multiplied by the total number of days in each stage to give the annual consumption for a sow. This is multiplied by the percentage of the total ration each feed represents to get the number of pounds of each feed consumed per sow per year. Annual quantities are allocated to quarterly consumption by dividing by 4, with no seasonal adjustments.

To get total sow consumption, multiply the calculated consumption patterns times quarterly-average sow inventories. Beginning and ending sow inventories are averaged to represent an average inventory. For example, the numbers from December 1 and March 1 give the average sow inventory for the winter quarter. The dates for hog inventory numbers differ from standard quarters and from inventory data for other species. Since the data show little fluctuation, such differences in timing are ignored. Multiply the average inventory times the quarterly consumption of feed grains per sow to get the total quarterly consumption of feed grains for breeding sows. This procedure was used to calculate quarterly consumption for wheat, coarse grains, soybean meal, and premixes/other.

Market Beef

Slaughter data for cattle are monthly Federally Inspected (FI) slaughter of steers and heifers. Inventory numbers are from the semiannual report, *Cattle* (USDA/NASS), and all trade numbers are from the USITC website.

The time from when a beef market animal is born until slaughter is assumed to be five quarters, and diets are developed over this time span. Calves are assumed to be weaned at approximately 6 months and not fed any creep rations (supplements to mother's milk to encourage growth) prior to weaning. Therefore, after weaning, calves spend 3 months in background lots, 3 months in grower lots, and 3 months in a full feedlot (finishing). As with hogs, weights at the beginning and ending of each stage give total weight gain and average daily gain. All months are assumed to be 30.5 days. Average dry matter intake (DMI) is calculated by taking 2.5 percent times the average body weight in the stage. This formula and all feeding rations are based on information from Kellems and Church (2002), Jurgens (1978), and Field and Taylor (2003).

The previous calculations yield average daily consumption of *dry matter* by calves in each stage. The next calculations break this down between feed grains, forages, wheat, soybean meal, and other. Ultimately, the consumption of dry matter by cattle is converted into an as-fed basis. Therefore, a rough estimate of the percentage of dry matter for each component is required. The most challenging part is to decide what percent to use for forages because of the combination of dried forages and forages fed in pastures. Next, the percentage in each quarter of feed grains, forages, wheat, and soybean meal fed on an as-fed basis is used to convert the total dry-matter daily consumption into the average daily consumption of each component, which then aggregates to the total consumption of each component in that stage of production.

Combining monthly slaughter into quarterly estimates, and then subtracting imports for immediate slaughter, gives the number of slaughtered animals raised in the United States. Aggregate slaughter and the calculated consumption at each stage determine total consumption. For example, to get total consumption for quarter 1 of 2003, take those cattle slaughtered in quarter 1 of 2003 times consumption in the fifth stage, plus those that are slaughtered in quarter 2 of 2003 times consumption in the fourth stage, plus those slaughtered in quarter 3 of 2003 times consumption in the third stage. This is broken down into grains, forages, wheat, and soybean meal. One drawback with this method is that total feed consumption in the current period cannot be calculated until there are slaughter data from 6 to 9 months ahead, needed to capture the flow of cattle and their consumption at each stage of growth.

Beef Cows

The diet of a cow is modeled based on the dietary requirements of her annual production cycle. She spends one quarter each in trimester I, trimester II, trimester III, and postpartum. The dry matter recommendations have correspondingly been included. Then, given the percentage of each component that makes up the whole diet in that stage, the total feed grain, forage, wheat, and soybean meal consumption can be calculated for the stage.

The cow inventory data are for the first and third quarters; USDA does not record data for the second and fourth quarters.[1] The best method is simply to average the two points to get a midpoint inventory number. Another aspect is the seasonality of calving. NASS reports indicate that approximately 70 percent of cows calve in the first half of the year. Therefore, it is assumed that 35 percent calved from January to March, 35 percent from April to June, 15 percent from July to September, and 15 percent from October to December.[2]

Finally, multiplying the total number of cows times the percentage in each stage times the total consumption in that stage gives the quarterly consumption by cows. This calculation rolls, so for each quarter of the year the number of cows in each stage should be appropriately modeled to depict seasonality in calving.

