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Policy and Projection Model for the Meat Sector in the People's Republic of China

Frank H. Fuller
Iowa State University

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Abstract
The ability of China to continue satisfying its food requirements is a question with important ramifications for U.S. agricultural exports. This report documents the Food and Agricultural Policy Research Institute (FAPRI) model of China's meat and egg sectors. The report begins with a brief description of China's trade patterns followed by a discussion of the model structure and the important parameter assumptions. It summarizes the procedure used to project feed grain demands, and concludes with suggestions for future model development.

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Iowa State University
Ames, IA 50011-1070

Frank Fuller is a visiting research associate, CARD/FAPRI.

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Economic development in China over the last 15 years has been characterized by rapid structural change and economic growth. A crucial factor enabling general economic expansion in China has been unprecedented increases in agricultural production and productivity that have freed a large segment of the rural population to be employed in nonagricultural activities. Growth in agricultural output has outpaced population increases in recent decades, allowing the country to maintain a high level of self-sufficiency in meeting its food needs; however, the ability of China to continue satisfying its food requirements is a question with important ramifications for U.S. agricultural exports and world agricultural trade in general.

This report documents the Food and Agricultural Policy Research Institute's (FAPRI) model of China's meat and egg sectors. The commodities included in this model are beef, pork, poultry, mutton, and eggs. Given a path for world prices and trade volumes, this model can be used in isolation to study the impacts of policy changes on China's meat sector, or it can be used in conjunction with the other country models in the FAPRI system to determine the impact of policy changes on world trade volumes and prices. The meat and egg production levels generated by this model are used to calculate the demand for feed grains in China. This report begins with a brief description of China's trade patterns followed by a discussion of the model structure itself and the important parameter assumptions. After the livestock model is described, the procedure used to project feed grain demands is summarized. The report concludes with a brief description of future model development.

Chinese Agricultural Trade

Historically, China's agricultural trade has been dominated by grain products. Since the recovery of the Chinese economy following the establishment of the People's Republic of China in the late 1940s, China has frequently exported significant quantities of food and feed grains. All throughout the 1950s China was a net exporter of grains, and though China continued to export more than a million metric tons (mmt) of grain every year from 1960 to 1985, only in 1975 was China a net grain exporter. China continues to be a net importer of grains, though it did briefly regain its status as a net grain exporter in 1993 and 1994. China's grain exports during the 1950s and the late 1960s were motivated by rapidly increasing grain supplies and the need to obtain foreign currency to purchase the equipment and technology needed for industrial development (Carter and Zhong 1988).

In 1978 China embarked on a major reform of its domestic agricultural policies, stressing diversification of the rural economy, utilization of regional comparative advantage in crop selection, expansion of free markets, and increases in government purchasing prices. The change having the greatest impact, however, was the shift away from communal production to a system based on household production units called the household responsibility system (HRS). This system of contracting land, productive resources, and output quotas to households was initiated by work teams in Anhui province in 1978. The success of these farmers in raising output levels prompted other work teams to adopt the HRS. Although the government was reluctant at first to abandon the work team as the primary unit of production, it officially recognized and eventually promoted the *household responsibility system* in the early 1980s (Lin 1988). McMillan, Whalley, and Zhu estimated that 78 percent of the increase in agricultural productivity from 1978 to 1980 is the result of instituting the household responsibility system and 22 percent from purchase price increases. Lin (1992) estimates that 42.2 percent of output growth over that same period resulted from implementation of the HRS and 15.98 percent from increases in the government procurement prices. By 1984 more than 97 percent of agricultural production in China was carried out under the HRS. Having reaped the one-time benefits of implementing the household responsibility system, China's grain output has continued to increase since 1984 but at a significantly lower rate than during the early years of the reform (Lin, Huang, and Rozelle 1996).

Economic development over the last three decades has not only increased the availability of food products in China, but also real incomes of both urban and rural consumers. As incomes have grown, Chinese consumers have increased their per capita consumption of meats, fruits, wheat, tobacco, and alcohol, while decreasing their direct consumption of coarse grains (Fan, Cramer, and Wailes 1994). Consequently, the composition of Chinese agricultural trade has shifted, and imports of wheat, malting barley, soybeans and meal, corn, and poultry have grown in recent years. To help satisfy its growing demand for meat, China has allowed imports of poultry meat and small amounts of beef, but direct imports of pork into China have been severely restricted. In an attempt to skirt restrictions on meat inflows, significant quantities of broiler meat and small quantities of pork have been imported by Hong Kong and then reexported to Mainland China. Transshipments through Hong Kong are not well documented, but it is estimated that at least two-thirds of China's poultry imports pass through Hong Kong first (Jin 1997). Transshipments have made it difficult to determine the actual level of Chinese meat imports.

