The Impact of Structural Change in Chinese Livestock Production on World Feed Grain Trade

Frank Fuller, Associate Scientist
Center for Agricultural and Rural Development
Iowa State University
579 Heady Hall, Ames, Iowa 50011-1070
Phone: (515) 294-0470, Fax: (515) 294-6336
Email:ffuller@gcard.iastate.edu

Cheng Fang, Assistant Scientist
Center for Agricultural and Rural Development
Iowa State University
465 Heady Hall, Ames, Iowa 50011-1070
Phone: (515) 294-6357, Fax: (515) 294-6336
Email:cfang@gcard.iastate.edu

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Abstract: Using household survey data from seven provinces in China, this study provides estimates of the price responsiveness of feed demand by traditional and specialized household pork and poultry producers. Estimated elasticities are used to simulate the impacts of structural change in China's livestock industry on feed grain trade.

Note: All correspondence should be directed to Frank Fuller

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China's rapid economic growth and gradual transition toward a market economy have brought about significant changes in its food consumption patterns and trade behavior. If China is unable to meet its future food and feed grain needs through domestic production, the ongoing transition may have important implications for international trade.

The magnitude of a potential shortfall in China's feed grain sector depends, in part, on feeding practices and feed efficiency in its major livestock sectors. Traditional household or "backyard" producers raise the vast majority of livestock in China. During the past two decades, however, the configuration of livestock production has been changing. For example, backyard pork production declined from 92.9 percent in 1982 to 80.7 percent in 1995, as an increasing number of households began specializing in pork production. This trend toward specialized and commercial production is likely to continue as China's agricultural economy continues to modernize.

Many studies have estimated Chinese food demand. However, the lack of reliable data has hampered attempts to econometrically estimate the feed demand behavior of household producers. Many studies of Chinese feed demand calculate feed requirements by multiplying feed conversion coefficients by livestock production levels to obtain a total demand for feed. The weakness of the fixed-coefficient approach is that feeding practices in China are quite diverse and can vary dramatically from the assumptions that underlie the calculation of standard conversion factors. Moreover, using fixed coefficients to estimate feed demand ignores the impact of substitution among feeds as a result of relative price changes. The lack of knowledge about China's livestock and feed demand relationships is a great weakness in current projections of

China's future feed requirements (Fan and Agcaoili-Sombilla (1995) and Qi (1998)).

The objectives of this study are to provide estimates of the price responsiveness of feed demand by traditional and specialized household producers of pork and poultry in China and to simulate the impact of changes in the structure of Chinese livestock production on world feed grain trade. The next section briefly describes the data and estimation procedures used to calculate the feed demand elasticities for Chinese backyard and specialized household producers. These estimates are incorporated in a policy simulation model that is used to project feed demands under two different assumptions regarding the rate of structural change in China's livestock sector. The paper concludes with a discussion of the simulation results and their implications for international feed grain trade.

Data and Estimated Price Responsiveness

The data used to estimate the price responsiveness of Chinese feed demand were collected by the University of Arkansas (UOA) and the Research Center for Rural Economy (RCRE) in China's Ministry of Agriculture. In 1997 the UOA and RCRE conducted a feed consumption survey covering seven provinces (Sichuan, Hunan, Jilin, Shandong, Shaanxi, Guandong, and Jiangsu) which were selected to capture a cross section of the different livestock production practices in China. The total pork production from these seven provinces was 14.5 mmt, accounting for 45 percent of China's total pork production in 1996. The survey collected information about each household's annual livestock production, feed use, labor inputs, grain production, and prices, as well as other demographic and marketing data. Detailed information about this survey can be found in Wailes et al (1998).

The survey differentiated between traditional household production and specialized households using the following criteria. A household production unit was considered a

specialized household if:

1) 60 percent or more of the household labor is allocated to the specialized enterprise,

2) 60 percent or more of the household income is derived from the specialized enterprise,

3) 80 percent or more of the household sales are from the specialized enterprise, and

4) Household per capita income is at least twice as high as the local area average.