Dairy Cows

The method for tracking the consumption by dairy cows is the same as for beef cows. The difference is in dry matter intake (DMI) at each stage of production. All consumption patterns for dairy cows were modeled after the National Research Council (NRC) nutrient recommendations for dairy cows and the interactive CD accompanying these recommendations. These sources indicate that cows go through a stage of peak milk production, followed by a stage where milk production decreases somewhat but total intake is maximized, a cow-weight recovery stage, and then a dry period.

Beef and Dairy Heifers

Replacement heifers include animals not already counted in the slaughter data. The approaches to determine quarterly feed use for beef and dairy heifers are identical. The heifer diets, and percentage of each component within the diet, are modeled in the same fashion as the cow diets. The data are for inventories observed on January 1 and July 1 of each year. While

[1]An attempt was made to estimate second- and fourth-quarter inventory levels by subtracting quarterly cow-slaughter numbers and then adding in the change in the number of heifers, but the estimates appeared to be highly inaccurate.

[2]Other data show much more calving in the first quarter and much less in the third quarter, with 82 percent of calves born in the first half of the year. Since the NASS data are used in our calculations, calving percentages consistent with that data are used.

most beef cows are in one of four stages of a cycle, replacement heifers range in age from 6 months (just weaned) to 24 months (just prior to first calf, and not yet included in the cow inventory). The approach is to broadly model feed patterns for heifers as they pass through their stages of growth.

Bulls

The typical bull diet assumes that in the summer bulls are fed no grain and simply graze pasture. Bull dry matter intake (DMI) is obtained from estimates in Kellems and Church (2002). For each quarter, multiply the total number of bulls times the consumption per bull during that stage.

Market Sheep

Market sheep are handled similarly to market beef. Average daily dry matter intake is estimated at 4 percent of body weight (as opposed to 2.5 percent for market cattle). Data are available from the USDA/NASS Livestock Slaughter report. As with beef, to get consumption for one quarter, for example January through March, the slaughter from that quarter is multiplied times the consumption in the last quarter of life, plus the slaughter of the next quarter is multiplied times the slaughter of the second-to-last quarter of life, and so on.

Slaughter lambs are assumed to live 4 quarters. This approach assumes that lambs are fed a very low percentage of grain for the first 6 months, and then fed more intensively over the last 6 months. The sheep feeding does not account for any exports/imports.

Ewes

The calculations for ewes are the same as for cows. Inventory numbers are available only for January 1 and July 1, so the inventories in March and October are simple averages of the preceding and succeeding semiannual numbers. The ewe model assumes that 90 percent of the ewes lamb between January and July. This estimate, which is available on the USDA/NASS July Sheep report, has been around 90 percent over the last several years. It is assumed that 45 percent of ewes lambed in the first 3 months and 45 percent in the second 3 months. Seasonality is captured by multiplying the total number of ewes times the approximate percentage in that stage times the consumption for that respective stage. Ewe diets were obtained from Kellems and Church (2002) and Jurgens (1978).

Layers

Calculation of layer feed consumption is direct. Average monthly layer numbers are from Chickens and Eggs (USDA/NASS). The estimated average daily layer consumption was about 100 grams (Leeson and Summers, 1997 and 2001). To get feed grain consumption for 1 month, multiply the total number of layers times the average daily consumption, times the percentage of that consumption that is feed grains, times 30.5 (the number of days in each month). This is done for each feed component and each month and aggregated on a quarterly basis.

Poultry

Feed consumption by market poultry is based on the total pounds of slaughter. A key parameter is the estimated feed conversion factor, 1.5 pounds of feed consumed per pound of gain, from Leeson and Summers (1997 and 2001). The total slaughter weight for each month is multiplied by the conversion factor to obtain the total required feed intake. To get consumption, multiply the total feed intake by the percentage breakdown of each feed component.

