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Increase in Protein Demand for China's Livestock Sector and Its Implications for International Agricultural Trade

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Abstract

The objectives of this study are designed to investigate supply, demand, and trade of protein ingredients (oilseed meals, fishmeal, meat and bone meal) in China; the influence of internal and external determinants; and changes in the macro-economic policies on these markets. The conceptual framework of the model used for that purpose follows the basic structural model for analyzing agricultural commodity makets. In the four-equation system (demand, supply, price, and stocks), the market equilibrium condition of supply and demand of specific protein meal or oilseeds can be reached through interaction between supply and demand. The theory of joint products is also presented to explain supply and demand dynamics between oilseeds and their products (oil and meal). Because of different types of commodities traded between China and the rest of the world, the basic structural model is extended to a two-country partial equilibrium trade model. The extended structural model is developed to connect household demand for livestock products with the requirements of protein meals via various types of livestock inventories. The deficit status and trade situation of protein ingredients is simulated. "A demand approach" is applied to determine it. Derived demand for protein meals is calculated based on the projection of China's total household demand for livestock products.

Supply of and demand for soybeans have become less-price responsive in China. There are positive relationships between livestock production and crush demand for protein meals as well as their joint oilseeds. The estimated results show constraints on the increase in soybean harvest areas in China, which is consistent with the lack of sufficient protein meals for China's livestock sector. Technical change has a positive and significant effect on China's soybean production.

China's WTO accession has no significant impact on its soybean imports. The rising livestock output is the main driving force boosting imports of soybeans. China's soybean imports have become sensitive to the development of price differences between the domestic and the world market. The regulations on Genetically

Modified Organisms and food safety policy potentially have strong influences on the trade of protein meals and their joint oilseeds. The basic scenario results show that China’s dependency on soybean imports will substantially increase.

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ABBREVIATIONS

AIDS	Almost Ideal Demand System
BSE	Bovine spongiform encephalopathy
CAAS	Chinese Academy of Agricultural Sciences
CARD	Center for Agricultural and Rural Development
CCAP	Chinese Center for Agricultural Policy in Beijing
COFCO	China's National Cereals, Oils, and Foodstuffs Import and Export Corporation
CP	Crude Protein
CPI	Consumer price index
EC	European Commission
ECM	Error Correction Mechanism
EFPRA	European Fat Processors and Renderers Association,
EU	European Union
FAO	Food and Agricultural Organization of United Nations
FAPRI	Food and Agricultural Policy Research Institute, a joint effort of Iowa State University's Center for Agricultural and Rural Development and the University of Missouri-Columbia
GDP	Gross Domestic Product
GMM	Generalized Method of Moment
GM	Genetically Modified
GMO	Genetically Modified Organsims
GMP	Good Manufacturing Practices
GNI	Gross National Income
HACCP	Hazard Analysis and Critical Control Point
HRS	Household responsibility system
IFPRI	International Food Policy Research Institute
ILRI	International Livestock Research Institute
ITSUR	Iterated Seemingly Unrelated Regression Estimator
Kg	Kilograms
MBM	Meat and Bone Meal
ME	Metabolizable Energy
MT	Metric Ton
MOA	China's Ministry of Agriculture
MOC	Ministry of Commerce
NRA	National Renderers Association

N3SLS	Non-linear Three-stage Least Squares
OLS	Ordinary Least Square
PS&D	United States Department of Agriculture Production, Supply and Demand data
RGCFDS	Research Group for China's Medium and Long-term Food Development Strategies
RDE	the residual demand elasticity
RMB	Ren Min Bin
ROW	the Rest of the World
SARS	Severe Acute Respiratory Syndrome
SC	State Council
SGB	State Grain Bureau
SSB	State Statistical Bureau
TRQ	Tariff-rate Quota
3SLS	Three-stage Least Squares
TSE	Transmissible Spongiform Encephalopathies
2SLS	Two-stage Least Squares
UK	United Kingdom
U.S.	United States of America
USDA	United States Department of Agriculture
VAT	Value-added Tax
WDI	World Development Indicators
WTO	World Trade Organization

1 Introduction

1.1 Problem statement

Since the early 1980s, China's rapid improvement in living standards accompanying rapid increase in demand for livestock and fish products (animal proteins) has brought about a rising concern over the availability of appropriate, affordable, and high-quality feed ingredients. The question of whether the expansion of China's feed grain output is sufficient to meet increased demand, driven by the country's booming livestock industry, has been studied extensively (Hayes, 1998; Fang and Fuller, 1998; Fuller and Fang, 1999; Huang et al., 1999; Rutherford, 1999; Rae and Hertel, 2000; Ma and Rae, 2004; Nin et al., 2004; Lu and Kersten, 2006). Previous studies yielded contradictory results because the definition of grain differed significantly and different approaches were used. In China, the priority of agricultural policy has been given to food security, which is measured by self-sufficiency in grain production. Under this policy, China has achieved the desired goal of both food grain and feed grain production. However, since the mid-1990s, China's deficit situation in protein ingredients[1] has significantly widened. This trend suggests that the research needs to give its attention to easing the shortages of proteins for the country's feed industry.

As an essential building component of life, protein is a crucial nutrient in the animal diet formulation (Gilbert, 2002). The task of modern feed technology and animal nutrition is to provide protein in animal rations in the most technically efficient way (Miller, 2002). An appropriate energy-protein ratio is required to optimize protein utilization. When insufficient energy is given, protein will be converted into energy rather than body protein. This is the reason an appropriate energy-protein ratio is required.

[1] In this study, protein ingredients refer to high-and-medium protein content meals, which include oilseed meals, fishmeal, and meat and bone meal (MBM).

There may be a broader spectrum of choices regarding the use of feed grain, but proteins for feed, particularly high-quality protein feed, cannot be avoided (Speedy, 2002).

Protein sources for livestock rations vary to a certain extent, providing considerable opportunities for further diversification and substitution (FAO, 2002). Oilseed meals, fishmeal, and meat and bone meal (MBM) are three key protein feeds in commercially produced livestock rations, and they are traded globally (Gilbert, 2002). In China, they provide most of required protein for intensively raised animals (specialized and commercial production) and also a part of the protein for traditionally raised animals.

In addition to rapid rising demand for livestock products, structural changes in China's livestock production toward specialized and commercial operations could accelerate the shortages of proteins. Compared to traditionally raised livestock, intensively raised livestock could utilize more advanced feeding technologies and consume more compound feeds and protein meals. Continued structural changes in China's livestock production have strong implications for international agricultural trade.

China's widening deficit in protein sources reflects as the massive imports of protein meals. Due to expanded oilseed processing and extraction capacities and rising demand for vegetable oils for human consumption, China's imports of proteins are mainly in the form of oilseeds, especially soybeans (Tuan et al., 2004). The major change in the global oilseed sector is that China, once a net soybean exporter, has turned into a leading importer. China's imports grew from almost zero in the 1980s to more than 50 million metric tons in 2010, accounting for more than 40% of the world's soybean trade (USDA PS&D database, various years). Table 1.1 presents the quantities of China's soybean production, total domestic consumption and imports. It indicates that the gap between total domestic consumption and its production have enlarged significantly since the mid-1990s.