This study uses data collected from specialized household and backyard pork, poultry, and egg producers.

We assume pork and poultry production at the household level can be characterized by a strongly separable cost function: $C(y, \mathbf{w}, \mathbf{r}, \mathbf{z}) = c^1(y, \mathbf{w}, \mathbf{z}) + c^2(y, \mathbf{r}, \mathbf{z})$, where y is production, $\mathbf{w}$ is a vector of feed prices, $\mathbf{r}$ is a vector of other input prices, and $\mathbf{z}$ is a vector of shift variables capturing regional effects and other factors affecting production costs. The advantage of assuming separability is that it allows us to analyze input demands in the Chinese livestock sector as a two-stage process, reducing the data demands of the analysis. In the first stage, the unit cost of each aggregate input (feeds and other inputs) is minimized. In the second stage, the aggregate inputs are combined in a cost minimizing fashion to obtain the desired output level. Consequently, separability allows us to focus on the first-stage optimization process for an input aggregate, such as feeds, independent of other input aggregates (Chambers 1988).

Using the derivative property of the cost function, we obtain the demand for grain from the feed sub-cost fuction as a function of feed prices and shift variables by differentiating the sub-cost function with respect to the grain price (w_g).

(1) $\left(\dfrac{\partial c^1(y, \mathbf{w}, \mathbf{z})}{\partial w_g} \right) = GDEM = G(y, \mathbf{w}, \mathbf{z})$

Demand equations similar to (1) could be derived for other feeds, and the collection of demand

equations could be estimated as a system. Unfortunately, there were not enough observations in the data set with non-zero demand levels to employ the system approach. Consequently, we focus in this study on the demand for feed grains as an aggregate and estimate the conditional demand equation in (1) for Chinese pork and poultry producers.

Since the data provide only a snapshot of Chinese pork production and the changes in elasticities over time cannot be estimated, we selected a double-log representation for equation (1). We constructed the dependent variable, household grain demand (*GDEM*), by combining the quantity of unprocessed grain with grain contained in formula feed[1] used by the households. The bran (*BNPR*), oilseed meal (*OMPR*), and a grain price index (*GNPR*) were included in our regression equation as input prices, and homogeneity was imposed on the estimated price coefficients. The output variable (*Y*) is the quantity of livestock output. Specialized household poultry products were separated into eggs and meat; however, due to the integrated nature of traditional poultry production, backyard poultry output is the household's combined meat and egg production.

The shift variables included in the backyard pork and poultry regressions are the household's per capita grain production (*HHGN*) and dummy variables for the region (*REGION*). Per capita grain production was included in the regression to measure the impact of credit constraints and grain scarcity on feed grain consumption. Limited financial resources constrain household purchases of grain for feed from the market. Moreover, since much of the pork and poultry produced by traditional households is consumed in the household, purchases of grain to feed livestock on credit are infrequent. Thus, the grain produced by the household is often the

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[1] Formula feed was converted to unprocessed grain at a rate of 1.0 kg formula feed = 0.7 kg grain.

primary source of feed grain in traditional households. Regional dummy variables were added to gauge the impacts of differences in topography, geography, climate, and socio-cultural characteristics on feed demand. The feed grain supply and the availability of bulk and roughage feeds differ across regions in China, and it can be expected that feed grain demand will also vary accordingly. The specialized household regressions included only the regional shift variables. The general regression equation is summarized in equation (2)

$$\ln(GDEM) = a_0 + a_1 \ln(GNPR) + a_2 \ln(BNPR) + a_3 \ln(OMPR)$$
$$(2) \qquad + a_4 \ln(HHGN) + a_5 \ln(Y) + \sum_{i=1}^{6} b_i REGION_i$$

