



International Food and Agribusiness Management Review
Volume 15, Issue 3, 2012

China's Meat and Egg Production and Soybean Meal Demand for Feed: An Elasticity Analysis and Long-Term Projections

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Abstract

China is a large meat and egg producer and correspondingly a large soybean meal consumer. Dual forces affect the derived demand for soybeans; rising livestock production to meet consumer demand for protein and the shift to commercial feed by the livestock industry. We employ a unique elasticity approach to estimate these dual forces on soybean meal demand over the next 20 years. We then discuss the implications of these forecasts with respect to the modernization of China's feed industry, land use changes in South America, and the need for yield research to reduce pressure on increasingly scarce land resources.

Keywords: meat production; soybean meal; feed demand; elasticity; forecasting; land use

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Introduction

Background

The “livestock revolution” (Delgado et al. 1999) is causing dramatic growth of feed demand. FAO (2006) though projects moderate annual growth rates of world cereals feed demand at 1.6% in 1999/01-2030 and 0.8% in 2030-50 (FAO, 2006). Others argue that world cereal feed demand will be significantly higher in the coming 30 years than was originally projected by international organizations (Keyzer et al. 2005).

One key component of the derived demand for feed grains and oilseeds is soybean meal, derived directly from soybeans. Soybeans are the fastest growing broad acre crop in the world in terms of hectares under cultivation. The growth is fueled directly by rising livestock demand for soy-based protein in their diet, and indirectly by income-based shifts to greater meat consumption around the world. The expansion of soybean hectares is a nontrivial event as most of the expansion involves land use changes in developing regions of the world, such as South America. The motivation for our research is twofold: first, to provide the industry and policy makers with valid estimates of long term soybean meal demand; and second, to draw attention to the important linkages between income growth, meat consumption, livestock industry and demand for feed crops, land use, and the need for yield-improving agricultural research.

China’s¹ Meat² and Egg Production: Historical View (1961-2010)

In 2010, world meat and egg production respectively reached 280 million metric tons and 66 million metric tons, with compound annual growth rates (1961-2010) of 2.9% and 3.1%, respectively (Figure 1). Meat and egg production quadrupled over the last 50 years of the 20th century. Resulting grain demand and the pressure on land resources will be high if the demand elasticities, the subject of this research, for feed grains and oilseeds are high. FAO estimates may in fact be low as was suggested by Keyzer et al. (2001, 2005). Pressure will be acute on output increasing crop strategies such as expanding crop hectares, increasing yield, double cropping, and reducing harvest and post-harvest loss.

Chinese producers play a major role in this steady meat and egg production quantity increase during the study period, especially after transitioning to a market economy beginning in the late 1970s (Ortega et al. 2009). The transition involves a number of components supportive of the expansion of the livestock sector, and as result lays the ground work for the expanded use of soybean meal. Most notably the ability to freely migrate from low paying rural occupations to higher paying urban opportunities gives rise to an urban middle class that is wealthier and consumes more protein. The transition to a market economy also allows greater flows of capital. As a result both domestic and international firms dramatically increased their investment in the food and agribusiness sector to meet the growing demand. Much of this investment was originally led by international food and retail firms that require high quality, uniform, and large supply volumes of animal products. There is a natural fit between modern livestock systems, their sole use of commercial feeds utilizing soybean meal, and emergence of the larger retailers and food companies (Xing 2009).

¹ Mainland China + Hong Kong + Macau

² In this study meat consists of pork, poultry meat, bovine meat, goat & mutton meat, and other meat. The data source is FAOSTAT.

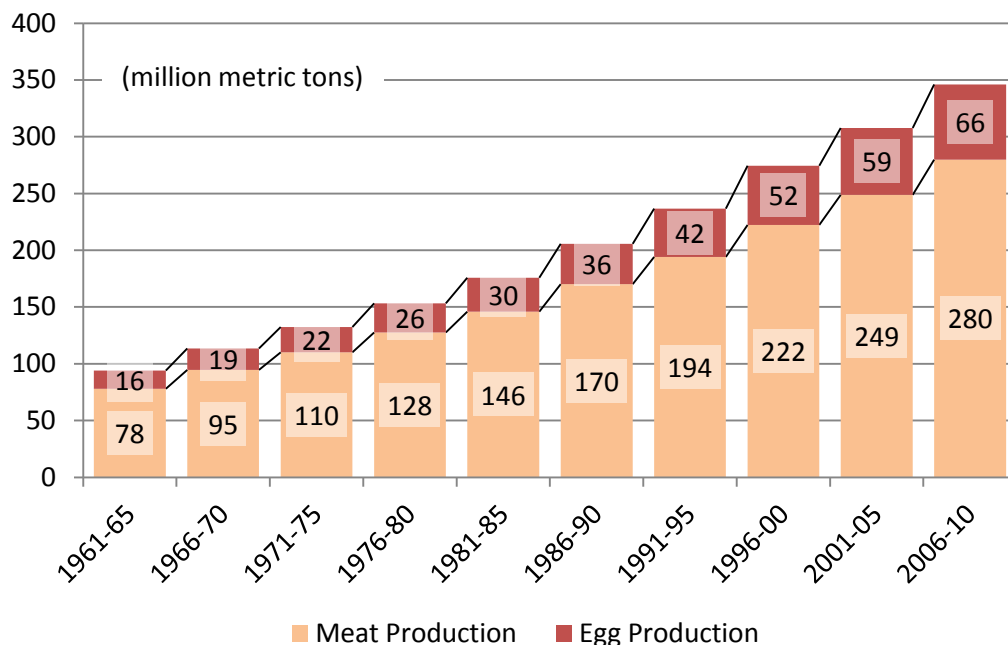


Figure 1. World Meat and Egg Production Quantity: 1961-2010
Source. FAOSTAT and Authors' Calculation.

China's Meat Production Composition and its Characteristics

Annually during the 2006-10 period, the world produced 104 million metric tons of pork (37% of the total meat production), 91 million metric tons of poultry (33%), and 65 million metric tons of beef & buffalo (23%). Pork (64%) and poultry (21%) comprise most of China's meat production. China produces 46% (48 million metric tons) of the world's pork and 17% (16 million metric tons) of the world's poultry. Since the 1980s, pork's share of all the meat produced in China has gradually declined from 83% during the 1981-85 period to 64% in 2006-10. Pork is still the preferred meat in China though the shares of poultry and beef have increased. The country's egg production has grown dramatically since the mid-1980s, increasing annually 6.7% between 1985 and 2010.