Revenue and Factor Shares

Revenue shares appear in the logarithmic differential equation form of the zero-profit conditions (tables 1- 6). Factor shares appear in the logarithmic differential equation form of the land-market clearing.

Appendix table 1

Unit revenue shares for cattle, broilers, and beef used in model[1]

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Cattle[2]				
Exogenous inputs	0.141918	0.141918	0.141918	0.141918
Land	0	0	0	0
Intermediate inputs	0	0	0	0
Feed	0.629065	0.629065	0.629065	0.629065
Coarse grain	0.127212	0.033934	0.035078	0.245662
Wheat	0.006702	0.006099	0.005577	0.010969
Meal	0.008911	0.008773	0.008789	0.017774
Forage	0.48624	0.580259	0.579621	0.354661
Residual cost of capital and management	0.229017	0.229017	0.229017	0.229017
Broilers[3]	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Exogenous inputs	0.219075	0.219075	0.219075	0.219075
Land	0	0	0	0
Intermediate inputs	0	0	0	0
Feed	0.44363	0.44363	0.44363	0.44363
Coarse grain	0.23103	0.22425	0.225201	0.232601
Wheat	0.005314	0.005482	0.004648	0.005252
Meal	0.207286	0.213898	0.213782	0.205777
Forage	0	0	0	0
Residual cost of capital and management	0.337295	0.337295	0.337295	0.337295
Beef[4]	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Exogenous inputs	0.1326	0.1326	0.1326	0.1326
Land	0	0	0	0
Intermediate inputs	0.8371	0.8371	0.8371	0.8371
Feed	0	0	0	0
Coarse grain	0	0	0	0
Wheat	0	0	0	0
Meal	0	0	0	0
Forage	0	0	0	0
Residual cost of capital and management	0.0303	0.0303	0.0303	0.0303

[1]Unit revenue shares are the proportion of unit revenue (price) represented by the cost of each factor of production.

[2]USDA/ERS, Commodity Costs and Returns http://www.ers.usda.gov/Data/CostsAndReturns/testpick.htm

[3]USDA/ERS, 1996. [4]MacDonald et al., 1999.

Appendix table 2

Unit revenue shares for swine, eggs, and pork used in model[1]

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Swine[2]				
Exogenous inputs	0.138985	0.138985	0.138985	0.138985
Land	0	0	0	0
Intermediate inputs	0	0	0	0
Feed	0.625333	0.625333	0.625333	0.625333
Coarse grain	0.397464	0.386924	0.367032	0.377689
Wheat	0.00675	0.006935	0.005635	0.006323
Meal	0.221119	0.231474	0.252666	0.241322
Forage	0	0	0	0
Residual cost of capital and management	0.235682	0.235682	0.235682	0.235682
Eggs[3]				
Exogenous inputs	0.3	0.3	0.3	0.3
Land	0	0	0	0
Intermediate inputs	0	0	0	0
Feed	0.229099	0.229099	0.229099	0.229099
Coarse grain	0.119308	0.115807	0.116298	0.12012
Wheat	0.002744	0.002831	0.0024	0.002712
Meal	0.107046	0.110461	0.110401	0.106267
Forage	0	0	0	0
Residual cost of capital and management	0.470901	0.470901	0.470901	0.470901
Pork[4]				
Exogenous inputs	0.19	0.19	0.19	0.19
Land	0	0	0	0
Intermediate inputs	0.7426	0.7426	0.7426	0.7426
Feed	0	0	0	0
Coarse grain	0	0	0	0
Wheat	0	0	0	0
Meal	0	0	0	0
Forage	0	0	0	0
Residual cost of capital and management	0.0674	0.0674	0.0674	0.0674

[1]Unit revenue shares are the proportion of unit revenue (price) represented by the cost of each factor of production.