Table 3 displays the regression results. Backyard pork and poultry producers have a very inelastic response to changes in feed prices, generally less than 0.25 in absolute value. This result reflects the fact that households grow most of the grain they feed to their livestock. As household grain production per person increases, more grain is fed to livestock, particularly swine. As the level of output increases household producers typically purchase a larger percentage of the grain they feed to animals (Fang and Fuller 1998). Consequently, the demand response of specialized houesholds to changes in grain prices is roughly twice as large as for traditional households. The positive coefficient for the oilseed meal and bran prices indicates that Chinese households substitute oilseed meal and bran for feed grains in livestock and poultry rations as relative feed prices change. The regional dummy variables also indicate that there are significant regional variations in feed grain demands, with producers in Jilin and Shaanxi feeding more grain on average.

Both homogeneity of demand with respect to prices and linear homogeneity of demand in output were tested. The backyard pork equation rejected homogeneity in input prices, but the

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Table 1. Regression estimates of feed grain demand for Chinese pork and poultry production

Independent Variables	Backyard Pork	Backyard Poultry	SHH Pork	SHH Poultry Meat	SHH Egg
Intercept	**1.160**	**1.885**	**1.781**	**1.261**	**2.030**
	(5.7)	**(12.7)**	**(3.5)**	**(2.7)**	**(4.4)**
Livestock Output	**0.816**	**0.684**	**0.886**	**0.940**	**0.877**
	(31.0)	**(28.1)**	**(14.2)**	**(19.7)**	**(18.0)**
Per Capita Household Grain Production	**0.103**	**0.036**			
	(4.0)	**(2.3)**			
Grain Price Index	**-0.254**	**-0.128**	-0.661	*-0.502*	-0.322
	(-4.2)	**(-2.1)**	(-1.2)	*(-1.7)*	(-1.5)
Oilseed Meal Price	**0.191**	**0.211**	0.172	*0.441*	0.124
	(4.9)	**(4.6)**	(0.5)	*(1.9)*	(1.2)
Bran Price	0.063	*-0.082*	0.490	0.060	0.199
	(1.2)	*(-1.7)*	(0.8)	(0.2)	(1.3)
Jilin Dummy	0.093	**0.215**	0.446	*-0.535*	0.041
	(1.2)	**(2.2)**	(0.9)	*(-1.9)*	(0.2)
Jiangsu Dummy	**-0.274**	**-0.329**	*-0.738*	-0.113	-0.238
	(-4.1)	**(-3.6)**	*(-1.9)*	(-0.5)	(-1.7)
Shandong Dummy	-0.135	**-0.281**	0.027	**-0.529**	-0.263
	(-1.6)	**(-2.5)**	(0.7)	**(-2.0)**	(-1.2)
Hunan Dummy	-0.084	**-0.384**	0.281	-0.059	-0.095
	(-1.4)	**(-4.3)**	(0.6)	(-0.1)	(-0.7)
Sichuan Dummy	**-0.211**	**-0.236**	**-1.589**	-0.154	**-0.514**
	(-3.6)	**(-2.6)**	**(-2.9)**	(-0.6)	**(-2.3)**
Guangdong Dummy	**-0.830**	**-0.973**	-0.383	-0.072	**-0.822**
	(-9.1)	**(-8.2)**	(-0.8)	(-0.3)	**(-2.4)**
Price Homogeneity (F-Test)	**72.63**	0.34	0.23	0.67	0.18
Linear Homogeneity in Output (t-Test)	**-7.00**	**-12.99**	*-1.82*	-1.24	**-2.52**
No. of Observations	1896	2005	112	69	76
R^2	0.491	0.550	0.557	0.902	0.875

Note: t-statistics are in parentheses. Bold denotes significance at the 5 percent level and italics denotes significance at the 10 percent level

other equations could not reject the null hypothesis of homogeneity. All equations, except the specialized household poultry equations, rejected the hypothesis of linear homogeneity in output.