Table 1.1: China's production, total domestic consumption and imports of soybeans from 1978 to 2010 (Thousand Metric Tons)

Year	Production	Imports	Total Dom. Cons.
1978/1979	7,565	261	7,552
1979/1980	7,460	810	8,063
1980/1981	7,940	540	8,337
1981/1982	9,325	530	9,745
1982/1983	9,030	30	8,740
1983/1984	9,760	0	8,960
1984/1985	9,695	0	8,615
1985/1986	10,509	280	9,529
1986/1987	11,614	190	10,054
1987/1988	12,184	208	10,910
1988/1989	11,645	33	10,469
1989/1990	10,227	1	9,121
1990/1991	11,000	1	9,713
1991/1992	9,710	136	8,756
1992/1993	10,300	150	10,150
1993/1994	15,310	125	14,335
1994/1995	16,000	155	15,761
1995/1996	13,500	795	14,073
1996/1997	13,220	2,274	14,309
1997/1998	14,728	2,940	15,472
1998/1999	15,152	3,850	19,929
1999/2000	14,290	10,100	22,894
2000/2001	15,400	13,245	26,697
2001/2002	15,410	10,385	28,310
2002/2003	16,510	21,417	35,290
2003/2004	15,394	16,933	34,375
2004/2005	17,400	25,802	40,212
2005/2006	16,350	28,317	44,440
2006/2007	15,967	28,726	46,120
2007/2008	14,000	37,816	49,818
2008/2009	15,540	41,098	51,435
2009/2010	14,700	50,338	59,430

Source: USDA PS&D database, various years

1.2 Research objectives

Based on above mentioned background, the objectives of this study are designed to investigate supply, demand and trade of protein ingredients (oilseed meals, fishmeal, MBM) in China; the influence of internal and external determinants and changes in the macro-economic policies on these markets.

The principal objectives are summarized as:

1. What is the supply, demand, trade situation and policy environment for protein ingredients and their associated grain and livestock products in China?
2. What are the impacts of China's increase in livestock production and trade liberalization on demand for protein ingredients?
3. What is the effect of technical change on production of main protein ingredient (soybean meal)?
4. What is the effect of the alternative protein ingredient (rapeseed meal) on the demand for the main protein ingredient (soybean meal)?
5. What are China's future supply, demand, and trade situations for protein ingredients?

From this, the following specific research objectives are derived:

a) To investigate the economic structure (supply, demand, and trade) and macroeconomic policy environment for China's livestock products, feed grain and protein ingredients;
b) To analyze the development of protein ingredient market after the Bovine spongiform encephalopathy (BSE) crisis and determine its effect on the use of processed animal proteins (MBM, blood meal, poultry meal, and feather meal) as protein sources in China;
c) To develop a structural econometric model that can provide a quantitative assessment of the impact of China's increasing livestock production on demand for protein ingredients and their joint oilseeds;
d) To estimate the effect of technical changes on China's soybean production;
e) To identify the substitution relationship between rapeseed and soybeans, driven by livestock production;
f) To determine the impact of China's World Trade Organization (WTO) accession on imports of soybeans;
g) To project China's future demand, supply and deficit positions in protein ingredients;

h) To draw general conclusions from the estimated elasticities and projected results and formulate appropriate policy recommendations for marketing agents and policy makers.

1.3 Research hypotheses

The hypotheses for this research are as follows:

1. Soybean meal provides the main protein source for feeding China's farm animals. According to FAOSTAT database (2010), China's soybean yield per hectare is about 35% lower than its competitors (U.S., Argentina, and Brazil). An increase in soybean yield can significantly ease the shortages of proteins. It is hypothesized that the technical change by improvement in agricultural infrastructure and rising investment in agricultural research has a positive effect on the soybean production in China.
2. China is the world's largest producer of rapeseed (FAOSTAT database, 2010). In China, rapeseed meal ranks as the second largest protein source after soybean meal. It is an alternative protein source that can replace soybean meal in animal rations. Identification of the substitution relationship between soybeans and rapeseed will help China's government formulate appropriate agricultural policy. It is hypothesized that there is a substitution relationship between soybeans and rapeseed in China.
3. China's WTO accession was a landmark event in its economic development and reform history.It has fundamental influence on international agricultural trade between China and the ROW. It is hypothesized that China's WTO accession has a positive impact on imports of soybeans.

1.4 Organization of the thesis

The organization of this dissertation is as follows. Chapter 1 states research problem, the objectives of this study, and research hypotheses. Chapter 2 provides background information related to this study. It includes an analysis of production, consumption, and trade of livestock products in China; nutrition characteristics of various protein ingredients; development of feed ingredient market and use of processed animal proteins after the BSE crisis; structural changes in China's livestock production; development of China's livestock industry, biotechnology and agricultural trade policies; the effects of country's food security policies on its livestock, feed grain, and oilseed markets.

Chapter 3 reviews existing research on the market of protein ingredients and their joint oilseeds for both China and the ROW. A complete understanding of previous studies on protein ingredients for China's livestock industry is essential for this study. Although only a few directly related studies are available, a number of related studies provide general information regarding nutrition characteristics of various protein ingredients, supply of and demand for protein ingredients in the ROW, and the appropriate approaches for analyzing oilseeds and their products (oils and meals). Relevant literatures can be divided into four sub-categories: (1) China's availability and deficit position of protein ingredients; (2) China's demand and trade of soybeans; (3) protein sources for feed industry in the ROW; (4) supply, demand, and trade of oilseeds and their products in the ROW.

Chapter 4 first outlines the commodities included in the model. Then it presents the conceptual framework of this study. The development of the conceptual framework follows the structural model. The theory of joint products is introduced to explain supply and demand dynamics between soybeans and their products. Because of the trade of different types of commodities between China and the ROW, the basic structural model is extended to a two-country partial equilibrium trade model. The system equations of the extended structural model are constructed to connect the household demand for livestock products with derived demand for protein ingredients, via various livestock inventories.

Chapter 5 presents the estimated results of the system equations for China and the ROW, based on the conceptual model constructed in Chapter 4. First it displays methodology and data sources, second it shows the estimated results of the system equations and finally, it provides a comprehensive discussion of the estimated parameters and elasticities.

Chapter 6 presents China's deficit position of protein ingredients based on the simulation results and its implication for global shortages of protein sources. "Demand approach" is employed to project the country's demand for livestock products and protein requirements for feeding its farm animals. Per capita household demand for livestock products is projected through incorporating of average per capita household consumption of livestock products in the base year, real household income growth rates, and income elasticities of the demand for livestock products. The consumption of livestock products at the national level is calculated by multiplying estimated average household consumption of livestock products by the number of population. Projected national consumption of livestock products, multiplied by the feed-meat conversion ratio, gives the country's total requirement for feed. Projected country's total feed requirement and the average use of protein meals in different raised animal rations (traditional and specialized) are incorporated to obtain the national demand for protein meals. Three alternative scenarios are developed that provide the baseline, high-bound, and low-bound projections for the demand, supply, and trade of protein meals.

Chapter 7 is dedicated to a summary of the study, the test results for the hypotheses, conclusions from the estimated results, and policy recommendations.