[2]USDA/ERS, Commodity Costs and Returns
http://www.ers.usda.gov/Data/CostsAndReturns/testpick.htm

[3]Calculated from feed balance (assumed). [4]MacDonald and Ollinger, 2000.

Cost-of-production data for corn, wheat, soybeans, rice, hogs, cattle, and milk are obtained from *Commodity Costs and Returns* (USDA/ERS). These data are divided by production revenue to find the revenue shares. Crop revenue includes U.S. Government payments, since they are necessary for land, capital, and management to show positive returns. In general, crops show fairly even allocations among exogenous inputs, land, and the residual cost of capital and management. For live animals, the major revenue share is allocated to feed costs, followed by the residual return to capital and management. Milk is an exception that reflects the way the data are reported. For milk, the animal value is implicit, as the milk costs include feed and veterinary costs. Thus, the large residual to capital and management includes the capital value of the dairy cow.

The remaining revenue shares come from a variety of sources. Forage and pasture revenue shares are from Barnett (2005). Those for poultry meat are

Appendix table 3

Unit revenue shares for milk, lambs and sheep, and poultry used in model[1]

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Milk[2]				
Exogenous inputs	0.192257	0.192257	0.192257	0.192257
Land	0	0	0	0
Intermediate inputs	0	0	0	0
Feed	0.492441	0.492441	0.492441	0.492441
Coarse grain	0.05359	0.015468	0.013019	0.095574
Wheat	0.004559	0.002946	0.002199	0.004154
Meal	0.035768	0.018123	0.024709	0.047621
Forage	0.398525	0.455904	0.452513	0.345093
Residual cost of capital and management	0.315302	0.315302	0.315302	0.315302
Lambs and Sheep[3]				
Exogenous inputs	0.1875	0.1875	0.1875	0.1875
Land	0	0	0	0
Intermediate inputs	0	0	0	0
Feed	0.375	0.375	0.375	0.375
Coarse grain	0.031361	0.028828	0.023288	0.020391
Wheat	0	0	0	0
Meal	0.004003	0.004759	0.003129	0.004839
Forage	0.339637	0.341413	0.348583	0.388552
Residual cost of capital and management	0.4375	0.4375	0.4375	0.4375
Poultry[4]				
Exogenous inputs	0.282	0.282	0.282	0.282
Land	0	0	0	0
Intermediate inputs	0.691	0.691	0.691	0.691
Feed	0	0	0	0
Coarse grain	0	0	0	0
Wheat	0	0	0	0
Meal	0	0	0	0
Forage	0	0	0	0
Residual cost of capital and management	0.027	0.027	0.027	0.027

[1]Unit revenue shares are the proportion of unit revenue (price) represented by the cost of each factor of production.

[2]USDA/ERS, Commodity Costs and Returns
http://www.ers.usda.gov/Data/CostsAndReturns/testpick.htm

[3]Umberger and McKinnon, 1996. [4]Ollinger, MacDonald, Madison, 2005.

broiler shares obtained from USDA/ERS, AER-747 (1996). The shares for lambs and sheep are from Umberger and McKinnon (1996). Beef shares come from MacDonald, Ollinger, Nelson, and Handy (1999), and pork from MacDonald and Ollinger (2000). Revenue shares for live poultry are from Ollinger, MacDonald, and Madison (2005). In general, meat industries show low residual returns to capital and management because the bulk of revenue is allocated to animal costs. The exceptions are poultry meat and eggs, treated as vertically integrated industries, with firms capturing the difference between meat and egg sales and feed costs. Thus, for poultry and eggs, the value of the animal is implicit, and the firms capture a large residual return to capital and management.

The revenue shares for the individual feed ingredients are calculated from the livestock-feed balances that determine feed use for the individual feeds based on animal numbers. That allows the per animal feed use by feed by animal type to be calculated. Using prices for feeds recorded in the *Livestock, Dairy and Poultry Outlook* report (UASA/ERS), revenue share can be calculated.