China's Feed Market

Low fiber high quality protein feeds are preferred for pork, poultry and egg production. Monogastric animals, such as pigs and chickens do not digest well most dietary fibers. Soybean meal is the world's predominant plant protein source, and is remarkable for its high quality nutrient makeup (Waldroup 2010). As a result soybean meal is the number-one protein source used in poultry and pork production throughout the world (Stein et al. 2008). Soybean meal, because of its relatively low fiber content and superior mix of amino acids, uniquely complements the other major feed ingredients such as cereals and starchy roots that are high in energy but low in protein. A high level of inclusion (30-40 percent) is used in high performance monogastric diets (FAO, 2002). The rapid rise of pork, poultry, and egg production in China has creates a derived demand for soybean meal and soybeans.

It is worth noting that soybeans are a protein crop that requires processing before feeding to livestock. The crushing process uses heat, pressure and chemical extraction to turn soybeans into two high quality, stable, and readily transportable products: 1) soybean meal- 78% of the soybean; and 2) soybean oil- 18% of the soybean.

China’s soybean meal demand for feed averaged 29.2 million metric tons over the 2006-07 period (Table 1). It was ranked as the 3rd largest plant-based feed source and comprised 10.9% of total feed fed. China’s domestic demand of soybean meal for feed in 2006-07 was 18 times larger than as it was in 1961-65 (1.6 million metric tons). The research presented in this paper focuses on this tight relationship between China’s meat & egg production and the soybean meal demand for feed.

Table 1. China’s Feed Composition (2006-07 year average)

Feed Ingredients*	mil. metric tons	share
Maize	99.0	37.0%
Sweet Potatoes	35.6	13.3%
Soybean Meal	29.2	10.9%
Vegetables, Other	27.1	10.1%
Cassava	15.4	5.7%
Rice (Milled Equivalent)	10.1	3.8%
Brans	9.4	3.5%
Potatoes	6.5	2.4%
Wheat	6.2	2.3%
Rape and Mustard Cake	6.1	2.3%
Other ingredients	23.2	8.7%
Total	267.7	100.0%

Notes.*Include cereals, starchy roots, sugar crops, pulses, oilcrops, and vegetables. Regarding oilcrops, beans/seeds, cake (meal), and vegetable oils are distinguished as different ingredients in this table. Animal-originated ingredients (livestock and aquatic products) are not included.

Source. FAOSTAT and authors’ calculation.

World Soybean Supply-Demand Balances and China’s Soybean Meal Demand

The world annually produced 28.6 million metric tons of soybeans in 1961-65, and reached an annual average of 231.5 million metric tons over the 2006-10 period. World annual production of soybeans is predicted to increase by 2.1% to 359.7 million tons by 2030 (Masuda and Goldsmith 2009).

The world annually fed 150.2 million metric tons of soybean meal on average over the 2006-07 period (Table 2). The largest users of soybean meal are the United States (32.5 million metric tons, 21.6% of the world total), China (29.2 million metric tons, 19.5%), Brazil (10.6 million metric tons, 7.1%), Spain (5.5 million metric tons, 3.7%), and France (4.3 million metric tons, 2.9%). These five soybean meal consuming countries account for more than half (55%) of world soybean meal demand.

Table 2. World Soybean Supply-Demand Balances (2006-07 year average)

Element	Soybeans		Soybean oil		Soybean meal	
	mil. tons	ratio	mil. tons	ratio	mil. tons	ratio
Domestic Production	219.0	99%	35.9	105%	152.6	100%
International Trade	71.3	32%	12.0	35%	59.6	39%
Stock Variation	3.0	1%	-0.6	-2%	0.2	0%
Domestic Supply	220.7	100%	34.3	100%	152.5	100%
Feed	8.7	4%	0.3	1%	150.2	99%
Seed	6.6	3%	-	-	-	-
Waste	3.5	2%	0.9	3%	-	-
Processing	191.3	87%	0.0	0%	-	-
Food	10.2	5%	24.1	70%	-	-
Other Utility	0.4	0%	9.0	26%	2.3	1%

Notes. 1. Each ratio of domestic supply quantity (Soybeans, Soybean oil, and Soybean meal) is set to 100%.
 2. 35.9 million metric tons of soybean oil and 152.6 million metric tons of soybean meal were processed from 191.3 million metric tons of soybeans in the world. 3. Average of world total exports and imports.

Source. FAOSTAT and authors' calculation.

China has steadily increased its share in the world of soybean meal utilization since the second half of the 1980s, (Goldsmith et al. 2004). China domestically produces 29.4 million metric tons of soybean meal and is able to meet its demand with domestic supplies (Table 3). However, out of 45.5 million metric tons of soybeans demanded, more than two-third (69%, 31.5 million metric tons) are imports. China's domestic production of soybeans (14.1 million metric tons) accounts for less than one-third (31%) of the total domestic supply quantity of soybeans.

Table 3. China's Soybean Supply-Demand Balances (2006-07 year average)

Element	Soybeans		Soybean oil		Soybean meal	
	mil. tons	ratio	mil. tons	ratio	mil. tons	ratio
Domestic Production	14.1	31%	6.4	75%	29.4	101%
Net Import (IM-EX)	31.5	69%	2.2	25%	-0.2	-1%
Stock Variation	0.0	0%	0.0	0%	0.0	0%
Domestic Supply	45.5	100%	8.6	100%	29.2	100%
Feed	2.5	5%	0.0	0%	29.2	100%
Seed	1.2	3%	-	-	-	-
Waste	0.6	1%	-	-	-	-
Processing	35.9	79%	-	-	-	-
Food	5.4	12%	4.1	48%	-	-
Other Utility	0.0	0%	4.5	52%	-	-

Notes. 1. Each ratio of domestic supply quantity (Soybeans, Soybean oil, and Soybean meal) is set to 100%.
 2. 6.4 million metric tons of soybean oil and 29.4 million metric tons of soybean meal were processed from 35.9 million metric tons of soybeans in China..