2 China's Livestock Sector, Protein Sources for Feeding Farm Animals and Policy Environment

2.1 China's production, consumption and trade of livestock products

2.1.1 Production of livestock products

Since the 1980s, China's fast population growth, massive rural-to-urban migration, an increase in living standards, and a shift in diet consumption patterns from traditional food staples such as cereals (wheat, maize, and rice) toward more livestock and fish products have resulted in a significant increase in demand for animal protein in China (Fischer et al., 2007). Therefore China's livestock sector has been growing faster than any other agricultural sub-sector. A group of researchers from the International Food Policy Research Institute (IFPRI), the Food and Agricultural Organization (FAO), and the International Livestock Research Institute (ILRI) have projected that future increases in global animal protein consumption would mainly come from low-and-middle income countries (Delgado et al., 1999). The term "Livestock Revolution" was used to describe the rapid expansion of livestock production in low-and-middle income countries and structural change in the global agriculture. Emerging economies (countries with constant economic growth), particularly by Brazil, China, and India, lead the "Livestock Revolution", which reflects the demand-driven characteristics.

The livestock sector in China not only provides ample dietary protein for human consumption but also has other important uses, including providing draught power, transportation, a source of fertilizer, as well as animal by-products. It is the core component of China's agricultural sector and has achieved a remarkable progress since the rural reforms[2] began in the late 1970s. The livestock sector's contribution to China's agricultural economy has grown continuously from 18% in 1980 to 22%

[2] China has started its rural reform at the end of the 1970s by abolishing the people's commune system and introducing the household responsibility system (HRS). Means of production, including was redistributed to individual households, based on household size. The right of decision making for livestock production was given to individual household.

in 1985, 26% in 1990, 30% in 2000, and 33% in 2007, measured by value (State Statistical Bureau-China's Statistical Yearbook, various years).

Table 2.1: China's outputs of major livestock products (Million Metric Tons)

Year	Total Meat Output	Pig meat	Beef	Mutton	Poultry	Eggs
1978	11.09	8.77	0.28	0.32	1.53	2.64
1979	13.35	10.87	0.32	0.38	1.59	2.78
1980	14.79	12.13	0.34	0.45	1.66	2.93
1981	15.44	12.67	0.35	0.48	1.73	3.03
1982	16.44	13.53	0.36	0.53	1.81	3.24
1983	17.08	14.01	0.40	0.55	1.90	3.51
1984	18.58	15.37	0.45	0.59	1.94	4.51
1985	20.94	17.57	0.51	0.59	2.02	5.54
1986	22.89	19.03	0.63	0.62	2.32	5.75
1987	24.06	19.49	0.84	0.72	2.69	6.11
1988	26.71	21.29	1.00	0.80	3.25	7.15
1989	28.13	22.35	1.12	0.96	3.37	7.42
1990	30.42	24.02	1.30	1.07	3.74	8.18
1991	33.37	25.82	1.58	1.18	4.48	9.46
1992	36.41	27.65	1.85	1.25	5.12	10.46
1993	40.55	29.84	2.37	1.37	6.41	12.07
1994	44.73	32.61	2.81	1.48	7.17	15.08
1995	48.25	33.40	3.60	1.75	8.67	17.08
1996	48.05	33.01	3.58	1.81	8.79	19.99
1997	54.72	37.16	4.43	2.13	10.22	19.36
1998	59.12	39.90	4.82	2.35	11.22	20.59
1999	60.10	39.90	5.08	2.52	11.76	21.74
2000	62.11	40.75	5.16	2.69	12.69	22.21
2001	62.99	41.65	5.11	2.72	12.52	22.50
2002	64.23	42.32	5.24	2.84	12.73	23.04
2003	66.26	43.43	5.45	3.09	13.13	23.71
2004	67.91	44.48	5.62	3.33	13.24	24.08
2005	71.19	46.62	5.70	3.50	14.05	24.73
2006	72.69	47.59	5.79	3.64	14.28	24.60
2007	70.43	43.93	6.15	3.83	15.04	25.65
2008	74.54	47.21	6.15	3.81	15.81	26.73

Source: FAOSTAT database, various years

Table 2.1 indicates that China's output of livestock products has achieved constant growth since 1978, with the average annual growth rate of 6.79% (FAOSTAT database, various years). Meat output increased about 6.72 times, from 11.09 million metric tons in 1978 to 74.54 million metric tons in 2008. Among all sub-categories of livestock products, the output of pig meat grew the slowest. It increased 5.38 times (from 8.77 million metric tons in 1978 to 47.21 million metric tons in 2008) with average annual growth rate (5.98%). The average annual growth rates for outputs of beef, mutton, poultry and eggs are at 11.24%, 8.92%, and 8.31%, respectively, much faster than that of pig meat. The output of poultry climbed to 15.81 million metric tons in 2008, an increase of 10.33 times compared with 1978. The output of beef reached 6.15 million metric tons and increased 21.96 times in the same period. The output of mutton came to 3.81 million metric tons and rose 11.91 times. Moreover, the output of eggs increased more than 10 times from 2.64 million metric tons in 1978 to 26.73 million metric tons in 2008.

One of the prominent features of China's livestock industry is that pork production has been dominant in overall meat production. As calculated in Table 2.2, pig meat production still accounted for 63% of total meat output in 2008, although it has fallen significantly since 1980, when it made up 82% of China's total meat output. Because of China's per capita income growth and diversification of meat consumption, the shares of poultry, beef, and mutton outputs have grown substantially. The share of poultry output almost doubled (from 11% in 1980 to 21% in 2008). In 1980, the shares of beef and mutton output accounted for 2% and 3% of total meat output. By 2008, these shares had increased to 8% and 5%, respectively.

Table 2.2: Shares of pig, beef, mutton and poultry in total meat production (%)

Year	Pig meat	Beef	Mutton	Poultry
1980	82	2	3	11
1985	84	2	3	10
1990	79	4	4	12
1995	69	7	4	18
2000	66	8	4	20
2005	65	8	5	20
2006	65	8	5	20
2007	62	9	5	21
2008	63	8	5	21

Source: calculated based on the data in table 2.1.

2.1.2 Consumption of livestock products

The rapid and continuous income rise is believed to be the main driving force that causes the changes in dietary consumption patterns from the main staple foods to more animal protein in China (Fuller et al., 2002). Table 2.3 displays the disparity between rural and urban household in grain and livestock product consumption during 1985-2008. Average annual per capita consumption of livestock products has generally increased for both rural and urban households, whereas average annual per capita grain consumption has declined substantially in the same period, with a larger decline for urban households (SSB-China's Statistical Year Book, various years). Between 1985 and 2008, per capita consumption of pig meat, beef and mutton, poultry, and eggs for urban households increased at the average annual growth rates of 0.63%, 2.30%, 4.01%, and 1.98%, respectively. On the other hand, the average annual growth rates of consumption of these livestock products for rural households were at 0.89%, 3.03%, 6.47%, and 4.33%, respectively. Comparison of these growth rates confirms that per capita consumption of livestock products for rural households is growing at a faster rate than that for urban households.