The land factor shares are from data taken from USDA/NASS *Crop Production* reports. The USDA/NASS reports indicated the area harvested for the grain, oilseed, and forage crops. The area of pasture has to be determined. The residual forage and pasture determined by the livestock-feed balance calculator is used to determine "production" of pasture for the model solution. This residual is converted to area using the harvested hay yield, and that area is combined with the recorded areas for harvested hay, corn silage, and sorghum silage to give total area for forage and pasture. The areas for the crops included in the model are summed to find the total area, and the factor shares are calculated.

Elasticities

Elasticities are critical parameters that come from a variety of sources. The elasticities can be grouped into several sets. The own- and cross-price elasticities of retail demand are obtained from several studies, and most are based on estimates from econometric models (table 7). Cross-price elasticities are nonnegative, implying that the commodities involved are substitutes and are small, which affects how the model reacts to disease outbreaks that alter prices. There are some spillover effects in meats, but not many elsewhere. The elasticities for beef, pork, and poultry meat are from Holt (2002), who estimated inverse demands for those products. Price flexibilities for meats are converted to elasticities using matrix inversion. In contrast to the more familiar inelastic annual estimates, these values are elastic and indicate the willingness of consumers to alter purchases in response to shortrun price changes. The elasticity of demand for lamb meat is an annual estimate used by Paarlberg and Lee (1998) to examine impacts of a tariff-rate quota for lamb meat, converted in our model to a quarterly figure based on the Holt estimates. The elasticity of demand for milk comes from Gould, Cox, and Perali (1991). The elasticities of demand for wheat and rice are from Gao, Wailes, and Cramer (1995). The elasticity of demand for soybean oil is from Yen and Chern (1992). The elasticity of demand for coarse grains for food and industrial use is based on a policy simulator model by Holland and Meekhoff (1979). The elasticity of demand for eggs comes from Huang (1996).

Substitution elasticities describe derived demand behaviors and affect supplies of the output commodities in the equation from which they are derived (tables 8, 9, and 10). Substitution elasticities for the meats are estimated by MacDonald and Ollinger (2000). Model solutions evaluated by individuals with experience in meatpacking were viewed as having excessive meat-yield changes as capital substituted for animals. Thus, the values used are lowered to reduce meat-yield changes. The substitution elasticities for animal feeds are generated with a technique used by McKinzie, Paarlberg, and Huerta (1986) that requires developing least-cost feed rations by animal species. Then, varying the prices of each ingredient, a set of pseudo-data is created through which share equations can be estimated from which, in return, the substitution elasticities relative to coarse grains can be extracted. With some exceptions, the estimated elasticities ranged from 0.7 to 1.2. The substitution elasticities for wheat use in cattle and swine feeds relative to coarse grains are 0.34 and 2.52, respectively. The substitution elasticity of forage and pasture relative to coarse grains in cattle feeding is estimated at 2.35. Estimates for the remaining substitution elasticities were not found, so values are used—given the differential supply equations, equations (139)-(143)—that are consistent with commonly accepted supply elasticity values. These are low and indicate little input substitution.

There are a number of elasticities tied to animal agriculture inventories. These are econometrically estimated as part of the study (table 11). There are again a couple of exceptions. Bird numbers are tied directly to poultry meat and egg outputs with elasticities of 1. This means there is no substitution between birds and other inputs in meat and egg production. If poultry output falls 10 percent, bird numbers fall 10 percent. The same relationship is imposed on milk production and dairy cow numbers.