Simulations

The estimated parameters discussed above were imbedded in a Chinese agricultural sector model (CASM), which includes a comprehensive grain supply and demand framework. Crop production is computed as the product of per hectare yields and the number of hectares planted to each crop. Area is modeled in a two-stage framework. The first stage determines the available cultivated area as a function of real gross domestic product (GDP). Total sown area is computed as the product of cultivated area and a multi-cropping index, which is a function of GDP and the gross revenues of major crops. In the second stage an acreage allocation system developed by Barten and Vanloot (1996) and modified by Holt (1998) was estimated using historical data for major crops and employed to allocate sown area to major crops. The system constrains total acreage to feasible levels, and the theoretical properties of homogeneity, symmetry, and adding-up are imposed on the specification. Grain yields grow according to historical trends

Total grain demand is the sum of food, feed, seed, and stock demands. Food demand for each grain is determined on a per capita basis for urban and rural consumers using constant-elasticity demand equations, which are functions of per capita income, the product price, and the price of substitutes. Seed demand is a constant proportion of area planted, and stock demand was estimated from historic stock levels and market prices. Total feed grain demand for pork and poultry producers is determined by the equations described in the previous section. This quantity of feed grain is added to demands from beef, dairy, and aquaculture production, which are calculated using per unit feed inputs derived from the RCRE survey data and from Fuller and

Rude (1997). This total feed grain demand is allocated to specific grain types based on relative prices. Chinese grain prices are linked to international prices through a price linkage equation, and meat production levels were taken from the Food and Agricultural Policy Research Institute's (FAPRI) international livestock model. Net trade identities are close the model.

In order to obtain international price response to changes in the structure of Chinese livestock and poultry production, the CASM was linked to the international grain and U.S. grain model components of the FAPRI modeling system. Three scenarios were conducted to simulated the impact of structural change in China's livestock industry on feed demand assuming livestock output remains at baseline levels. The results of these three scenarios are compared to the 1999 FAPRI baseline (FAPRI 1999) to demonstrate the impacts of structural change on feed demand and trade.

The FAPRI baseline assumes backyard pork production accounts for 76 percent of Chinese pork output in 1999. Backyard producers lose production share at a rate of 2 percentage points per year until 2007. From 2007 onward, the backyard share is held constant at 60 percent. In scenario1 we assume the share of total output produced on backyard operations declines more slowly than the FAPRI baseline, falling 1 percent annually from 1999 to 2008. In 2008, backyard production accounts for 68.9 percent of total Chinese pork output.

Scenario 2 focuses on the poultry sector, decreasing the share of backyard production 2.5 percent annually. The baseline assumes that backyard poultry production declines from 57 percent of total meat and egg output in 1999 to 50 percent in 2003. From 2003 onward the backyard share remains constant at 50 percent for the rest of the projection period. Given the constant 2.5 percent annual rate of decline assumed in scenario 2, the backyard share of poultry output falls to 44.25 percent in 2008. Scenario 3 is simply the combination of scenarios 1 and 2.