Table 2.3: Per capita consumption of food grain and livestock products for rural and urban households (kg/per year)

	Urban Per Capita Consumption of					**Rural Per Capita Consumption of**				
Year	Grain	Pig Meat	Beef and Mutton	Poultry	Eggs	Grain	Pig Meat	Beef and Mutton	Poultry	eggs
1985	134.76	16.68	2.04	3.24	6.84	257.45	10.32	0.65	1.03	2.05
1990	130.72	18.46	3.28	3.42	7.25	262.08	10.54	0.80	1.25	2.41
1995	97.00	17.24	2.44	3.97	9.74	256.07	10.58	0.71	1.83	3.22
2000	82.31	16.73	3.33	5.44	11.21	250.23	13.28	1.13	2.81	4.77
2005	77.0	20.15	3.71	8.97	10.40	208.85	15.62	1.47	3.67	4.71
2006	75.92	20.00	3.78	8.34	10.41	205.6	15.46	1.56	3.51	5.00
2007	77.60	18.21	3.93	9.66	10.33	199.48	13.37	1.51	3.86	4.72
2008	N/A	19.26	3.44	8.00	10.74	199.07	12.65	1.29	4.36	5.43

Source: SSB-China's Statistical Year Book, various years

As shown in Table 2.3, pig meat remains the most commonly consumed livestock product for China's households (SSB-China's Statistical Yearbook, various years). Average pig meat consumption for urban households increased slightly from 16.68 kg in 1985 to 20.15 kg in 2005, whereas average pig meat consumption of rural households rose faster than that of urban households–from 10.32 kg in 1985 to 15.46 kg in 2005. However, since 2005, pig meat consumption has declined slightly, from 20.15 kg in 2005 to 19.26 kg in 2008 for urban households and from 15.62 kg in 2005 to 12.65 kg in 2008 for rural households, respectively. These trends indicate that both urban and rural household's demand for pig meat is nearly reached its limit.

In China, poultry was traditionally regarded as a luxury meat and eaten only on special occasions (Pan, 2003). Table 2.3 demonstrates that following a rapid and continuous rise in household income, both urban and rural household poultry consumption has grown significantly from 1985 to 2008. Average consumption of poultry grew at the fastest rates among all meat sub-categories, with annual growth of 4.01% and 6.47% for urban and rural households, respectively. Urban per capita poultry consumption reached 8 kg in 2008, a rise of 2.47 times from 1985, whereas rural per capita poultry consumption was 4.36 kg in 2008, a 4.23 times increase. The share of urban and rural consumption of poultry as a percent of total meat consumption rose from 15% to 26% for urban households and from 9% to 24% of total meat consumption for rural households.

Consumption of beef and mutton has been low for both urban and rural households as China's ruminant sector is poorly developed and China's consumers prefer pig meat and poultry. As displayed in Table 2.3, annual average per capita consumption of beef and mutton were only at 2.04 kg and 0.65 kg in 1985 for urban and rural households, respectively. These numbers reached 3.44 kg and 1.29 kg in 2008, an increase of 1.69 times and 1.98 times compared with those in 1985. The share of urban household consumption of beef and mutton as a percentage of total meat consumption grew from 9% in 1985 to 11% in 2008, whereas the share for rural households rose from 5% in 1985 to 7% in 2008. The increase in ruminant meat consumption by younger generations, the development of a western-style fast-food industry, and the rise in restaurant consumption caused per capita consumption of beef and mutton to grow to some extent (Pan, 2003).

Moreover, egg consumption by urban residents rose by 57% (from 6.84 kg in 1985 to 10.74 kg in 2008) while egg consumption by rural residents increased by 1.65 times (from 2.05 kg in 1985 to 5.43 kg in 2008). Egg consumption by rural residents grew at a rate more than double than that of urban residents.

Table 2.4 indicates that both urban and rural residents have shifted their dietary consumption pattern away from main staple grains toward animal protein. There is an obvious difference in consumption of grain and livestock products between urban and rural residents. Urban residents consume less grain and more livestock products (pig meat, beef and mutton, poultry, and eggs) compared with rural residents. Income disparity between urban and rural residents, inequality of economic development across regions (east coast and inland) and between urban and rural areas, and inadequate transport and logistics infrastructure in rural areas are the major causes for this discrepancy. Income disparity and inequality of economic development have been enlarged and intensified as a result of rapid continued expansion of non-agricultural sectors. Income disparity has widened from 1.86 in 1985 to 2.79 in 2000 and 3.31 in 2008 (SSB- China's Statistical Yearbook, various years).

Table 2.4: Income disparity and livestock products and grain consumption ratios between urban-rural residents

	Real income ratio between urban-rural residents	Consumption ratios between urban-rural residents				
Year		Grain	Pig Meat	Beef and Mutton	Poultry	Eggs
1985	1.86	0.52	1.62	3.14	3.15	3.34
1990	2.20	0.50	1.75	4.10	2.74	3.01
1995	2.71	0.38	1.63	3.44	2.17	3.02
2000	2.79	0.33	1.26	2.95	1.94	2.35
2005	3.22	0.37	1.29	2.52	2.44	2.21
2006	3.28	0.37	1.29	2.42	2.38	2.08
2007	3.33	0.39	1.36	2.60	2.50	2.19
2008	3.31	N/A	1.52	2.67	1.83	1.98

Source: Ratios in Column 2 are calculated from data of SSB, China's Statistical Yearbook, various years. Ratios in Column 3, 4, 5, 6, and 7 are obtained according to data in Table 2.3.

The differences in the consumption of livestock products between urban and rural residents show a declining trend. In other words, the gap is being closed, but at a per capita level, urban residents consume around twice or three times as much beef, mutton, poultry, and eggs as rural residents. As illustrated in Table 2.4, in 2008 urban residents still consumed pig meat, beef and mutton, poultry, and eggs 1.52, 2.67, 1.83, and 1.98 times more than rural residents.

Comparison of production and consumption data of livestock products, presented in Table 2.1 and 2.3, shows that at the national level, consumption series significantly lag behind production series. The reasons for this discrepancy include exclusion of out-of-home consumption on the consumption side and over-report on the production side (SSB-China's Statistical Yearbook, various years).

Although both urban and rural household consumption of livestock products has steadily grown since the mid-1980s, per capita consumption of livestock products in China is still lower than that in Western countries. Based on the 2003 average, per capita intake of animal protein in China was 17 gram/capita/day, compared with 33 gram in Canada, 33 gram in France, 27 gram in Germany, and 40 gram in the U.S. (FAOSTAT Database, various years). Continued income growth, rural-to-urban migration, and rising meat consumption by rural households are expected to narrow the gap of protein intake between China and Western countries in the future (Keyzer et al., 2005).

2.1.3 Trade of livestock products

Because of the rapid expansion of non-agricultural sectors, particularly the service sector, the output share of the agricultural sector in the country's Gross Domestic Production (GDP) has sharply declined, from 29.8% in 1985 to 11.8% in 2006 (China's Ministry of Agriculture-China's Rural Development Report, 2007). Similarly, in terms of value, the share of agricultural trade in the country's total trade has also dropped. As displayed in Table 2.5, the share of agricultural imports of total imports has decreased from 12.1% in 1985 to just 4% in 2006, while during the same period, agricultural exports as a percentage of total exports have declined by 22.2% (from 25.4% in 1985 to 3.2% in 2006). Between 1985 and 2008, the share of agricultural exports of total exports declined at 9.43% annually, roughly twice as fast as the shrinking of agricultural imports.

Table 2.5: Share of agricultural sector in GDP and share of agricultural imports and exports in China's trade (%)

	1985	1990	1995	2000	2005	2006
Share of agricultural sector in GDP	29.8	28.4	20.8	16.4	12.5	11.8
Share of agricultural imports in total imports	12.1	16.1	9.3	5.0	4.3	4.0
Share of agricultural exports in total exports	□5.4	17.2	9.4	6.3	3.6	3.2

Source: MOA-Rural Development Report, 2007.