Source. FAOSTAT and authors' calculation.

Objectives

In this research we examine the close relationship between meat/egg production and soybean meal demand for use as feed in China. Specifically we have three objectives in this paper: 1) to estimate the long-term elasticity of soybean meal demand for feed with respect to egg and meat production in China; 2) to forecast the long-range meat and egg production quantities and soybean meal demand through 2030 in China; and 3) to discuss the implications of animal production growth in China on international soybean markets, land use, and yield-improving agricultural research.

Methodology

Estimates and projections of supply/demand for feed grains in China commonly utilize the implied demand approach where multiplying feed-meat conversion ratios by animal numbers yields feed grain demand quantities (Zhou et al. 2008). The feed-meat conversion ratios vary due to animal variety, feed composition, use of additives, animal raising practices, and animal accommodation (Zhou et al. 2003; Xin et al. 2005). Researchers apply a wide range of ratios (see Zhou et al. 2008) and there is no agreement for estimating current and future feed grain demand. We diverge in this paper with an alternative approach that estimates an elasticity of soybean meal demand for feed with respect to meat and egg production quantity.

First we use an error-correction model to estimate the cointegrating equation between domestic meat and egg production and soybean meal demand in China. The parameter in the cointegrating equation represents the long-term elasticity of soybean meal feed demand due to changes in the livestock production. The error correction mechanism (ECM), following Hendry et al. (1984) and Mills (1990, pp.273-276), is expressed as:

$$(1) \Delta \ln(\text{soym}_t) = \phi \Delta \ln(\text{mteggprod}_t) - \gamma (\ln(\text{soym}_{t-1}) - \alpha - \beta \ln(\text{mteggprod}_{t-1})) + \delta + \varepsilon_t$$

Where:

$\ln(\text{soym}_t)$ = natural logarithm of China's soybean meal demand quantity for feed in year t,

$\ln(\text{mteggprod}_t)$ = natural logarithm of China's meat and egg production quantity in year t,

ε_t = error term, and

α , β , γ , δ , and ϕ are parameters.

$$(2) \ln(\text{soym}_{t-1}) = \alpha + \beta \ln(\text{mteggprod}_{t-1})$$

is the cointegrating equation and β is the long-term elasticity.

There are several methods for estimating the specific cointegration parameters. Gonzalo (1994) shows that Johansen's (1988) maximum likelihood approach clearly has better properties than the other estimators such as; ordinary least squares by Engle and Granger (1987), nonlinear least squares by Stock (1987), principal components by Stock and Watson (1988), and canonical correlations by Bossaerts (1988). Adopting Johansen's (1988) approach, we use a vector error-correction model (VECM) including the time series of soybean meal demand and meat and egg

production quantity in China. Following Johansen (1995), the trend parameter is either set to zero or unrestricted. The same is done for the constant terms, α and δ .

With the estimated long-term elasticity $\hat{\beta}$, the next year's soybean meal demand for feed is projected using a recursive form as follows:

$$(3) \ln(\text{soym}_{t+1}) = \hat{\beta} \ln(\text{mteggprod}_{t+1}) + \hat{\alpha}$$

$$(4) \ln(\text{soym}_t) = \hat{\beta} \ln(\text{mteggprod}_t) + \hat{\alpha}$$

Subtracting equation (4) from (3) results in:

$$(5) \ln(\text{soym}_{t+1}) = \ln(\text{soym}_t) + \hat{\beta} \Delta \ln(\text{mteggprod}_{t+1}).$$

Taking the exponential of both sides provides the forecast equation:

$$(6) \text{soym}_{t+1} = \text{soym}_t * e^{\hat{\beta} \Delta \ln(\text{mteggprod}_{t+1})}.$$

where mteggprod_{t+1} is estimated beforehand.

Exponential Smoothing with a Damped Trend

We employ exponential smoothing with a damped trend³ to estimate meat and egg production quantities using a Box-Jenkins or ARIMA type univariate time series model. Introducing a damped trend into an exponential smoothing model makes sense to allow for decreasing rates of growth (a plateau) over time. Following Gardner and McKenzie (1985) and Gardner (1985), the general damped-trend linear exponential smoothing model is as follows:

$$(7) P_t = \mu_t + \beta_t t + \epsilon_t$$

where P_t is China's meat and egg production quantities at time t , μ_t is the mean level of production at time t , β_t is parameter at t , t is the time trend or year, and ϵ_t is error term at t .

The smoothing equations are:

$$(8) \text{Level: } L_t = \alpha P_t + (1 - \alpha)(L_{t-1} + \phi T_{t-1}), \text{ and}$$

$$(9) \text{Trend: } T_t = \gamma(L_t - L_{t-1}) + (1 - \gamma)\phi T_{t-1}$$

where L_t = smoothed level at t of the series, computed after P_t is observed,

α = smoothing parameter for the level of the series,

ϕ = trend modification or damping parameter,

T_t = smoothed trend at the end of period t , and

γ = smoothing parameter for trend.

The error-correction form of the smoothing equations is:

³ Refer to Gardner and McKenzie 1985; Hyndman et al. 2008; Masuda and Goldsmith 2009.

$$(10) L_t = L_{t-1} + \phi T_{t-1} + \alpha e_t, \text{ and}$$

$$(11) T_t = \phi T_{t-1} + \alpha \gamma e_t$$

where $e_t = P_t - \hat{P}_t(1)$ is a one-period-ahead forecast error.

The forecast for k period(s) ahead from origin t is:

$$(12) \hat{P}_t(k) = L_t + \sum_{i=1}^k \phi^i T_t.$$

If $0 < \phi < 1$, the trend is damped and the forecasts approach an asymptote given by the horizontal linear line or plateau: $L_t + T_t \phi(1 - \phi)$. The equivalent process is ARIMA (1, 1, 2)⁴ which can be written as:

$$(13) (1 - \phi B)(1 - B)P_t = (1 - \theta_1 B - \theta_2 B^2)\epsilon_t,$$

where $\theta_1 = 1 + \phi - \alpha - \alpha \gamma \phi$, and $\theta_2 = (\alpha - 1)\phi$.