Table 2. Change in Chinese Feed Grain Demand by Sector

	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08
	Million Metric Tons								
Backyard Pork									
Baseline	55.06	55.77	56.96	58.36	59.76	61.04	62.14	63.04	65.95
Scenario 1	1.4%	2.8%	4.3%	6.0%	7.7%	9.5%	11.5%	13.6%	12.6%
Scenario 2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Scenario 3	1.4%	2.8%	4.3%	6.0%	7.7%	9.5%	11.4%	13.5%	12.6%
SHH Pork									
Baseline	15.48	15.48	15.48	15.48	15.48	15.49	15.49	15.49	15.49
Scenario 1	-4.7%	-9.3%	-14.1%	-19.2%	-24.4%	-29.9%	-35.5%	-41.4%	-42.7%
Scenario 2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%
Scenario 3	-4.7%	-9.2%	-14.1%	-19.2%	-24.4%	-29.9%	-35.5%	-41.5%	-42.8%
Backyard Poultry									
Baseline	14.62	14.58	14.72	15.28	16.15	17.04	17.96	18.90	19.85
Scenario 1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Scenario 2	0.5%	1.0%	1.6%	1.4%	0.2%	-1.0%	-2.2%	-3.4%	-4.6%
Scenario 3	0.5%	1.0%	1.6%	1.4%	0.2%	-1.0%	-2.2%	-3.4%	-4.5%
SHH Poultry									
Baseline	14.86	16.00	17.43	18.75	19.75	20.76	21.78	22.84	23.89
Scenario 1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%
Scenario 2	-0.8%	-1.6%	-2.3%	-1.9%	-0.4%	1.2%	2.9%	4.5%	6.1%
Scenario 3	-0.8%	-1.6%	-2.3%	-2.0%	-0.4%	1.2%	2.8%	4.4%	6.1%
Total									
Baseline	100.02	101.84	104.60	107.87	111.15	114.33	117.37	120.27	125.19
Scenario 1	0.0%	0.1%	0.3%	0.5%	0.7%	1.0%	1.4%	1.8%	1.3%
Scenario 2	0.0%	-0.1%	-0.2%	-0.1%	0.0%	0.1%	0.2%	0.3%	0.4%
Scenario 3	0.0%	0.0%	0.1%	0.3%	0.7%	1.1%	1.6%	2.1%	1.8%

Table 2 provides the impact of scenarios on Chinese feed grain demand, and Table 3 displays the results for U.S. and Chinese grain trade. Slowing the rate of structural change in pork sector results in an increase in the demand for feed grain by backyard pork producers and a decrease in specialized household demand. The net change is a 1.68 million metric ton (mmt) increase in feed grain demand in 2007/08, reflecting the relative inefficiency of traditional producers. More than 75 percent of the additional feed demand is satisfied by grain pulled from international markets. U.S. corn exports rise 800 thousand metric tons (tmt) in 2007/08, causing a $0.76 per metric ton increase in the U.S. corn export price.

The change in feed demand in the second scenario reflects the fact that specialized household poultry producers tend to feed more feed grain per kilogram of output than traditional producers. Initially feed grain demand in China falls slightly because the growth of specialized household production is somewhat slower than in the baseline. From 2004/05 onward, feed grain demand exceeds the baseline by up to 540 tmt, as the share of production by specialized households rises above the baseline level. Consequently, Chinese corn imports in 2007/08 are 8.8 percent and wheat imports 1.2 percent above the baseline. U.S. corn exports rise up to 0.5 percent, and the U.S. corn export price increases $0.25 per metric ton.

Results for the third scenario are, essentially, the sum of the changes from the first and second scenarios. The pork sector results dominate the changes on total feed grain demand, outweighing the decrease in feed consumption in the poultry sector during the first five years of the simulation. In the last year of the simulation period, Chinese corn imports are 1.4 mmt and wheat imports are 152 tmt above the baseline level. Greater quantities of rice fed to swine reduce Chinese rice imports up to 16 percent. Impacts on world grain prices are marginal. The U.S. export price for corn rises a maximum of 1.05 percent ($1.18 per metric ton).