Prior to the rural reform, China was a net exporter of livestock products, in terms of both quantity and value (SSB-China's Statistical Yearbook, various years). The objective of the trade of livestock products, just as the trade of other agricultural products, is to earn hard currency to import advanced technologies and finance the country's industrialization (Jim et al., 2009). Since the mid-1980's, the share of the trade of livestock products in China's total agricultural trade has declined significantly, as the trade volume and value of other agricultural products, particularly soybeans, have skyrocketed.

In China, the livestock industry concentrates on pig and poultry production. As a result, the trade of livestock products is reflected as the trade of pig and poultry meat. Table 2.6 presents China's pig meat trading data. China's imports and exports of pig meat, in terms of both volume and value, are negligible compared with the total quantity and value of pig meat output (FAOSTAT database, various years). China is a net exporter of pig meat. China's exports of pig meat show a decreasing trend, while the imports reflect the opposite trend.

Table 2.6: Quantity and value of China's pig meat trade

Year	Pig Meat Import Quantity (mt)	Pig Meat Import Value (1,000 $)	Pig Meat Output (mt)	Pig Meat Export Quantity (mt)	Pig Meat Export Value (1,000 $)
1986	10	15	19032358	190505	561342
1987	9	29	19490155	236048	825499
1988	9	28	21294622	188315	724619
1989	222	354	22345933	89365	163588
1990	229	367	24015697	125458	220202
1991	7	13	25824130	118544	193699
1992	5	32	27647184	51204	90284
1993	24	33	29836491	22391	31955
1994	3	8	32613176	19721	33367
1995	1068	2058	33401322	37556	68427
1996	2539	3430	33014694	56318	97538
1997	2888	2554	37156348	30178	58554
1998	18361	9294	39900430	29891	47466
1999	8209	9543	39900331	10139	12497
2000	34024	39245	40751626	6475	9279
2001	5139	4231	41654251	6899	9422
2002	4608	4057	42322776	19965	25993
2003	9676	10935	43433462	21205	29904
2004	14087	16636	44478789	14997	27453
2005	10110	12404	46621907	18171	35740
2007	25582	39563	43933037	11861	28991

Source: FAOSTAT database, various years

As displayed in Table 2.7, the imports and exports of poultry meat account for a larger share of its total production compared with that of pig meat (FAOSTAT database, various years). The imports and exports of poultry meat have risen quickly.

In 2007, the imports of poultry meat accounted for 6.10% of China's total output of poultry, whereas the share of exports of poultry meat was at 3.46%. Table 2.7 shows that the exports of poultry meat declined significantly in 2004 due to the problem of Severe Acute Respiratory Syndrome (SARS). Until the 1990s, China was a net exporter of poultry meat. The imports of poultry meat have exceeded its exports since 1999. Chinese consumers' meat consumption pattern is different from that in Western counties. Specific cuts of livestock, particularly feet and wings, get more value in China's market. Due to lower per capita income, meat prices in China are generally lower than those in Western countries. Value difference between meat and specific cuts leads to China's exports of meat to Western countries and imports of specific cuts of livestock, especially poultry.

Table 2.7: Quantity and value of China's poultry meat trade

Year	Poultry Import Quantity (mt)	Poultry Import Value (1,000 $)	Poultry Output (mt)	Poultry Export Quantity (mt)	Poultry Export Value (1,000 $)
1986	5252	2702	2321471	34346	51086
1987	16091	12940	2687372	28474	47519
1988	27143	19664	3254625	37343	71362
1989	49032	37265	3370523	46618	88432
1990	67752	48268	3740003	52042	109004
1991	85993	55598	4479763	63235	137615
1992	78248	50482	5120819	105933	209488
1993	100113	58472	6407831	121087	226829
1994	137432	73241	7173749	200610	422244
1995	263831	83632	8674030	309781	688494
1996	319540	150548	8794032	406323	880216
1997	216481	139008	10219450	398051	753377
1998	204648	118022	11222432	379934	661862
1999	832642	440014	11761395	435010	726829
2000	877334	507031	12687886	550737	887492
2001	724191	461243	12524144	583105	980580
2002	605673	452186	12732101	565406	882372
2003	693964	502147	13134509	510339	795703
2004	252482	212033	13236598	332885	625289
2005	472351	428687	14054260	476659	903375
2006	695941	549338	14284774	487145	928099
2007	916676	1084977	15038657	520219	1048398

Source: FAOSTAT database, various years

As shown in Table 2.6 and Table 2.7, China has become a net exporter of pork, a net importer of chicken meat, and an overall net meat importer. The imports and exports of livestock products, in terms of both quantity and value, account for small shares of total output.

2.2 Protein sources for animal feed

2.2.1 Protein sources for China's livestock industry

Protein feeds provide high quality proteins in animal rations (Gilbert, 2002). The nutritive values of various protein feeds are measured by their protein contents, composition of amino acid, as well as digestibility of protein (Hasha, 2002). Differences in animals' digestive systems can affect the utilization of proteins. Ruminant animals normally have less demand for high quality digestible protein because they can efficiently digest the cellulose in the grass and other pasture-based feeds. In contrast, monogastric animals (pork and poultry) need to be fed largely by protein concentrates, such as soybean meal, since they have more restrictions in protein utilization.

Almost all feed ingredients contain protein either traded (grain and protein meals) or non-conventional feed. In China, seven major types of by-products are defined as non-conventional feed, which include crop straws, by-products of forestry (leaves and fruit peels), distiller's grain, oil cakes (other than soybean meal), by-products from livestock slaughtering, renewable feed (chicken dung) and some minerals (Ke, 2001). According to their contents of protein, feed ingredients can be broadly categorized into three sub-groups (Zhou, 2002):

- High protein content feed ingredients: Fish meal more than 60%, MBM 55%, and soybean meal 48-50%;
- Medium protein content feed ingredients: Rapeseed meal 32%, sunflower meal 28%, and coconut meal 22%;
- Low protein content feed ingredients: Cereal 9-12%.

Table 2.8 explains the crude protein (CP) and lysine contents in China's main feed ingredients.

Table 2.8: Crude protein and lysine content in China's feed ingredients (%)

	CP Content	Lysine Content
High protein content feedstuffs		
Fish meal	> 60	5.20
MBM	55	2.60
Soybean meal	48-50	3.02
Medium protein content feedstuffs		
Rapeseed meal	32	1.30
Sunflower seed meal	28	1.68
Coconut meal	22	0.58
Low protein content feedstuffs		
Cereals	9-12	

Source: CP and lysine contents are obtained from Feedstuffs Handbook (Zhou, 2002).

High and medium protein content feed ingredients including oilseed meals, fishmeal and MBM provide the largest portion of protein for feeding different types of farm animals. Oilseed meals (soybean meal, rapeseed meal, sunflower seed meal, and coconut meal) are by-products of oil extraction. Protein from soybean meal is highly digestible with a balanced essential amino acid profile. For this reason, soybean meal has been used as the standard protein source in various types of animal rations during all stages of feeding, with the highest incorporation rates in high performance pig and poultry rations. Rapeseed meal contains slightly lower protein (32%) and lysine (1.3%) contents than soybean meal, but it has high levels of eruic acid and glucosinolates (National Pork Board, 2008). High levels of eruic acid and glucosinolates cause unpalatable problems and lower feed incorporation rates. When rapeseed meal is fed as the main supplemental protein, the efficiency of feed-meat conversion and weigh grains of pigs and poultry reduce. Based on the nutritional guidance in the Feedstuffs Handbook (Zhou, 2002), sunflower meal also has less protein (28%) and less lysine (1.68%) content than soybean meal, but it has more methionine. Because of its low lysine content, high fiber content, and low digestibility, sunflower meal must be supplemented with soybean meal in pig and poultry rations (FAO-Animal Feed Resources Information System, 2009).