If $\phi = 1$, the model is equivalent to the standard version of Holt's model⁵ and the trend is linear. The equivalent process is ARIMA (0, 2, 2):

$$(14) (1 - B)^2 P_t = (1 - \theta_3 B - \theta_4 B^2)\epsilon_t$$

where $\theta_3 = 2 - \alpha - \alpha \gamma$, and $\theta_4 = \alpha - 1$.

For damped trend estimation the default is set at $\phi = 0.98$. The level and trend parameters are grid-searched to minimize the mean square error (MSE). Estimations are conducted using Stata 12.

Data

There are two distinct challenges for scholars conducting research on China's livestock and feed supply and demand. First are problems associated with Chinese estimates of their own agricultural output and food and feed utilization. Numerous scholars have wrestled with China's data quality problem. Second, there is a lack of a comprehensive dataset that uses a common methodology and covers all years and all necessary livestock, meat, grain, oilseed, meal, and oil commodities.

Many researchers discuss the accuracy and reliability of China's statistics. They point out that livestock production data are overstated, especially through 2000 (Fuller et al. 2000; Ma et al., 2004; Wang et al., 2005). Under some assumptions, Fuller et al. (2000) construct a more accurate adjusted dataset (1985-96) for livestock production than the State Statistics Bureau (SSB) reported in the China Statistical Yearbook. Ma et al. (2004) use the 1997 Ag Census and other sources to create a revised China National Statistical Bureau (CNSB) livestock demand and supply series (1980-99). Zhou et al. (2003) report that the Chinese government adjusted downward the 1995-97 official meat output figures on several different occasions. Such actions

⁴ In the general ARIMA (1, 1, 2), $-1 < \phi < 1$.

⁵ Refer to Holt 1957; Holt 2004; Holt et al. 1960. Holt (2004) is a reprinted version of Holt (1957).

confirm researchers' suspicions that some data are overstated. Wang et al. (2005) derive a supply-demand balance sheet for 2000 using official animal production data but had to adjust the consumption side of the equation. They use the net export data from the United States Department of Agriculture (USDA), carcass-retail weight loss parameters from Putnam and Allshouse (1996), and away-from-home and processed-products consumption proportions from Wang et al. (2004).

The poor quality of data forces researchers to employ creative means to develop a valid dataset. Yet even today, there does not exist a valid domestic set of data across time and across commodities sufficient to allow for the estimation of derived demand for soybean meal. Therefore we need to rely on the international FAOSTAT dataset. The comprehensiveness of the FAOSTAT data we use is important for time series forecasting because the data cover 1961-2007 for soybean meal demand and 1961-2010 for meat and egg production quantities. While clearly not optimal, FAOSTAT data are comprehensive across time and commodities. The critical requirement then for this research is to validate these data in order to ensure that the data are reliable for a forecast model.

FAOSTAT data deal with net stock variation and domestic allocation as either food or feed by explicit usage. FAOSTAT data for the 1999-2001 period though show significant differences with government meat and egg consumption and production data from the State Statistics Bureau of China (SSB). We employ Wang et al. (2005) and Putnam and Allshouse (1996) adjustment methods on the SSB data. The FAOSTA data are valid as the adjusted SSB are now comparable. (See Table 4 in Appendix).

Results

Elasticity of Soybean Meal Demand

Our first objective is to estimate the long-term elasticity of soybean meal demand for feed with respect to egg and meat production in China. The estimation result of equation (2) indicates strong support for a cointegrating equation such that

$$(15) \ln(\text{soym}_t) = 0.909 * \ln(\text{mtegprodt}_t) + 0.888$$

should be a stationary series (see Table 5). The coefficient 0.909 represents the long-term elasticity of soybean meal demand for feed with respect to the domestic meat and egg production in the livestock industry. The result suggests that China's soybean meal demand increases by 0.909% as the domestic meat and egg production quantity increases by 1.000%.

This makes sense as the usage of commercial feeds (soybean meal) is growing rapidly at the same time the livestock sector is expanding rapidly (Xing and Goldsmith 2012). China has a long standing tradition as one of the world's leading fish and livestock producers in the world. Historically fish and livestock producers utilized informal feed sources such as domestic household waste. Commercial feed usage was small. Increasing fish, meat, egg, and dairy demand triggered new investment in the livestock sector and the construction of larger scale commercial farms, in recent years. These new facilities utilize commercially produced feeds, which almost universally use soybean meal as the main source for protein. So the adoption rates

of soybean meal result from both the rise in livestock production, but are also accelerated by the switch to commercial feeds (Xing and Goldsmith 2012). Therefore over the medium term it is expected that the rate of growth of soybean demand may even outpace the rate of growth of China's livestock production. This acceleration effect should moderate over time as the industry achieves high commercial feed adoption levels.

Table 5. Estimation Result: Elasticity of Soybean Meal Demand for Feed in China

	Coef.	Std. Err.
ln(soymeal demand)	1.000	(fixed)
ln(meat&egg production)	0.909 ***	0.330
const.	0.888	5.635
Log Likelihood	85.386	
# of observation	41 (1963-2003, # of lags = 2)	

Note. *** Denotes significant at 1%.

Meat and Egg Production Forecast Results

China's meat and egg production quantities were 80.8 and 28.0 million metric tons respectively, and total 108.8 million metric tons in 2010 (Table 6). The summed production quantity grew annually at 2.6% during the 1999-2010 period.

Table 6. China's Domestic Meat and Egg Production Quantity: Projection Summary

	Production Quantity (mil. metric tons)				Compound Annual Growth Rate		
	1999/01	2010	2020	2030	1999/01-10	2010-20	2020-30
Meat & Egg Total	83.9	108.8	127.1	141.9	2.6%	1.6%	1.1%
Meat Total	61.7	80.8	92.9	102.8	2.7%	1.4%	1.0%
Pig Meat	40.8	51.7	56.1	59.6	2.4%	0.8%	0.6%
Poultry Meat	12.3	17.0	22.1	26.2	3.3%	2.7%	1.7%
Beef & Buffalo Meat	5.1	6.5	7.8	8.8	2.5%	1.7%	1.2%
Sheep & Goat Meat	2.6	3.9	4.9	5.6	4.1%	2.1%	1.4%
Other Meat	0.9	1.6	2.1	2.6	6.1%	3.0%	1.9%
Eggs	22.1	28.0	34.2	39.1	2.4%	2.0%	1.4%

Note. 1. The forecast period is 2011-2030. 2. Other meat includes all other consumed animal proteins. Does not include fish.