China's trade patterns also are changing to better match its comparative advantage in supplying goods that are relatively labor intensive rather than land intensive. Thus, exports of high value and processed agricultural products are gaining in their share of Chinese agricultural exports (Zhi 1996). China has been an exporter of pork since the early 1970s and poultry since the mid 1980s. Although there has been a concerted effort to increase the use of lean-meat pigs, Chinese pork generally contains more fat and is of lower quality than pork exported by the United States and European Union (EU). Consequently, the bulk of Chinese pork exports are sent to Hong Kong and the Former Soviet Union (FSU). Poultry exports, on the other hand, tend to be high-quality, boneless meat products. Low wages give China a comparative advantage over the United States and Thailand in servicing the Japanese boneless meat market. China's domestic poultry market favors dark meat, paws, and other parts that are complementary to U.S. poultry exports; consequently, the United States has captured the largest share of Chinese poultry imports (Jin 1996).

China's trade policy for livestock products may be characterized as a system of tariffs and discretionary import quotas. Although tariff schedules have been published in recent years, import quotas and other nontariff barriers, often motivated by self-sufficiency goals, are the primary impediment to imports of agricultural commodities. Unfortunately, quota levels change with domestic market conditions, and the rules determining these levels are unknown.

Projection of China's agricultural trade patterns is critically dependent upon the future course of import policies. As the demand for meat and other grain-consuming value-added products increases in China, the need for China to produce more of both grains and grain-using products is putting great stress on China's agricultural resources. Unless agricultural productivity continues to increase at a sufficient pace, China's imports of grains and/or meats will grow. At this point, Chinese officials believe the country's agricultural sector will be able to supply the products necessary to satisfy future demands (Xinhua 1996); however, it is not clear what strategy the Chinese government will take in the event that domestic output falls short.

Model Structure

The FAPRI model of China's livestock sector consists of a demand system, a set of production equations, trade relationships, and domestic market clearing conditions. Each of these components is described in detail. The actual model equations and supplementary information about feed demand parameters and model responsiveness to exogenous shocks are provided in Appendix A.

Meat and Egg Demand

The demand for beef, pork, poultry meat, and sheep meat is modeled as a two-stage budgeting process. In the first stage, consumers allocate their income across commodity groups, such as housing, clothing, grains, meat. Once group expenditure levels are determined, consumers decide how much of each good in the commodity group to purchase. The model does not contain a complete representation of the first-stage decision process; rather meat's share of consumer expenditures is determined by an Engle curve augmented by a price term. The functional form was chosen to allow the expenditure elasticity for meats as a group to decline as incomes rise. Estimating the meat expenditure equation using annual aggregate consumption data yields a price elasticity of -0.12 and an expenditure elasticity of 1.11. While these estimates are certainly plausible, the rate of growth in meat consumption generated by this high meat expenditure elasticity is not likely. Fan, Wailes, and Cramer (1995) have used survey data to estimate meat expenditure elasticities for rural Chinese consumers, and they arrived at a price elasticity of -0.309 and an expenditure elasticity of 0.898. A similar study was conducted by Wu, Li, and Samuel (1995) using urban consumer survey data. These authors found that the expenditure elasticity was 0.378. Using the price elasticity computed by Fan, Wailes, and Cramer and an intermediate value of 0.55 for the expenditure elasticity, the model produces a more plausible projection path for meat consumption.

Once meat expenditures are determined, an almost ideal demand system (AIDS) is used to allocate the consumer's meat budget to beef, pork, poultry, and sheep meat purchases. As with the meat expenditure equation, estimation of the demand system using aggregate data did not produce satisfactory results.[1] Consequently, Marshallian own-price elasticities for pork and beef were taken from Gao, Wailes, and Cramer (1996). The sheep meat own-price elasticity was obtained from an early version of the U.S. Department of Agriculture's Commodity Projection and Price Analysis (CPPA) model, and the poultry own-price elasticity was chosen between CPPA's value of -1.11 and Gao, Wailes, and Cramer's value of -.53 to ensure net substitution among all meats. The individual meat expenditure elasticities are proportional to those estimated by Gao, Wailes, and Cramer. Cross-price elasticities were obtained by imposing symmetry, homogeneity, and adding-up restrictions on the demand system.