According to the nutritional information in the Feedstuffs Handbook (Zhou, 2002), fishmeal not only contains the highest proportion of protein (more than 60%) but is also rich in essential amino acids that are in a highly digestible form, such as lysine, methionine, threonine, and tryptophan. Compared with protein meals from oilseeds, fishmeal also provides a good source of minerals (calcium and phosphorus). Fishmeal has frequently been used as a high-protein supplement to increase protein content and utilization in pig and poultry diets. Growth rates, feed intake, and feed conversion rates are improved when fishmeal is fed to pigs and poultry (Fishmeal Information Network, 2009). Moreover, fishmeal is also used for feeding ruminant animals.

Before the BSE crisis, processed animal proteins including MBM, blood meal, poultry meal, and feather meal were the crucial components in animal rations in the European Union (EU). During animal slaughtering and meat processing, between 33% and 43% of the live animal weight is removed and treated as animal by-products that will not used for human consumption (Hamilton, 2002). These removed by-products are turned into processed animal proteins and animal fat through rendering processes. The global composition of animal by-products for the rendering industry is as follows: North America renders 25 million metric tons; the EU renders 17 million metric tons; and Argentina, Australia, Brazil, and New Zealand render an additional 10 million metric tons (National Renderers Association-Essential Rendering Global Market, 2008).

Processed animal proteins from the rendering process contain a high proportion of protein and are rich in amino acids. Moreover, these proteins are also excellent sources of calcium, phosphorus, and other minerals (FAO-Animal Feed Resources Information System, 2009). Global supply of the predominant protein meal consists of oilseed meal (316 million metric tons), processed animal protein (10 million metric tons), and fishmeal (7 million metric tons) (Gilbert, 2002). Although processed animal proteins only account for 3% of global protein utilization, the contribution of processed animal proteins in animal rations is significant, particularly in North America. The protein values of processed animal proteins have been largely influenced by the sources of raw materials and processing methods.

In North America, raw materials used to produce rendered animal protein are mainly by-products from the beef and pork industry. In total the U.S. processed animal protein production consists of 57% MBM, 28% poultry meal and 15% feather meal (NRA-Annual Convention, 2008).

MBM is the primary product of processed animal proteins. Based on the National Renderers Association (NRA) animal nutrition guidance (2009), the MBM from Canada and the U.S. typically contains approximately 50% protein, 35% ash, 8% - 12% fat, and 4% - 7% moisture and the digestibility of amino acids in the MBM varies greatly. The protein content of MBM (over 50%) is higher than soybean meal (48%), but the lysine content of MBM (2.6%) is lower than that of soybean meal (3.02%). When MBM is used as the primary protein source for feeding pigs and poultry, high ash and mineral content causes palatability problems (FAO-Animal Feed Resources Information System, 2009). Therefore, the inclusion levels of MBM in pig and poultry diets cannot exceed certain amounts.

Due to the long-term development of the rendering industry and traditionally key ingredients in farm animal rations, processed animal proteins produced from North America are unique, free of hair, free of feathers, and have relatively stable nutrition contents (Meeker and Hamilton, 2006). The development of the rendering industry in China and other Asian countries suffers from a lack of protein rich raw materials. For this reason, processed animal proteins from these countries contain less protein levels along with low digestible amino acids.

Generally MBM has been considered as a cost-effective protein supplement for feeding farm animals. The amino acid digestibility and bioavailability values of

MBM have been improved by a large margin through progress in rendering technologies. A study conducted by the NRA stated that lysine digestibility has increased by 27% from 65% in 1984 to 92% in 2001 (Hamilton, 2002). In addition, MBM also provides a good method for the disposal of animal by-products and reduces environmental pollution.

Although the EU placed a ban on feeding MBM to all farm animals, MBM has been an important component in animal rations in North America. The poultry industry has been an important market for MBM and utilizes 37% of the total processed animal proteins in North America (Pearl, 2002). There are many studies addressing use of MBM as a protein supplement in poultry diets. When the use of MBM replaces fishmeal in chicken diets, the feeding results show that growth is similar but the feeding efficiency is getting lower (FAO-Animal Feed Resources Information System, 2009). A study by Leitgeb et al. (1998) concluded that weight gain and feed-meat conversion ratio remain unchanged when use of MBM replaces soybean meal by up to 10% in chicken diet. When MBM replaces 20% to 60% of the soybean meal in turkey diets, there is no evidence of a negative impact on the performance of turkeys (FAO-Animal Feed Resources Information System, 2009).

Pigs have the ability to obtain sufficient protein from both plant and animal sources. MBM was widely used as a protein supplement for feeding pigs in North America and the EU. Preliminary feeding practices indicated that pig growth performance decreases as the level of MBM as a substitute for soybean meal increases in corn-based pig diets (Evans and Leibholz, 1979). Traylor et al. (2005) found that the inclusion rate of MBM in growing and finishing diets for pigs can be up to 9% without negative effects on performance of pig growth if amino acids (tryptophan) are also added. According to the NRA animal nutrition guide (2009), the inclusion rate of MBM is recommended to be from 2.5% to 5% in growing and finishing rations for pigs.

Because the processed animal proteins primarily targeted for feeding pigs, poultry, and cattle have high ash contents, the use of processed animal proteins in aquaculture feed was rare in the 1960s and 1970s (National Research Council, 1993). The digestibility and high ash contents are the main constraints for use of processed animal proteins in aquaculture feed. Following the improvement of digestibility of processed animal proteins and development of modern biotechnology, the nutrition constraints of processed animal proteins can be resolved. Processed animal protein will be a good substitute for fishmeal with these improvements.

Yang et al. (2004) indicated that processed animal proteins replace fishmeal in diets for gibel carp without negative effects on feed utilization and growth. A study by Ai et al. (2006) showed that 45% of fishmeal can be substituted by MBM in yellow croaker feed without largely reducing growth. Bureau (2006) emphasized that processed animal proteins are valuable feed ingredients for the formulation of aquaculture feed because of their digestible protein, energy, available essential amino acids, and minerals.

In Asian aquaculture shrimp culture has become important. Processed animal proteins appear to be sufficient to meet the protein requirement for feeding shrimp (Yu, 2006). Several studies (Tuan and Yu, 2003; Cruz-Suarez et al., 2004) have investigated the effects of the protein efficiency ratio of shrimp when rendered animal proteins are used to replace fishmeal. The results showed that the replacement of fishmeal by processed animal proteins does not result in a significant reduction in the feeding efficiency until 80% of the fishmeal is substituted with processed animal proteins. This confirms that processed animal proteins are good protein sources to partially replace fishmeal in aquaculture feed.

Prior to the implementation of the complete ban on feeding MBM to all farm animals in the EU in 2000, the share of MBM utilized was estimated to be 3% - 7% of feed rations for pigs, 2% - 3% of feed rations for poultry, 5% - 6% of feed rations for egg-laying hens, and 1% - 6% of feed rations for cattle (Morgan, 2001).