Source. FAOSTAT and authors' estimation.

Following equations (10) and (11), China's meat and egg production quantities were estimated⁶ as univariate time series and projected through 2030. Over the near future (2010-20) we forecast a decline to a level of 0.8% annual growth in pork production while other meat production quantities' growth rates keep steady: poultry 2.7%, beef and buffalo 1.7%, and lamb, mutton and goat 2.1%. This change by consumers away from just pork to greater protein variety reflects a maturation of preferences as incomes rise over time. Total meat production quantity grows annually at 1.4% and reaches 92.9 million metric tons in 2020. During the same period (2010-20), egg production quantity grows annually at 2.0% and reaches 34.2 million metric tons in 2020.

⁶ See Appendix 2, Table 8 for details.

Over the distant future (2020-30), we forecast continued moderate increases in both meat and egg production. Pork production's annual growth remains at 0.6% and other meat production quantities' growth rates keep above 1.0 percent: poultry meat 1.7%, beef and buffalo meat 1.2%, and sheep and goat meat 1.4%. Pork's share of total meat production continues above 50%. Total meat production quantity grows at an annual rate in the period of 1.0%, and reaches 102 million metric tons in 2030.

During the same period (2020-30), annual egg production quantity also continues to increase at 1.4% and reaches 39 million metric tons in 2030. The summed (meat + egg) production quantity is estimated to increase continuously with gradually declining annual growth rates to 1.6% in 2010-20, and 1.1% in 2020-30. The total production quantity reaches 127 million metric tons in 2020 and 141 million metric tons in 2030.

Soybean Meal Utilization Forecast Results

China's annual growth rate for soybean meal demand is projected at 2.9% over the 2000-2030 period. Soybean meal annually grew at 5.7% between 2000 and 2010. We forecast a slowing to 1.7% in 2010-20 and 1.3% in 2020-30 (Table 7). Note the dramatic decrease of 70% going forward in the annual growth rate in the demand for soybean meal. Meat production during the same period increases only at an annual rate of 2.6% (Table 6). Also remember the tight long run relationship between meat production and soybean meal demand in the form of a high estimated livestock demand elasticity of 0.91. While certainly not definitive, there appears to be some evidence that the switch to commercial feed played a significant role in soybean meal demand in the recent past. Soybean meal demand's growth rate outpaces meat and egg production's growth rate because of the industrial feed phenomenon currently underway in China (Xing and Goldsmith 2012). As China's livestock industry matures soybean meal will be driven increasingly more by livestock production growth and the derived demand for meat, rather than the shift to commercial feeds, as is common in developed countries.

Table 7. China's Domestic Soybean Meal Demand for Soybean Meal: Projection Summary

	Million Metric Tons				Compound Annual Growth Rate		
	1999/01	2010	2020	2030	1999/01-10	2010-20	2020-30
Soy Meal Domestic Feed Demand	14.4	25.1	29.7	33.7	5.7%	1.7%	1.3%
Soybean Equivalent	17.6	30.7	36.4	41.2	-	-	-
				+24 MMT			
Land Required							
	@ 2.3 t/ha			10 Mil. Ha			
	@ 3.0 t/ha			8 Mil. Ha			
	@ 4.0 t/ha			6 Mil. Ha			

Notes. 1. (Soybean meal Domestic Feed Demand)/0.817. For Soybean meal/Soybean Ratio: $0.817 = 19.6/24.0$, see Table 3. 2. Direct soybean demand for feed is not included.

Source. FAOSTAT and authors' estimation.

The domestic soybean meal supply/demand quantity was 14.4 million metric tons in 2000 and estimated at 25.1 million metric tons in 2010 (Table 7). The soybean meal demand for feed in China is forecasted to reach 29.7 million metric tons in 2020 and 33.7 million metric tons in 2030.

The projected quantity in 2030 is more than 30% greater than that in 2010 and it is equivalent to 41.2 million metric tons of soybeans. In other words, more than 41 million metric tons of soybeans will be needed from either domestic production or imports to meet China's domestic soybean meal feed demand in 2030. Those soybeans would require an additional 4.6 million hectares of land, assuming current world average yield.

Results Summary and Implications for Food and Agribusiness Managers and Firms

Results Summary

Our estimate of China's livestock demand elasticity for soybean meal at .91 results in an overall estimate of an increase in Chinese soybean meal utilization of 34 million metric tons in 2030, a 30% increase. The drivers of this demand too are undergoing change as well. The demand increase for soybean meal will increasingly be due to the shift to meat in Chinese diets and less from the increasing use of commercial feeds. This shifts parallels developed countries where soybean meal demand results from the twin forces of domestic and export meat demand.

China's additional soybean meal demand of 19 million metric tons in 2030 compared with 2000 will require an additional 24 million metric tons of soybeans, or 10 million hectares at the current world average yield levels (2.3 t/ha). Currently Illinois, a leading soybean state in the United States, produces soybeans on 4 million hectares. We model just one large country here, but similar shifts to higher levels of animal protein consumption are occurring throughout the developing world. So meeting just the world's needs for protein feeds will be a significant force affecting the soybean complex over the next 20 years.

Implications for Food and Agribusiness Managers and Firms

We use a model to better understand the relationship between livestock production and soybean meal demand. Countries differ with respect to their adoption of commercial feeds in general and the inclusion of soybean meal in particular. We argue that our structural estimate of elasticity is superior to a simple own-variable time series regression forecast, because we take into account both historical trends in soybean meal demand and the tight relationship between livestock production and feed demand. And as a result we provide managers a more robust forecast of overall soybean meal demand. Specifically we estimate this relationship to be 0.91, which suggests that China's soybean meal feed demand increases by 0.9% as the domestic meat and egg production quantity increases by 1.0%. This is consistent with related elasticity estimates. Researchers estimate high income elasticities of demand for pork and poultry in China: respectively, .72 and .80 (Global Food in 3-Dtm 2010) and .86 and 1.01 (Ortega et al. 2009). Thus there is a tight linkage between Chinese income growth and meat consumption. There is obviously a unitary relationship between meat and livestock production, thus it is logical to expect a tight relationship between livestock production and soybean meal demand.