Egg demand is determined independently of meat demand by a modified linear equation. Per capita egg consumption, in levels, is a function of the logarithm of the retail egg price, deflated by the stone price index for meats, and per capita real income. The meat price index was chosen to deflate the

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[1] The estimation results for the meat demand system, as well as for pork, beef, and sheep meat supplies, are found in Shaw et al. 1997.

egg price to proxy the price substitution effects between meat and egg consumption. As in the meat expenditure equation, real income enters the egg demand equation in logarithmic form to ensure that the income elasticity for eggs falls as income rises. The income effect is particularly important to the consumption path for eggs because per capita consumption of eggs in China has been historically quite high; thus, strong growth in future income may cause egg consumption to reach unfeasible levels if the income elasticity is not carefully specified. The own-price elasticity of -.9032 was estimated by Gao, Wailes, and Cramer, and the income elasticity of 0.54 was taken from Wu, Li, and Samuel (1995). Price and income elasticities used in the model are summarized in Tables 1 and 2.[2]

Table 1. Compensated Meat Demand Elasticities

	Hicksian Elasticities			
	Effect of a 1% Change in the Price of			
	Pork	Beef	Poultry	Sheep Meat
Pork	-0.20	0.06	0.12	0.03
Beef	0.94	-1.00	0.05	0.02
Poultry	0.59	0.02	-0.64	0.03
Sheep Meat	0.49	0.02	0.12	-0.64

Table 2. Uncompensated Meat Demand Elasticities

	Marshallian Elasticities					
	Effect of a 1% Change in the Price of					
	Pork	Beef	Poultry	Sheep Meat	Expenditure	Income
Pork	-0.98	0.01	-0.04	-0.014	1.03	0.51
Beef	0.30	-1.04	-0.08	-0.01	0.84	0.42
Poultry	-0.15	-0.03	-0.78	-0.01	0.97	0.49
Sheep Meat	-0.11	-0.02	0.01	-0.67	0.79	0.39

Meat and Egg Supply

Meat production in China, like many other developing nations, consists of a mixture of small production units raising livestock for personal consumption (backyard producers), small producers specialized in meat production (specialized households), and large state-run or commercial farms (intensive producers). Production methods, as well as productivity and output quality, vary greatly

[2]Price and income elasticities of demand are calculated using the mean values for all variables over the period from 1984 to 1995.

across the different production technologies. Since the agricultural reforms that began in 1978, the mix of production units has been constantly changing, shifting in favor of specialized household and intensive production. Ideally, a model of Chinese livestock production would contain a characterization of each of the three major production technologies, and the mix of producers would be endogenously determined. At present we do not know enough about the cost structure and actual output levels of specialized household and backyard production to adequately specify separate production functions; therefore, the model described here characterizes livestock production as an aggregate technology.

Livestock production was modeled using two general structures. First, the preeminence of pork production necessitated as much detail as possible to ensure the viability of pork meat output relative to slaughter, births, animal inventory, and breeding herd growth. Consequently, structural equations and identities are included for each of the important elements in the pork production process. In particular, pigs born and breeding inventory equations are specified as functions of lagged inventories and the pork-grain price ratio. Hog slaughter and slaughter weight equations are also functions of the pork-grain price ratio and lagged inventory, as well as the slaughter-to-inventory ratio. Finally, pork production itself is calculated as the product of hog slaughter and slaughter weight. Second, a reduced form, partial adjustment structure is employed to model beef, poultry, sheep, and egg production. The partial adjustment structure allows one to approximate the production dynamics that are important in modeling livestock products.

The elasticities of supply with respect to the meat-grain price ratio and the soybean meal price are given in Table 3. These elasticities indicate the response of the individual equations in the short (1 year) and long (10 year) run, given all other variables remain constant. When other prices and quantities in the model are allowed to adjust following a price shock, the substitution effects on the demand side can accentuate or dampen the supply response for a given commodity. The model responses to various price shocks are displayed in Tables A.1. through A.3.

Table 3. Own-price and Grain-price Supply Elasticities

	Impact Own-price	Long-Run Own-price	Impact Soymeal Price	Long-run Soymeal Price
Pork	0.61	0.71		
Beef	0.33	0.49		
Poultry	0.26	3.00	-0.06	-0.67
Sheep meat	0.45	4.96		
Eggs	0.52	5.26	-0.10	-1.02

Note: Supply elasticities are calculated using the mean values for all variables over the period from 1984 to 1995.