International trade elasticities were difficult to obtain in many cases since, despite decades of research, there is little consensus about the magnitudes. Further, for the model to behave correctly for livestock disease issues, intra-sector trade must be modeled. This is done by inserting both excess demand and excess supply functions. The elasticities of excess demands for beef, pork, and poultry meat are from estimates for Japanese purchases of U.S. meats by Yang and Koo (1994) (table 12). The estimates for beef are similar to the values reported by Zhao, Wahl, and Marsh (2006). The excess demand elasticities for coarse grains, wheat, and soybeans and products are from policy simulators. The other trade elasticities are assumed. These are set at either 0 or 1, with some exceptions. Those for lamb meat, eggs, and rice are set in the elastic range. The elastic excess supply to the United States reflects that little lamb meat is consumed in the United States compared with other meats, global lamb meat trade is small, and lamb meat is more important to other countries. For rice, the excess demand is elastic because very little rice moves in world markets, even though the United States is a major exporter. Egg exports are small relative to U.S. and rest-of-world production.

Finding ending stocks elasticities proved difficult, since these values are rarely reported in the current literature. Older studies did include ending stock estimates, exclusively for crops. An elasticity for wheat can be found in Gallagher et al. (1981). An ending stocks elasticity for rice appears in Cramer et al. (1990). Experiments with model solutions produced a set of elasticities that gave reasonable behavioral responses (table 13). The ending stocks elasticity for forage and pasture is estimated using the quarterly data calculated from the livestock-feed balance workbook.

The remaining ending stocks are treated as residuals in the model solution, so that the elasticities are implicit. This is done because the stocks for these commodities are generally small relative to use, and some commodities like soybean meal are difficult to store. Thus, ending stocks for such commodities are treated mostly as transaction or pipeline stocks. The model solutions suggest that these implicit percentage changes are small.

Appendix table 4

Unit revenue shares for lamb and sheep meat and coarse grains used in model[1]

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Lamb and sheep meat[2]				
Exogenous inputs	0.2	0.2	0.2	0.2
Land	0	0	0	0
Intermediate inputs	0.75	0.75	0.75	0.75
Feed	0	0	0	0
Coarse grain	0	0	0	0
Wheat	0	0	0	0
Meal	0	0	0	0
Forage	0	0	0	0
Residual cost of capital and management	0.05	0.05	0.05	0.05
Coarse grains[2]				
Exogenous inputs	0.42792	0.42792	0.42792	0.42792
Land	0.254407	0.254407	0.254407	0.254407
Intermediate inputs	0	0	0	0
Feed	0	0	0	0
Coarse grain	0	0	0	0
Wheat	0	0	0	0
Meal	0	0	0	0
Forage	0	0	0	0
Residual cost of capital and management	0.317673	0.317673	0.317673	0.317673

[1]Unit revenue shares are the proportion of unit revenue (price) represented by the cost of each factor of production.

[2]USDA/ERS, Commodity Costs and Returns http://www.ers.usda.gov/Data/CostsAndReturns/testpick.htm and *Feed Outlook*.

Appendix table 5

Unit revenue shares for forage and wheat used in model[1]

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Forage[2]				
Exogenous inputs	0.5	0.5	0.5	0.5
Land	0.16	0.16	0.16	0.16
Intermediate inputs	0	0	0	0
Feed	0	0	0	0
Coarse grain	0	0	0	0
Wheat	0	0	0	0
Meal	0	0	0	0
Forage	0	0	0	0
Residual cost of capital and management	0.34	0.34	0.34	0.34
Wheat[3]				
Exogenous inputs	0.493707	0.493707	0.493707	0.493707
Land	0.316117	0.316117	0.316117	0.316117
Intermediate inputs	0	0	0	0
Feed	0	0	0	0
Coarse grain	0	0	0	0
Wheat	0	0	0	0
Meal	0	0	0	0
Forage	0	0	0	0
Residual cost of capital and management	0.190176	0.190176	0.190176	0.190176

[1]Unit revenue shares are the proportion of unit revenue (price) represented by the cost of each factor of production. [2] Barnett, undated.

[3]USDA/ERS, Commodity Costs and Returns http://www.ers.usda.gov/Data/CostsAndReturns/testpick.htm and *Wheat Outlook*.