China's meat production capacity depends on modernizing livestock and feed manufacturing industries as well as securing feed grains and oilseed crops. Models that ignore the switch from non-commercial to commercial feed sources will understate future soybean meal demand. Thus

managers need to be aware that two driving forces are at play here, one due to the rise in live-stock production and a second due to the switch to commercial feeds.

Regarding soybean meal, China re-imposed the 13% value added tax, effective July 1, 1999, for soybean meal imports to discourage its imports and encourage more imports of whole soybeans (Hsu 2000). Imported soybeans serve as the raw material for more than two-thirds of China’s soybean meal, partially as a result of the government support to promote domestic crushing, feed and food manufacturing (Goldsmith et al. 2004). In addition, China’s traditional food self-sufficiency policy places great importance on staple cereals such as rice, wheat, and maize rather than industrial crops like soybeans. Thus local crush and the importation of soybeans, not im-ported soybean meal or expansion of domestic soybean production, will meet future soybean meal demand.

China’s soybean imports reached 37.1 million metric tons in 2006-09 and commanded 49.6% of global imports (Figure 2). China’s soybean imports originate from the Western Hemisphere: 38% from the US, 35% from Brazil, and 26% from Argentina (2006-07). The tight linkage in China between; income growth, meat demand, domestic livestock production, feed industry modernization, will drive land use decision making in the key soybean exporting regions in the Americas. Simultaneously in many of the same regions expansion of biofuel production drives similar land use decision making in the context of maize and sugarcane. Expansion in soybean hectares is unlikely in the United States as biofuel demand continues to indirectly incentivize US farmers, the world’s largest producers of both corn and soybeans, to plant corn. The approach of the “blend wall” of 15% ethanol blend or a decrease in crude oil prices though would serve as dampening forces.

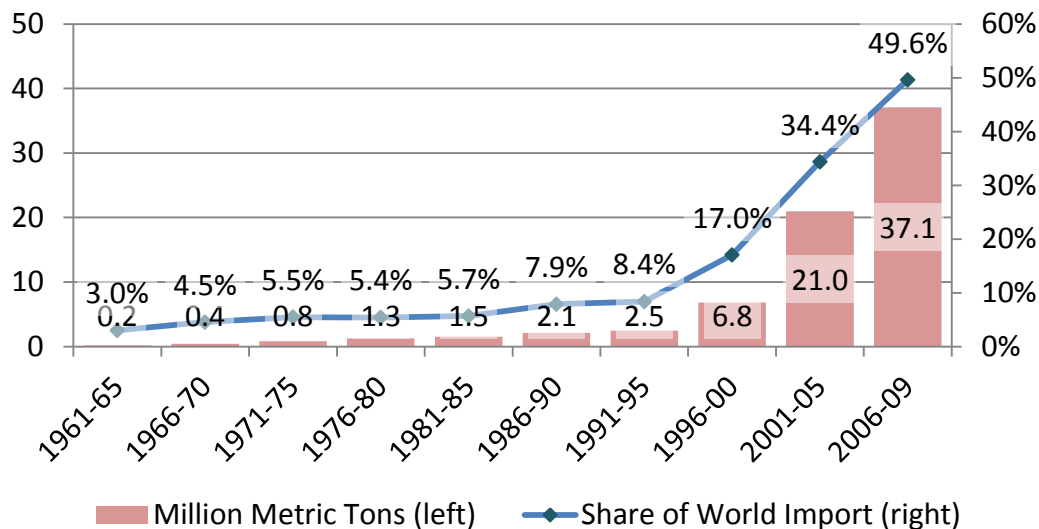


Figure 2. China’s Soybean Imports (1961-2009)

Note. China = Mainland China + Hong Kong + Macau.

Source. FAOSTAT and authors’ calculation.

Finally, soybean yield growth contributes about 1/3rd of the overall increase in the global supply of soybeans, with the expansion of soybean hectares contributing the other 2/3rds (Masuda and Goldsmith 2009). But yield growth is only forecasted at about .5% per year through 2030 (Masuda and Goldsmith 2009). The implications for managers are twofold. First there will continue to be increasing pressure in South America to shift land use to soybean cultivation. In more temperate countries currently producing sunflower, canola and maize, such as Argentina, more acres will switch to soy. In tropical regions such as Brazil, pasture, native vegetation such as *cerrado* and dry land forests will be transformed to crop production, often to soybeans as well. Land prices and incentives to double crop in Brazil will rise as environmental concerns, land use policies, and more effective enforcement of land reserve laws constrain land clearing for use in crop production. Opportunities will open up for African production of soybeans, not necessarily as an exporter but to meet domestic and regional needs previously met by imports. Reducing harvest and post-harvest losses of soybeans, estimated at 4% in the center-west region of Brazil (Sebben 2010), would also help ease the supply constraint.

The second implication of poor soybean yield growth involves the need for agricultural research to increase soybean yields beyond their current .7% per year. We forecast soybean meal demand growth rates in China at about 1.5% per year. Rising soybean demand will necessitate increasing land under soybean cultivation if producers in the major soybean producing regions of the world cannot intensify soybean production. Certainly double cropping soybeans and

Under the present conditions soybean seed research is vulnerable to intellectual property theft. The high growth soybean regions have weak intellectual property rights, and cumbersome policies with respect to genetically modified crops. This poor research and development environment dampens the incentives for private sector investment in soybean technologies (Goldsmith et al, 2006). So yield growth lags, and puts pressure on land use shifts to soybean production to meet global feed demand. The challenge then for managers and policy makers is how to expand research and development to intensify production, such that growing demands can be met on the same or smaller land base. Land dedicated to soybean production could actually decline by 2030 if global soybean yield could increase from its current level of 2.3mt/ha to 4.0 mt/ha (Goldsmith, 2009). While the public sector has historically played a significant role in agricultural R&D, government resources now are limited and higher priorities preclude significant public investment in agricultural research. The private sector will need to fill the void, but requires a business environment in the new agricultural growth regions conducive for research and development investment.