Trade

Chinese beef trade, egg imports, and pork import paths are exogenously specified by the analyst according to his or her expectations based on available outlook information. China has not imported pork in the last two decades, and, unless import policies change, it is not likely they will import significant quantities of pork in the near future. Without an import history, it is impossible to estimate a Chinese import demand elasticity for pork; moreover, with an endogenously determined pork price, we cannot calculate imports residually. Hence, pork imports by China can either be determined exogenously or by an ad hoc synthetic import demand equation. Until better information is available about the demand for imported pork, we have chosen to determine the pork import path outside the model. Although there is a recent history of beef imports and exports by China, many of the considerations discussed with regard to Chinese pork imports also apply to beef trade.

China's pork exports, poultry trade, and egg exports have a sufficient history to estimate import and export demand equations. By specifying imports and exports individually rather than as net trade, we implicitly assume that Chinese meat exports and meat exports from the rest of the world are different commodities; however, the two products are not consistently treated as different goods in the sense that both imported beef and domestically produced beef sell in the domestic market at a common price. The assumption of a single market price is not based upon theoretical considerations, but rather the fact that retail prices for imported beef are not currently available.

Each of the export demand equations depends upon the ratio of relevant Chinese and U.S. prices. The egg export equation also contains a trend variable to improve fit. The poultry import and export equations depend on relative prices and per capita real income. Since poultry imports are the only meat imports endogenously determined in the model, the poultry import equation also contains the only import tariff. The average elasticities and growth rates for the trade demands over the 1984 to 1995 period are reported in Table 4.

Table 4. Trade Demand Elasticities and Growth Rates

	Price Elasticity	Income Elasticity	Trend Growth Rate
Pork Exports	-0.55	-	-
Egg Exports	-1.60	-	-0.002%
Poultry Exports	-0.35	1.31	-
Poultry Imports	0.49	1.83	-

Prices and Price Linkages

Chinese domestic prices are determined in the model by the condition that supply must equal demand plus net exports. If the condition is not met by the initial prices and quantities, prices adjust up or down to clear the markets. International livestock price movements affect the domestic market through the import and export demand equations. The U.S. corn price and the Rotterdam soybean meal price are converted to Chinese yuan and used as proxies for the domestic corn and meal prices. The grain prices, as well as the international prices, are exogenous to the model, but the meat and egg prices are internally solved and will react to any changes in exogenous variables or policy variations.

Feed Grain Demands

China has been able to rapidly increase its meat production in the last decade without dramatically increasing its demand for feed grains. This accomplishment is due, in large part, to the traditional practice of feeding large quantities of nongrain, green feeds. One study of backyard swine production in Sichuan province estimates that farmers feed an average of 1.86 kg of feed concentrate for every kilogram of liveweight gain. The animal's diet is supplemented by an additional 22 kg of forage, green roughage, and other nontraditional feeds for every kilogram of liveweight (Gou, Yang, and Kang 1996). The fact that such feeding practices continue despite the low total feed efficiency is a reflection of the grain scarcity in China relative to many developed economies. Nevertheless, market reforms and adoption of modern of livestock production practices in China have caused many specialized household and large commercial and state farms to adopt more grain intensive feeding practices because of their increased feed efficiency (Liu, Lu, and Niu 1996). This trend has prompted much debate and research in recent years to determine the potential growth of China's feed demand and to find ways to substitute nontraditional feeds for grain in a more efficient manner.

A number of paradigms for increasing meat production have been suggested by Chinese researchers. It is generally accepted that it is not possible for China to adopt widespread use of a high-concentrate feed diet, such as is used in the United States, because the use of feed grains would have to triple at current meat output levels. One alternative that has made significant progress in China is the "grain-saving" model, which employs intensive feeding techniques that increase feed efficiency. These technologies emphasize poultry and swine production rather than ruminant production because of their superior feed conversion. Although this technology is able to greatly improve feed use, it relies heavily on grain inputs, and is still likely to cause feed grain consumption to climb rapidly in the coming years (Cao and Yao 1996). Other scientists in China advocate developing a feeding system that exploits the potential for nongrain feeds. These researchers suggest that great quantities of feed grain could be saved by substituting for grain feeds with feeds composed of processed animal excreta, fruit residue, straw, forage, and water plants. While green feeds have long been a staple in animal diets in China, their use in the production of nutritionally balanced feed concentrates is currently quite limited (Cao and Yao 1996; Wang and Hu 1996; Gao, Yang, and Kang 1996). The paradigm chosen in the current model to calculate feed demands is best represented by the "grain-saving" model.