Appendix table 6

Unit revenue shares for rice and soybeans used in model[1]

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Rice[2]				
Exogenous inputs	0.479147	0.479147	0.479147	0.479147
Land	0.172603	0.172603	0.172603	0.172603
Intermediate inputs	0	0	0	0
Feed	0	0	0	0
Coarse grain	0	0	0	0
Wheat	0	0	0	0
Meal	0	0	0	0
Forage	0	0	0	0
Residual cost of capital and management	0.34825	0.34825	0.34825	0.34825
Soybeans[3]				
Exogenous inputs	0.321523	0.321523	0.321523	0.321523
Land	0.331835	0.331835	0.331835	0.331835
Intermediate inputs	0	0	0	0
Feed	0	0	0	0
Coarse grain	0	0	0	0
Wheat	0	0	0	0
Meal	0	0	0	0
Forage	0	0	0	0
Residual cost of capital and management	0.346642	0.346642	0.346642	0.346642

[1]Unit revenue shares are the proportion of unit revenue (price) represented by the cost of each factor of production.

[2]USDA/ERS, Commodity Costs and Returns http://www.ers.usda.gov/Data/CostsAndReturns/testpick.htm and *Rice Outlook*

[3]USDA/ERS *Costs of Production* and *Feed Outlook*.

Appendix table 7

Price elasticities for final goods

	Beef	Pork	Poultry	Lamb	Dairy	Eggs	Wheat	Rice	Coarse grains	Soy oil
Beef	-1.521	0.077	0.206	0.789	0	0	0	0	0	0
Pork	0.077	-1.45	0.32	0	0	0	0	0	0	0
Poultry	0.206	0.32	-2.677	0.263	0	0	0	0	0	0
Lamb	0.789	0	0.263	-1.052	0	0	0	0	0	0
Milk	0	0	0	0	-0.397	0	0	0	0	0
Eggs	0	0	0	0	0	-0.1103	0	0	0	0
Wheat	0	0	0	0	0	0	-0.309	0.036	0	0
Rice	0	0	0	0	0	0	0.229	-0.328	0	0
Coarse grain	0	0	0	0	0	0	0	0	-0.4	0
Soy oil	0	0	0	0	0	0	0	0	0	-0.314

Sources: Various, as described in text.

Appendix table 8

Elasticities of substitution in meat production relative to capital

	Exogenous inputs	Animal
Beef	0.338944	0.2
Pork	0.428395	0.2
Poultry meat	0.435933	0.2
Lamb meat	0.443000	0.2

Source: MacDonald and Ollinger, 2000.

Appendix table 9

Elasticities of substitution in livestock relative to coarse grains

	Exogenous inputs	Wheat	Meal	Forage pasture
Beef cattle	0.3	0.341903	0.933330	2.3474
Swine	0.3	2.528800	0.971301	NA
Broilers	0.3	0.702133	0.893466	NA
Dairy cattle	0.3	0.706631	0.915752	1.1248
Layers	0.3	0.702000	1.070307	NA
Lambs and sheep	0.3	0.510600	-0.01110	0.494

NA= Not Allowed.

Source: Estimated using technique in McKinzie, Paarlberg, and Huerta, 1986.

Appendix table 10

Elasticities of substitution for crops relative to capital

	Exogenous inputs	Land
Wheat	0.3	0.3
Coarse grains	0.3	0.3
Soybeans	0.3	0.3
Forage and pasture	0.3	0.3
Rice	0.3	0.3

Source: Based on differential supply equations, equations (139)-(143), and consistent with commonly accepted supply elasticity values..