BSE and feed ban on processed animal proteins

BSE, also known as mad cow disease, is a transmissible, neurodegenerative, and fatal brain disease of cattle that has an incubation period of four to five years (World

Health Organization, 2009). The first case of BSE was found in the United Kingdom (UK) in the mid-1980s (Fox and Peterson, 2004). BSE is a type of transmissible spongiform encephalopathy (TSE), also known as prion disease. BSE exists in a wide number of species including cattle, sheep, deer, cats, and other species. It is widely believed that BSE may be transmitted to humans by eating the brain of infected carcasses (Food and Drug Administration, 2005).

Current theories cannot fully explain the cause, original source and transmission of BSE (Hamilton, 2002; Fox and Peterson, 2004; World Health Organization, 2009). BSE is believed to be caused by a specific type of infectious agent called a prion, which has a number of unusual properties including a relative resistance to chemical and physical inactivation procedures that are normally applicable to microorganisms (Taylor and Woodgate, 2003).

Feeding processed animal proteins to farm animals has created considerable safety and political concerns (primarily the BSE problem) but also salmonella contamination, dioxins, and veterinary drug residue issues (FAO, 2002). Normally, soybean meal is the primary protein source for feeding cattle. Because the EU's demand for soybean meal for feeding farm animals far exceeds domestic production, the majority of soybean meal for feeding animals is from either imported soybean meal or meal derived from imported soybeans. The livestock industry in the EU is characterized as an intensive landless livestock production system[3], which requires a large quantity of purchased feed ingredients, in particular protein concentrates. Processed animal proteins, containing all types of low-cost animal by-products (pig, poultry, and ruminant raw materials), have the price advantages over alternative plant protein meals, such as soybean meal (Hasha, 2002). For this reason, processed animal proteins are widely used for feeding all farm animals including cattle and dairy cows in the EU.

[3] Less than 10% of the dry matter fed to animals is farm-produced, and the annual average stocking rates are above ten livestock units per hectare of agricultural land (Steinfeld and Maeki-Hokkonen, 1997).

Processed animal proteins were regarded as a safe protein supplement because it was widely believed that appropriate treatments (133^{o}C/3 bar/20 min) could control the spread of disease and eliminate microbes (Hard, 2002). Scrapie (TSE) is a fatal, degenerative disease that occurs worldwide, which can affect the nervous systems of sheep and goats (Canadian Food Inspection Agency, 2009). Feeding contaminated processed animal proteins derived from sheep infected with scrapie to cattle is thought to cause BSE and be responsible for the spread of BSE (European Union On-Line, 1998; Horn et al., 2001). The wide use of processed animal proteins in cattle and dairy cow feed combined with a change in the rendering process in the early 1980s resulted in an accelerated spread of BSE in the EU, particularly in the UK (Mathews, 2008).

The spread of BSE has brought food policy and regulation changes in not only BSE affected countries but also the countries with no confirmed BSE cases. These changes have fundamental implications for the use of processed animal proteins as feed ingredients in farm animal rations globally. Because the transmission of BSE is supposedly linked to feeding ruminant MBM to cattle, the UK banned the feeding of ruminant-derived protein to all ruminants in 1988 (Fox and Peterson, 2004). In response to BSE outbreaks in mainland Europe in 1994, the EU adopted similar feed bans as the UK (1994/381/EC). However, these actions were found to be insufficient in preventing the spreading of BSE outbreaks. Detected BSE cases were on the rise in the EU countries in the late 1990's and early 2000's. A landmark regulation, 2000/766/EC, was adopted concerning the prevention, control, and eradication of certain TSEs. In December 2000, based on the 2000/766/EC regulation, the EU launched a 6-month ban on the use of all processed animal proteins for feeding all farm animals, which was extended in June 2001. All types of processed animal proteins regardless of the raw material species (ruminants, pigs, and poultry) were prohibited from being fed to all farm animals, whereas fishmeal was allowed to be added to feed for pigs and poultry only.

Correspondingly, FAO has recommended a global ban on use of MBM for feeding ruminant animals (FAO, 2001). In most regions of the world, MBM is not allowed to be fed to ruminant animals, but it can still be used as a cost-effective protein supplement for feeding monogastric animals (pigs and poultry). Following the EU feed ban, China launched a ban on imports of all types of processed animal proteins from the EU in early 2001. Canada confirmed its first domestic case of BSE on May 20, 2003 (Canadian Food Inspection Agency, 2004). The global reaction involved blocking exports of ruminant processed animal proteins from U.S. and Canada. China's government took far-reaching actions including a ban on all imported processed animal proteins from Canada and the U.S. regardless of species.

2.2.2 Feed market developments following the BSE Crisis

Effects of feed ban on demand for alternative protein feeds

Before the feed ban, approximately 17 million metric tons of animal by-products in the EU were rendered into 2.5 million metric tons of MBM, which was used as a protein supplement for feeding farm animals (USDA-FAS, 2002). Because the ban has been extended, the EU has to make permanent adjustments in dealing with the disposal of massive amounts of animal by-products. Except for use of MBM in pet food, the majority of MBM has been incinerated, dumped, or used as a renewable energy source. In 2008, the market distribution of processed animal proteins in the EU was as follows: 39% was used by the energy industry, 33% was used for pet food, 24% was used for fertilizers, and the remaining amount was used for specialized feed ingredients and food (Caparella, 2009). The 2000/766/EC and 2002/1774/EC regulations forced the European rendering industry changing into a waste recycling industry.

The EU's feed ban on processed animal proteins has fundamental implications for the European feed ingredient market. The MBM share in the European feed market must be replaced by alternative protein sources, such as vegetable-based protein meals. Possible alternative protein meals include soybean meal, rapeseed meal, sunflower seed meal, and fishmeal. Due to the nutritional advantages of soybean meal and limited availability of rapeseed meal, sunflower seed meal, and fishmeal, the market share of banned MBM has been mainly substituted by soybean meal, which was the largest beneficiary. Soybean meal is the most commonly used and preferred protein source accounting for 53% of total protein supplement in the EU with only 3% from domestic production (Brookes, 2001). Assuming that the banned MBM is entirely replaced by soybean meal, the EU would need to import an additional 3.2 million metric tons of soybeans and for that purpose, at least 1.7 million hectares of cropland would be required, which is equivalent to nearly 2.7% of the world's total soybean crop area (USDA-FAS, 2002).

Fishmeal is a good alternative for the replacement of MBM because it has high protein content (over 60%) and it is rich in essential amino acids that are in a readily digestible form (Fishmeal Information Network. 2009). However, certain limitations may seriously challenge the use of fishmeal as the main alternative protein source including resource constraints, global unequal distribution of fish resources, price factor (fishmeal is one of the most expensive protein sources), and high levels of contaminants. The global supply of fishmeal as a protein source is unsustainable. Oceans are already over-fished and industrial fishing makes a recovery of the fish population recovery more difficult (Environmental Protection Encouragement Agency, 2001). For this reason, the global output of fishmeal cannot increase in the future. Constraints in fish resources have resulted in increasing fishmeal prices. Global fishmeal resources are concentrated in several countries, such as Chile and Peru. In addition, fishmeal has the weakness of containing high levels of contamination from dioxin and heavy metals.

Rapeseed meal and sunflower seed meal have somewhat contributed as substitutes for MBM. According to the Feedstuffs Handbook (Zhou, 2002), the lysine contents of rapeseed meal and sunflower seed meal are 1.30% and 1.68%, respectively, which are significantly lower than the lysine content of soybean meal (3.02%). To substitute soybean meal with rapeseed and sunflower seed meal in animal rations, synthetic amino acids are added to correct the amino acid profile (FAO-Animal Feed Resources Information System, 2009).