China's demand for feed grains and protein meals is calculated from the production of pork, poultry, eggs, and beef. It is assumed that sheep and goats are grazed in China and that cattle receive only a small quantity of grain per head to supplement their primary diet of straw and forage; consequently, the predominant share of grain feed demand is derived from swine, poultry, and egg production. The linkage between livestock output and feed grain demand is described by the relationship in equation (1); namely, that the total demand for feed i (d_i) is the sum over all meats of the per unit input of feed i (c_{ij}) into meat j times the output of meat j (X_j):

$$d_i = \sum_j c_{ij} X_j \,. \tag{1}$$

It is evident from equation (1) that changes in either the level of meat production or the per unit feed requirement will cause total feed demand to change. Meat output levels originate in the livestock model, and changes in these levels generated by that model are used in calculating feed demand changes. Unit input coefficients can either be viewed as fixed over time or as changing in response to prices for meats and feed grains. When the coefficients are allowed to change, the rate at which they move and the direction are determined largely by parameters imbedded in the meat production technology. Given the complicated and varied structure of meat production, uncovering the exact relationships between these parameters is beyond reasonable analytical tractability. While it is possible to derive an approximation for the relationship between price movements and unit grain requirements, it is assumed for simplicity in this model that the input coefficients are fixed with respect to price changes.

In addition to price effects, the unit input of grain in the production of a pork, poultry meat, and eggs is affected by the meat production technology. Consequently, feed demands are segregated in the model by production technology as well as product type. The total demand for any given feed used in the production of a particular meat product is the sum of the demands created by each type of production technology. For example, the demand for corn derived from pork production will be the sum of corn used by backyard producers, specialized household producers, and large-scale intensive growers. As the technological mix of production changes in China, the level and composition of total feed grain demand also will be altered. Likewise, improvements in production methods, genetic breeding stock, and management practices will have an impact on the demand for feed. In order to capture these effects, feed demands are generated by equation (2):

$$d_i = \sum_{meat} \left(\begin{array}{l} \left(\dfrac{Meat\ Production}{Meat\ Yield\ per\ Head} \right) \times (FCR) \times \begin{pmatrix} Industry \\ Share \end{pmatrix} \times \\ \begin{pmatrix} Grain's\ Share \\ of\ Total\ Feed \end{pmatrix} \times \begin{pmatrix} Grain\ i's\ Share \\ of\ Grain\ Feed \end{pmatrix} \end{array} \right). \qquad (2)$$

Changes in technology and industry composition are effected through the feed conversion ratio (FCR), meat yield from liveweight, industry share, and grain's share of total feed. These coefficients are treated as parameters, and change according to exogenously determined time paths. Grain *i*'s share of grain feed is also dependent upon technology, but it is assumed that the feed rations remain constant over the projection period.

Relatively few studies detailing livestock feeding practices in China have been published; nevertheless, a fairly complete study of China's feed industry was conducted by the World Bank in the early 1990s. This study provides estimates of feed conversion ratios, industry share, and feed rations for various livestock production technologies. These estimates are the primary source for the coefficients utilized in feed demand calculations. The coefficients reported by the World Bank were updated according to recent unpublished data obtained from Dr. Cungen Zhang, a professor specializing in livestock production at the Chinese Academy of Agricultural Sciences. The feed rations were then calibrated to feed utilization data obtained from the Production, Supply, and Distribution Database (PS&D) maintained by the U.S. Department of Agriculture's Foreign Agricultural Service (FAS). Tables A.4 and A.5 display the technology parameters and final rations employed in the model.

As mentioned, changes in technology and industry structure over time are incorporated into the feed demand calculation by varying the feed conversion ratio, industry share, and grain's share of feed coefficients. The time paths for these parameters are exogenously determined by the analyst. The present specification incorporates a 1 percent annual improvement in feed efficiency for all swine and poultry technologies. Swine production by backyard and state farm producers is expected to decline at annual rates of 1 percent and 3.2 percent respectively. Specialized household production of swine is assumed to increase by 7 percent annually over the next decade. Commercial poultry and egg production are anticipated to grow by 3 percent annually, implying a 1.7 percent decline year on year in village poultry and egg production. Finally, grain's share of feed is expected to increase annually for specialized household swine producers, commercial egg producers, and village poultry and egg farmers by 0.5 percent, 1 percent, and 3 percent respectively.