Appendix table 11

Elasticities used in model solution to capture animal dynamics

Dependent variable	Value	Independent variable
Layer numbers[1]	1	Egg output, current period
Bird numbers[1]	1	Poultry meat output, current period
Slaughter cattle, post-birth, calves	1	Number of cows, current period
Beef cows	0.014551	Replacement beef heifers, t-8
Beef cows	0.028313	Expected return cow sold t+9 relative to current sale
Pig crop	0.526875	Breeding hog inventory, previous period
Forage inventory	0.13591	Price next relative to current value
Replacement beef, heifers	0.106481	Expected return animal sold t+16 relative to t+5
Pig crop	0.001921	Expected price hogs t+2 relative to price t-1
Hog breeding Inventory	0.025028	Current price of hogs
Hog breeding inventory	0.855952	Last quarter's breeding inventory for hogs
Milk cow numbers[1]	1	Milk output
Replacement heifers, dairy	0.083785	Expected price milk t+8 relative to price of cattle t+5
Ewes	0.042211	Expected return to ewes t+4 -t+8 relative to current value
Ewes	0.85	Ewe inventories t-1
Replacement ewes	0.03408	Expected return t+4-t+12 relative to current period
Replacement ewes	0.85	Replacements t-1
Lamb crop	0.900894	Ewes
Beef cow inventory	0.85	Lagged inventory
Dairy cow inventory	0.85	Lagged inventory
Broilers	0.05	Lagged output
Layers	0.15	Lagged output

[1]Exceptions assumed equal to 1.0.

Source: Econometrically estimated by authors, except as noted.

Appendix table 12

Elasticities for international trade used in model

Commodity	Exogenous demand	Excess supply
Wheat	0.3	0.3
Beef	-1.010	1.00
Pork	-0.890	1.00
Poultry meat	-0.448	0.00
Lamb meat	0.000	5.00
Cattle	-1.000	1.00
Swine	-1.000	1.00
Birds	0.000	0.00
Milk/dairy	0.000	5.00
Eggs	-5.000	0.00
Lambs	-1.000	1.00
Wheat	-0.700	0.00
Coarse grains	-1.500	0.00
Soybeans	-1.000	0.00
Forage and pasture	0.000	0.00
Rice	-5.000	0.00
Soybean meal	-1.500	0.00
Soybean oil	-2.000	0.00

Source: Estimates compiled from a number of sources, excess supply and demand functions, and authors' best judgment.

Appendix table 13

Elasticities for ending stocks

Commodity	Elasticity of expected price to current prices
Wheat	0.8
Coarse grains	0.8
Soybeans	0.8
Rice	0.8
Soybean oil	0.5
Milk	0.8
Forage and pasture	0.13591

Source: Adapted from various published sources.

Appendix table 14

Number of animals destroyed in a hypothetical FMD outbreak

Scenario	Dairy	Sheep	Hogs		Cattle	
			Market	Breeding	Market	Breeding
Slaughter of direct-contact animals:						
Low	0	0	4,559.00	0	0	0
Mean	121.72	3.02	21,501.32	777.22	50.00	4.54
High	981.00	108.00	70,290.00	6,047.00	123.00	33.00
Slaughter of direct- and indirect-contact animals:						
Low	0	0	4,559	0	0	0
Mean	117.01	16.66	20,143.48	630.29	72.49	17.75
High	2,263.00	994.00	58,790.00	6,117.00	1,472.00	233.00
Ring slaughter of all animals within 1 km:						
Low	0	0	5,387.00	0	83.00	0
Mean	75.84	0	16,045.10	471.20	98.32	4.88
High	588.00	0	43,796.00	5,999.00	291.00	38.00

Source: Model estimation results.

Appendix table 15

Changes in aggregate net returns to capital and management

Sector	Standard outbreak	High outbreak
	Million dollars	
Beef processing	7	-3
Beef cattle	-1,958	-3,072
Pork processing	-93	-279
Swine	-1,559	-2,079
Lamb and sheep meat	18	31
Lamb and sheep	-10	-14
Poultry meat	-77	-118
Eggs	2	4
Milk/dairy	781	1,272
Soybean crushing	4	3
Crops	112	193
Total	-2,773	-4,062

Source: Model estimation results.