Table 3. The Impact of Structural Change on Chinese and U.S. Grain Trade

	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08
Chinese Net Exports				Thousand Metric Tons					
Rice									
Baseline	583.1	955.6	1240.0	1186.2	1107.1	1120.2	1030.6	912.3	821.8
Scenario 1	582.1	949.5	1225.8	1161.2	1066.6	1060.4	947.9	798.2	713.9
Scenario 2	585.0	960.4	1248.3	1194.9	1111.9	1119.6	1023.8	897.4	798.3
Scenario 3	584.1	954.3	1234.0	1169.8	1071.2	1059.6	940.8	782.8	689.6
Wheat									
Baseline	-981.8	-1553.7	-2169.7	-2814.5	-2568.5	-2280.7	-1878.1	-1707.4	-1634.5
Scenario 1	-981.6	-1552.7	-2170.6	-2824.1	-2586.5	-2313.0	-1928.2	-1804.2	-1768.6
Scenario 2	-982.4	-1554.3	-2166.9	-2807.9	-2556.3	-2272.0	-1877.1	-1716.9	-1654.3
Scenario 3	-982.1	-1553.3	-2167.7	-2817.3	-2574.2	-2304.0	-1926.9	-1813.3	-1787.0
Corn									
Baseline	3746.7	3419.9	2104.0	914.4	152.4	-905.2	-1975.9	-3105.7	-4006.3
Scenario 1	3731.8	3333.2	1918.7	591.5	-364.2	-1663.7	-3018.4	-4459.4	-5063.2
Scenario 2	3774.1	3481.9	2205.0	1008.6	173.8	-966.3	-2123.8	-3350.3	-4357.5
Scenario 3	3759.2	3395.2	2019.8	686.0	-342.7	-1724.9	-3166.7	-4704.4	-5416.8
U.S. Net Exports				Million Metric Tons					
Rice									
Baseline	2.88	2.80	2.74	2.69	2.64	2.60	2.54	2.49	2.43
Scenario 1	2.88	2.80	2.74	2.69	2.64	2.60	2.54	2.48	2.41
Scenario 2	2.88	2.80	2.74	2.69	2.64	2.60	2.54	2.49	2.43
Scenario 3	2.88	2.80	2.74	2.69	2.64	2.60	2.54	2.48	2.41
Wheat									
Baseline	25.90	27.03	28.26	28.68	29.01	29.56	30.25	30.08	29.83
Scenario 1	25.90	27.03	28.26	28.68	29.01	29.56	30.25	30.04	29.80
Scenario 2	25.90	27.03	28.26	28.68	29.01	29.56	30.25	30.07	29.82
Scenario 3	25.90	27.03	28.26	28.68	29.01	29.56	30.25	30.03	29.79
Corn									
Baseline	44.04	45.18	47.27	48.85	50.02	51.41	53.47	55.60	57.64
Scenario 1	44.05	45.25	47.42	49.10	50.42	52.00	54.28	56.67	58.43
Scenario 2	44.01	45.13	47.19	48.78	50.02	51.47	53.60	55.80	57.92
Scenario 3	44.03	45.20	47.34	49.03	50.42	52.06	54.40	56.87	58.72

Conclusions

This study provides estimates of the price responsiveness of feed demand by traditional and specialized household producers of pork and poultry in China and simulates the impact of changes in the structure of Chinese livestock production on world feed grain trade. The feed demand estimation reveals that backyard producers have very inelastic demands for feed grains. The per-capita quantity of grain the household produces and regional differences are significant determinants of feed grain use by traditional producers. Feed grain demand by specialized household producers is roughly twice as responsive to feed prices changes as demands by traditional households. The larger response to prices reflects that greater dependence of specialized household producers on markets for their feed inputs. In addition, regional factors have less impact on specialized household feed demand, possibly indicating a greater uniformity in feeding practices and production techniques.

Using a CASM in combination with the FAPRI modeling system, three alternative assumptions regarding the rate of structural change in China's pork and poultry industries were simulated. The nonlinear nature of FAPRI's baseline assumptions complicate comparisons; nevertheless, the simulations indicate that feed grain demand in China, while affected, is not terribly sensitive to varying rates of structural change in pork and poultry production. Slowing the rate of modernization of the pork sector increases China's demand for feed grain, as does increasing the rate of modernization in the poultry sector. Modest deviations of 1 to 3 percent from the baseline rates increased Chinese grain imports by less than 2 mmt. U.S. corn exports increased less than 2 percent, and corn prices at Gulf ports rose just over 1 percent. These results suggest that the modernization of China's livestock sector will not place unmanageable strains on the international grain market, nor will it greatly increase China's dependence on imported grain.

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