Future Model Development

The model described in this report is clearly limited in its commodity coverage. Fish consumption is a rapidly growing component of meat demand in China, and future models of the Chinese meat sector will include both demand and supply components for aquaculture products. Likewise, dairy products, although not capturing as large a share of Chinese food expenditures as aquaculture, are likely to become more important as incomes rise and should be included in future modeling efforts.

In addition to expanding the commodity coverage, future models will contain a more detailed structure for ruminant production. One of the peculiar facets of China's beef industry is the large draft and water buffalo component of the cattle herd. These animals are generally older at slaughter, and their meat is frequently consumed by the producer and does not pass through market channels. Future model developments will attempt to capture the impact of draft animals in the herd and the changes associated with modernization of the beef industry on beef production. Similarly, goat and sheep production will be modeled in a manner that ensures inventory growth, births, and slaughter are consistent with sheep meat production.

The feed demand component of the model also could be refined in a number of ways. First, incorporating dairy and aquaculture production processes into the livestock model will improve the accuracy of the model's feed demand projections. Second, adding an approximation for the response of unit feed coefficients to price movements, allowing the feed mix to adjust to changing market conditions, will capture important demand fluctuations currently absent in the model. Third, the feed demand component of the model would be greatly enhanced by the development of an explicit substitution relationship between nongrain and grain feeds. Thus, as China is able to increase its use of green feeds, the model would correspondingly decrease demand for grain feeds.

Finally, future modeling efforts should strive to improve the model's ability to capture changes in trade and domestic policy. Except for poultry, the present model does not incorporate the influence of import tariffs; moreover, import quotas and other restraints enter the model indirectly through assumed import and export paths. One reason for the lack of policy variables in the present model is that most import flows are exogenously determined. Endogenizing import demands for beef, pork, eggs, and sheep meat would facilitate the inclusion of import tariffs on these commodities. The limited amount of information available about Chinese agricultural and trade policy hinders the incorporation of policy variables into the model structure; however, as policy information becomes more accessible, the model can be updated to reflect this information.

APPENDIX A.

CHINA LIVESTOCK MODEL EQUATIONS

Consumption

$$\left(\frac{\text{Meat Expenditure}}{\text{Total Expenditures}}\right) = 81.54 - 4.78 * \ln\left(\frac{\text{Stone Index}}{\text{GDP Deflator}}\right) - 6.96 * \ln(\text{real GDP}) \tag{A.1}$$

$$\begin{aligned}\text{Pork Expenditure Share} = {} & 0.54 + 0.03 * \ln(\text{pork price}) + .01 * \ln(\text{beef price}) \\ & - 0.02 * \ln(\text{poultry price}) - 0.01 * \ln(\text{mutton price}) \\ & + 0.02 * (\text{per capita meat expenditures / stone index})\end{aligned} \tag{A.2}$$

$$\begin{aligned}\text{Beef Expenditure Share} = {} & 0.13 + 0.01 * \ln(\text{pork price}) - .002 * \ln(\text{beef price}) \\ & - 0.005 * \ln(\text{poultry price}) - 0.001 * \ln(\text{mutton price}) \\ & - 0.008 * (\text{per capita meat expenditures / stone index})\end{aligned} \tag{A.3}$$

$$\begin{aligned}\text{Poultry Expenditure Share} = {} & 0.24 - 0.03 * \ln(\text{pork price}) - .005 * \ln(\text{beef price}) \\ & + 0.03 * \ln(\text{poultry price}) - 0.001 * \ln(\text{mutton price}) \\ & - 0.004 * (\text{per capita meat expenditures / stone index})\end{aligned} \tag{A.4}$$

$$\text{Sheep Meat Expenditure Share} = \begin{pmatrix}1 - \text{Pork Share} - \text{Beef Share} \\ - \text{Poultry Share}\end{pmatrix} \tag{A.5}$$

$$\begin{aligned}\text{Per Capita Egg Consumption} = {} & 5.08 - 7.43 * \ln\left(\frac{\text{egg price}}{\text{stone index}}\right) \\ & + 4.44 * \ln(\text{per capita GDP})\end{aligned} \tag{A.6}$$

$$\text{Stone Index} = \sum_{\text{meat } i} (\text{expenditure share})_i * \ln(\text{retail price})_i \tag{A.7}$$