Future Areas of Research

An understanding of the maturation process of meat and fish demand in emerging economies requires further study. The plateauing of demand for meat and the shifts among proteins has significant implications for the soybean complex. Currently market demand growth outpaces rates of yield improvement, but convergence will occur. But high population country demand will slow in the emerging countries such as China, while it will accelerate in the fast growing countries of sub Saharan Africa. The soybean industry, so dependent on meat demand, needs to better understand the supply-demand dynamics of developing economies to prepare for the next generation of new markets.

References

- Bossaerts, P. 1988. Common Nonstationary Components of Asset Prices. *Journal of Economic Dynamics and Control* 12: 347-364.
- Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S., and C. Courbois. 1999. Livestock to 2020: The Next Food Revolution. *Food, Agriculture, and Environmental Discussion Paper* 28. IFPRI, Washington, D.C.
- Engle, R.F. and C.W.J. Granger. 1987. Co-integration and Error Correction: Representation, Estimation, and Testing. *Econometrica*. 55 (2): 251-276.
- FAO. 2002. Protein Sources for the Animal Feed Industry. Expert Consultation and Workshop, Bangkok, April 29 - May 3.
- FAO. 2006. World Agriculture: Towards 2030/2050 (Table 3.7). Interim Report. Rome.
- FAO. FAOSTAT. <http://faostat.fao.org/>
- Fuller, F., D. Hayes, and D. Smith. 2000. Reconciling Chinese Meat Production and Consumption Data. *Economic Development and Cultural Change* 49 (1): 23-43.
- Gardner, E. S. Jr. 1985. Exponential Smoothing: The State of the Art. *Journal of Forecasting* 4: 1-28.
- Gardner, E. S. Jr. and E. McKenzie. 1985. Forecasting Trends in Time Series. *Management Science* 31 (10): 1237-1246.
- Global Food in 3-Dtm. 2010. Innovosoy, Inc., Champaign, IL. <http://globalfoodin3d.com/> (accessed June 2010).
- Goldsmith, P.D., B. Li, J. Fruin, and R. Hirsch. 2004. Global Shifts in Agro-Industrial Capital and the Case of Soybean Crushing: Implications for Managers and Policy Makers. *International Food and Agribusiness Management Review* 7 (2): 87-115.
- Goldsmith, P.D., G. Ramos, and C. Steiger. 2006. Intellectual Property Piracy in a North-South Context: Empirical Evidence. *Agricultural Economics* 35 (5): 335-349.
- Goldsmith, P.D. 2009. The 21st Century and the Post-Modern Challenges for the Global Soybean Industry. Plenary speech at the VIII World Soybean Research Conference, Beijing, August.
- Gonzalo, J. 1994. Five Alternative Methods of Estimating Long-run Equilibrium Relationships. *Journal of Econometrics* 60: 203-233.

- Hendry, D.F., A.R. Pagan, and J.D. Sargan. 1984. Dynamic Specification (Ch.18). In *Handbook of Econometrics Vol. II*, edited by Griliches, Z., and M. D. Intrigator. Elsevier.
- Holt, C.C. 1957. Forecasting Seasonal and Trends by Exponentially Weighted Moving Averages. *ONR Research Memorandum 52*: 1-10. Pittsburgh, PA: Carnegie Institute of Technology.
- Holt, C.C., F. Modigliani, J.F. Muth, and H. A. Simon. 1960. *Planning, Production, Innovation, and Work Force*. Prentice-Hall, Englewood Cliffs, NJ.
- Holt, C.C. 2004. Forecasting Seasonal and Trends by Exponentially Weighted Moving Averages. *International Journal of Forecasting* 20: 5-10.
- Hsu, H.H. 2000. China Switches from Soybean meal to Soybean Imports. USDA, ERS, Washington, D.C. *International Agricultural and Trade Reports: China* WRS-99-4: 13-16.
- Hsu, H.H. and F.W. Crook. 2000. China's Feed Manufacturing Industry Is Booming. Washington, D.C.: USDA. *International Agricultural and Trade Reports: China* WRS-99-4: 29-39.
- Hyndman, R.J., A. B. Koehler, J. K. Ord, and R.D. Snyder. 2008. *Forecasting with Exponential Smoothing: The State Space Approach*. Springer.
- Johansen, S. 1995. *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*. Oxford University Press, New York.
- Johansen, S. 1988. Statistical Analysis of Cointegration Vectors. *Journal of Economic Dynamics and Control* 12: 231-254.
- Keyzer, M.A., M.D. Merbis, I. F. P. W. Pavel, and C.F.A. van Wesenbeek. 2005. Diet shift towards meat and the effects on cereal use: can we feed the animals in 2030? *Ecological Economics* 55: 187-202.
- Ma, H.G., Huang, J.K., and S. Rozelle. 2004. Reassessing China's Livestock Statistics: An Analysis of Discrepancies and the Creation of New Data Series. *Economic Development and Cultural Change* 52: 445-473.
- Masuda, T. and P. D. Goldsmith. 2009. World Soybean Production: Area Harvested, Yield, and Long-Term Projections. *International Food and Agribusiness Management Review* 12 (4): 145-164.
- Mills T.C. 1990. *Time Series Techniques for Economists*. Cambridge Univ. Press.
- Ortega, D.L., H. Holly Wang and J. Eales. 2009. Meat Demand in China. *China Agricultural Economics Review* 1(4): 410-419.
- Putnam, J.J. and J.E. Allshouse. 1996. Food Consumption, Prices, and Expenditures, 1970-95. *Statistical Bulletin* 939. Washington, D.C.: USDA.

Putnam, J.J. and J.E. Allshouse. 1999. Food Consumption, Prices, and Expenditures, 1970-97. *Statistical Bulletin 965*. Washington, D.C.: USDA.

Stata, 2011. www.stata.com.

Sebben, D. 2010. *Harvest and Post-Harvest Loss in Mato Grosso*. Presentation to the ADM Institute for the Prevention of Post-Harvest Loss. University of Illinois. August.