Production

$$\text{Pork Production} = \text{hog slaughter} * \text{slaughter weight} \tag{A.8}$$

$$\text{Hog Slaughter Weight} = -0.06 + 0.0005 * \left(\frac{\text{pork price}}{\text{CPI}}\right) - 0.02 * \left(\frac{\text{hog slaughter}}{\text{hog inventory}}\right) + 0.00006 * \text{year} \tag{A.9}$$

$$\text{Hog Slaughter} = -138736 + 0.71 * \text{hog inventory} + 0.68 * \text{pigs born} \tag{A.10}$$

$$\text{Pigs Born} = 4184611.1 + 301623.7 * \ln\left(\frac{\text{pork price}}{\text{corn price}}\right) + 135266.2 * \ln(\text{sow inventory}) \tag{A.11}$$

$$\text{Sow Inventory} = 520624 + 100000 * \left(\frac{\text{pork price}}{\text{CPI}}\right) - 500 * \left(\frac{\text{corn price}}{\text{CPI}}\right) + 0.12 * \text{hog inventory} - 270.47 * \text{year} \tag{A.12}$$

$$\ln(\text{Beef Production}) = -109.7 + 0.34 * \ln\left(\frac{\text{beef price}}{\text{CPI}}\right) + 0.31 * \ln(\text{beef production})_{t-1} + 0.058 * \text{year} \tag{A.13}$$

$$\text{Poultry Production} = -260.4 + 106.3 * \left(\frac{\text{poultry price}}{\text{corn price}}\right) - 22938.1 * \left(\frac{\text{soymeal price}}{\text{CPI}}\right) + 0.995 * (\text{poultry production})_{t-1} \tag{A.14}$$

$$\ln(\text{Sheep Meat Production}) = 2.02 + 0.45 * \ln\left(\frac{\text{lamb price}}{\text{CPI}}\right) + 0.91 * \ln(\text{sheep meat production})_{t-1} \tag{A.15}$$

$$\text{Egg Production} = -3791.5 + 816.3 * \left(\frac{\text{egg price}}{\text{corn price}}\right) - 108065 * \left(\frac{\text{soymeal price}}{\text{CPI}}\right) + 0.97 * (\text{egg production})_{t-1} \tag{A.16}$$

Trade

$$\ln(\text{Pork Exports}) = 5.35 - 0.55 * \ln\left(\frac{\text{pork price}}{\text{US hog price in yuan}}\right) \tag{A.17}$$

$$\text{Poultry Exports} = 237.7 - 38.7 * \left(\frac{\text{poultry price}}{\text{US wholesale price in yuan}}\right) + 100 * \left(\begin{array}{l}\text{real GDP}\\ \text{per capita}\end{array}\right) \tag{A.18}$$

$$\text{Poultry Imports} = -154.1 + 521.7 * \left(\frac{\text{poultry price}}{(\text{US wholesale price in yuan}) * \text{import tariff}}\right) + 193.7 * (\text{real GDP per capita}) \tag{A.19}$$

$$\ln(\text{Egg Exports}) = 104.84 - 1.6 * \ln\left(\frac{\text{egg price}}{\text{US wholesale price in yuan}}\right) - 0.05 * \text{year} \tag{A.20}$$

Market Clearing For Commodity *i*

$$\text{Production}_i + \text{Imports}_i = \text{Export}_i + \text{Consumption}_i \tag{A.21}$$

Table A.1. Model Supply Responses to Price Changes

	Percent Response to a 10% Increase in the Chinese Price of						
Supply	Pork	Beef	Poultry	Sheep Meat	Eggs	Corn	Soymeal
				(Percent)			
Pork							
Impact	5.26	0.43	0.59	0.18	0.00	-2.16	0.02
5-Year	9.37	0.54	0.69	0.18	0.00	-2.57	0.07
10-Year	9.65	0.55	0.66	0.17	0.00	-2.50	0.11
Beef							
Impact	1.45	3.27	0.43	0.15	0.00	0.82	0.01
5-Year	1.87	4.78	0.45	0.14	0.00	1.41	0.05
10-Year	1.86	4.79	0.43	0.14	0.00	1.47	0.07
Poultry							
Impact	0.41	0.09	1.03	0.06	0.00	-0.62	-0.20
5-Year	1.31	0.25	3.92	0.17	0.00	-1.87	-0.71
10-Year	1.84	0.35	6.38	0.23	0.00	-2.55	-1.10
Sheep Meat							
Impact	1.31	0.32	0.67	4.43	0.00	0.78	0.02
5-Year	2.76	0.63	1.31	19.78	0.00	2.24	0.12
10-Year	2.87	0.65	1.32	33.93	0.00	2.59	0.20
Eggs							
Impact	1.38	0.30	0.56	0.18	2.88	-0.97	-1.47
5-Year	3.45	0.69	1.26	0.38	15.07	-1.95	-3.28
10-Year	3.81	0.76	1.34	0.40	29.53	-1.99	3.43

Table A.2. Model Hog Production Responses to Price Changes

	Percent Response to a 10% Increase in the Chinese Price of		
	Pork	Corn	Soymeal
		(Percent)	
Sow Inventory			
Impact	1.95	0.15	0.01
5-Year	8.51	-1.42	0.06
10-Year	8.87	-1.34	0.09
Pigs Born			
Impact	6.75	-2.78	0.02
5-Year	8.71	-2.37	0.07
10-Year	8.89	-2.30	0.10
Hog Slaughter			
Impact	4.56	-1.88	0.01
5-Year	8.66	-2.39	0.06
10-Year	8.93	-2.32	0.10
Hog Slaughter Weight			
Impact	0.67	-0.28	0.00
5-Year	0.66	-0.19	0.01
10-Year	0.65	-0.18	0.01
Hog Inventory			
Impact	0.00	0.00	0.00
5-Year	4.36	-1.24	0.03
10-Year	4.58	-1.20	0.05

Table A.3. Model Trade Responses to Price Changes

	Percent Response to a 10% Increase in the Price of			
	U.S. Pork	U.S. Broilers	U.S. Eggs	U.S. Dollar
	(Percent)			
Pork Exports				
Impact	5.34	-0.02	0.00	5.35
5-Year	5.35	-0.01	0.00	5.36
10-Year	5.35	0.00	0.00	5.36
Poultry Exports				
Impact	0.00	0.84	0.00	0.84
5-Year	0.00	0.68	0.00	0.63
10-Year	0.00	0.58	0.00	0.51
Poultry Imports				
Impact	0.01	-4.08	0.00	-4.13
5-Year	0.00	-3.71	0.00	-3.48
10-Year	0.00	-3.43	0.00	-2.99
Egg Exports				
Impact	-0.03	-0.12	16.41	15.03
5-Year	0.00	0.01	16.46	12.48
10-Year	0.00	0.01	16.46	12.41

Table A.4. Feed Demand Technology Parameters

	FCR Kg Feed/Kg Liveweight		Production Share in Percent		Grain's Share of Total Feed	
	1996	2006	1996	2006	1996	2006
Swine						
Backyard	5.93	5.37	79.2	71.6	50.0	50.0
Specialized Household	4.46	4.03	10.7	24.0	90.5	95.1
Large Intensive	3.96	3.58	10.1	7.3	100.0	100.0
Poultry						
Commercial Layers	2.48	2.24	30.9	41.5	100.0	100.0
Commercial Poultry	2.23	2.01	30.9	41.5	91.2	100.0
Village Poultry	3.47	3.13	69.1	59.7	57.0	76.6

Table A.5. Feed Rations

	Swine			Poultry Meat and Eggs		Cattle
Feed	Backyard	Specialized Household	Large Intensive	Poultry Meat	Layers	3.0 mt Feed/Head
			(Percent)			
Corn	34.0	38.5	38.5	50.0	50.0	70.0
Wheat	1.5	2.5	2.5	1.0	1.0	0.0
Course Grain	0.5	0.5	0.7	0.5	0.5	30.0
Bran[a]	62.9	52.0	50.9	31.4	32.2	0.0
Soymeal	0.0	2.5	2.5	9.5	9.5	0.0
Fishmeal	0.1	0.5	0.5	0.8	0.7	0.0
Rapemeal	0.0	0.0	0.0	0.9	0.2	0.0
Cottonseed Meal/Cake	0.0	0.0	0.0	0.0	0.4	0.0
Peanut Meal	0.0	2.0	2.0	3.0	1.1	0.0
Sunmeal	0.0	0.0	0.4	0.4	0.4	0.0
Bonemeal	0.0	0.5	1.0	1.5	2.0	0.0
Additives	1.0	1.0	1.0	1.0	2.0	0.0
Total	100.0	100.0	100.0	100.0	100.0	100.0

[a]Bran includes rice and wheat bran, brewers grains, and other nontraditional grain feeds.

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