Stein, H.H., L.L Berger, J.K. Drackley, G.C Fahey, Jr., D.C Hernot, and C.M. Parsons. 2008. Nutritional Properties and Feeding Values of Soybeans and Their Co-Products (Ch. 18). In *Soybeans: Chemistry, Production, Processing and Utilization*, edited by L.A. Johnson, P.J. White, and R. Galloway, 613-660. Urbana-Champaign, IL: AOCS Press.

Stock, J.H. 1987. Asymptotic Properties of Least Squares Estimators of Cointegrating Vectors. *Econometrica* 55 (5): 1035-1056.

Stock, J.H., Watson, M.W., 1988. Testing for Common Trends. *Journal of American Statistical Association* 83 (404): 1097-1107.

Waldroup, P.W., 2010. Soybean Meal Demand. Soybean Meal Information Center Fact Sheet. <http://www.soymeal.org/FactSheets/soymealdemand.pdf>. (accessed December 2010).

Wang, J.M., Z.Y. Zhou, and R.J. Cox. 2005. Animal Product Consumption Trends in China. *Australasian Agribusiness Review* 13: Paper 2.

Wang, J.M., Z.Y. Zhou, and J. Yang. 2004. How Much Animal Product do the Chinese Consume? Empirical Evidence from Household Surveys. *Australasian Agribusiness Review* 12: Paper 4.

Xin, X.A., Z.H. Yang, and Z.Y. Zhou. 2005. China's Feedgrain: Production and Consumption (Ch. 7). In *Grains in China: Foodgrain, Feedgrain and World Trade*, edited by Zhou, Z.Y. and W.M. Tian. Ashgate Publishing.

Xing, L. 2009. *Estimating the Non-Commercial-Commercial Feed Gap in China and Its Impact on Future World Demand for Soybeans*. Master's Thesis, Department of Agricultural and Consumer Economics, University of Illinois.

Xing, L. and P.D. Goldsmith. 2012. Estimating the Non-Commercial – Commercial Feed Gap in China. *Chinese Journal of Agricultural Economics*. Under Review. June.

Zhou, Z.Y., W.M. Tian, X.A. Liu, and G.H. Wan. 2003. Research Methodological Issues in Projecting China's Feedgrains Demand and Supply. *Zhongguo Nongye Jingji Pinglun (China Agricultural Economic Review)* 1(1): 54-74.

Zhou, Z.Y., W.M. Tian, and B. Malcolm. 2008. Supply and Demand Estimates for Feed Grains in China. *Agricultural Economics* 39(1): 111-122.

Appendix 1.

Table 4. Comparison of China's Meat and Egg Production/Consumption Balances: FAOSTAT and SSB1 Adjusted by Wang et al. (2005)

1999-2001 year average (million metric tons)	Meat Total		Pigmeat/Pork		Poultry Meat		Bovine Meat/Beef		Mutton & Goat Meat		Other Meat	
	FAOSTAT	SSB Adj.	FAOSTAT	SSB Adj.	FAOSTAT	SSB Adj.	FAOSTAT	SSB Adj.	FAOSTAT	SSB Adj.	FAOSTAT	SSB Adj.
Production/Output	61.7	60.2	40.8	40.4	12.3	11.8	5.1	5.3	2.6	2.7	0.9	0.9
Net Import	1.0	-0.6	0.2	-0.1	0.6	-0.4	0.1	0.0	0.0	0.0	0.0	0.0
Domestic Supply	62.7	59.6	41.0	40.2	12.9	11.3	5.2	5.3	2.7	2.7	0.8	0.8
Food Manufacture	0.0	-	0.0	-	0.0	-	0.0	-	-	-	-	0.0
Food Consumption	62.6	-	41.0	-	12.9	-	5.2	-	2.7	-	-	0.8
Other Utility	0.0	-	0.0	-	0.0	-	0.0	-	-	-	-	0.0
Food Cons. (kg/capita/yr)	49.0	47.0	32.1	31.8	10.1	9.0	4.1	4.2	2.1	2.2	0.7	0.7
-- w/loss rate (kg/capita/yr)	-	37.7	-	24.2	-	8.5	-	3.1	-	1.9	-	-
Eggs												
1999-2001 year average (million metric tons)	FAOSTAT	SSB Adj.										
Production/Output	22.1	22.4										
Net Import	0.0	0.0										
Domestic Supply	22.2	22.3										
Seed	0.5	-										
Waste	1.1	-										
Food Consumption	20.1	-										
Other Utility	0.4	-										
Food Cons. (kg/capita/yr)	15.8	17.6										
-- w/loss rate (kg/capita/yr)	-	16.8										

Notes. 1. Wang et al. (2005) adjusted the Official Statistics by the State Statistical Bureau, People's Republic of China. 2. Based on Putnam and Allshouse (1996). According to Putnam and Allshouse (1999), the revised version, the carcass retail weight loss parameters are for the U.S. food consumption.

Sources. FAOSTAT, Wang et al. (2005), and authors' calculation.

Appendix 2.

Estimation Results of Damped Trend Exponential Smoothing

Following the equations (8) and (9), the damped parameter was set as 0.98 then the level (α) and trend (γ) parameters were grid-searched and determined to the minimize forecasting mean square error (see Table 8). With the estimated parameters, equation (12) computed the forecasts for 2009-30.

Table 8. Estimation Summary: Meat and Egg Production Quantities in China

Univariate time series	α (level)	γ (trend)	ϕ (damped)	Forecasting MSE	# of obs.
Pig Meat	0.60	0.20	0.98	1.512E+12	48
Poultry Meat	0.80	0.30	0.98	1.121E+11	48
Beef & Buffalo Meat	0.80	0.30	0.98	2.903E+10	48
Sheep & Goat Meat	0.90	0.30	0.98	4.462E+09	48
Other Meat	0.90	0.15	0.98	2.999E+09	48
Eggs	0.90	0.30	0.98	3.682E+11	48

Notes. 1. The observation period is 1961-2008. 2. Meat Total = Pork + Poultry + Beef and Buffalo meat + Sheep and Goat meat + other meat.