Development of the feed ban in the EU

The status of BSE across different countries has become the main barrier to processed animal protein trade. When a case of BSE in any country is detected, exports of MBM from that country will likely cease instantly (NRA-Economic Impact, 2009). More countries, such as Japan, have taken a similar action to fight against BSE as the EU by imposing the feed ban on all processed animal proteins in all farm animal rations and by banning the imports of all types of processed animal proteins regardless of the raw material species (pig, poultry, or ruminant animals) and BSE status of the country of origin (USDA-FAS, 2002; Fox and Peterson, 2004).

The current feed ban guarantees that all contaminated MBM is excluded from the entire food chain (EC-Working Document, 2003). The 2000/766/EC and 2002/1774/EC regulations are necessary to prevent the large-scale spread of BSE, maintain consumer confidence and protect the health of consumers at a high level. But, they also implied losing valued feed protein sources and environmental pollution from the disposal of animal by-products through non-economic methods (incineration and landfill) and their associated environmental impacts from disposal of MBM. Both increased feed costs caused by the ban on feeding MBM and the additional costs of disposal of MBM will be passed on to meat consumers and tax payers. The price advantage and competitiveness of meat produced in the EU have been undermined (EC-Working Document, 2003).

The 2002/1774/EC council decision, which was implemented on May 1, 2003, established the principle concerning the collection, transport, storage, processing, and disposal of animal by-products, which are not intended for human consumption. This regulation put an option for use of processed animal proteins for feeding farm animals. As shown in Figure 2.1, only processed animal proteins derived from category 3 raw materials[4] may return to the feed market in the EU.

[4] Category 3 materials are the by-products from slaughter house which are suitable for human consumption but are not intended for human consumption for commercial reasons or because of consumer choice (2002/1774/EC).

There is a common misconception that the rendering industry only disposes hazardous animal by-products, which are unfit for human consumption, for hygienic reasons (Taylor and Woodgate, 2003). In fact, the majority of raw materials (animal by-products) are identified fit for human consumption and subject to edible rendering.

Ruminant animals, such as cattle and sheep, are strictly prohibited from being fed any processed animal proteins regardless of species, and there is no proposal in place to relax this prohibition. Processed animal proteins can only be used for feeding non-ruminant animals, such as pigs, poultry, and fish. Species-to-species feeding is also strictly prohibited, which means that porcine meal is only allowed to be fed to broilers and poultry meal can only be fed to pigs. Hazardous animal proteins derived from category 1 and category 2 raw materials[5] must be incinerated, land-filled, or used to produce bio-energy under strict conditions.

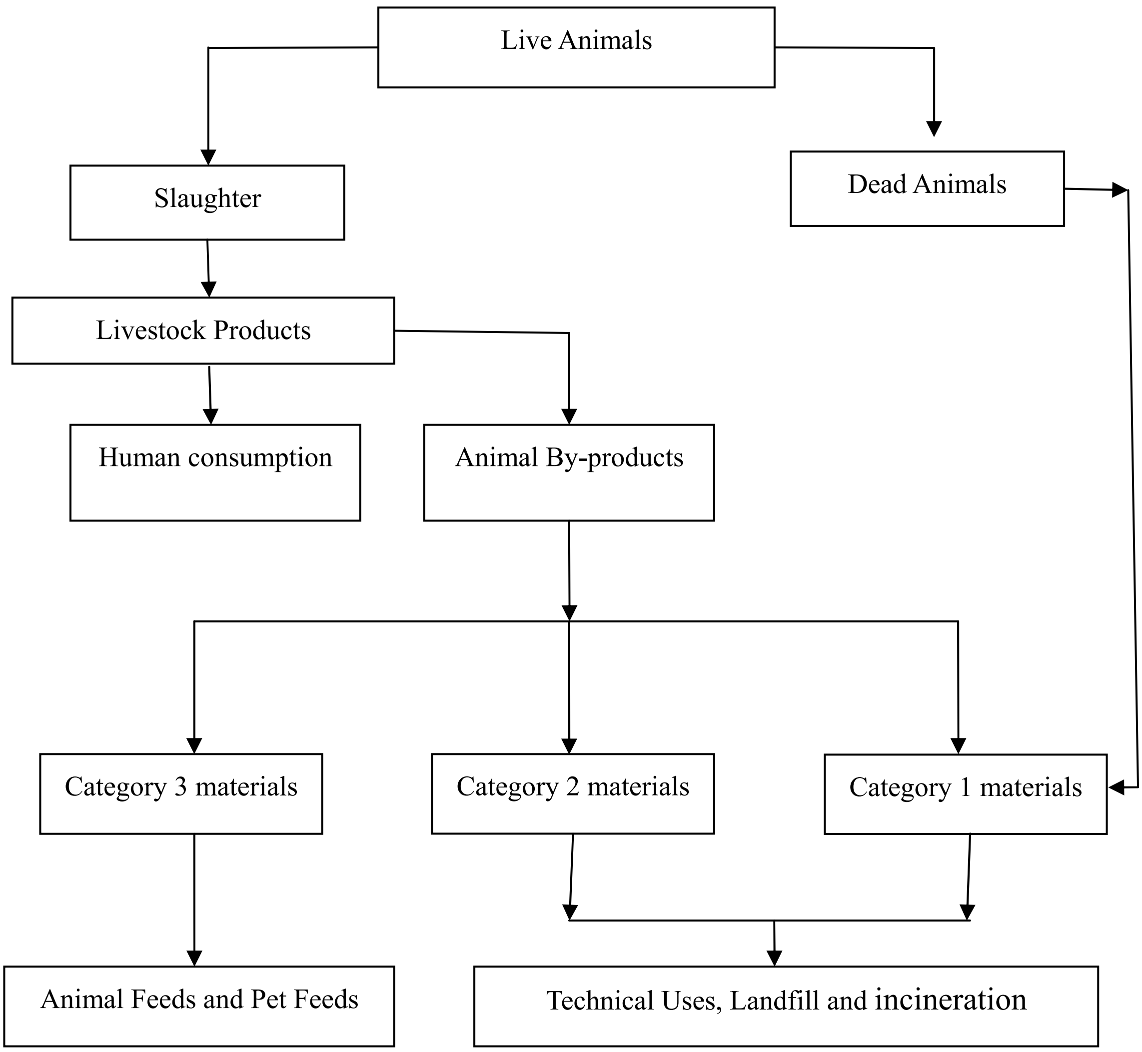
The number of BSE cases in Europe has dropped dramatically from tens of thousands at its peak in the late 1980s and early 1990s to approximately 120 in 2008 in all 27 EU countries including the UK (Caparella, 2009). De Vos and Heres (2008) developed a stochastic simulation model to assess the BSE risk of the use of processed animal proteins in non-ruminant rations. Their results showed that BSE risk of using category 3 MBM derived from Dutch cattle in non-ruminant feed is low. Therefore the EU has proposed to relax the feed ban on the use of non-ruminant MBM for feeding non-ruminant animals (pigs and poultry) to increase the availability of protein feeds and to contest the increased feed prices.

The cost of crude protein per unit is the primary concern for the formulation of animal feed. Against the continued pressure from rising prices of protein feeds, pig and poultry farmers in the EU will accept non-ruminant processed animal proteins as the cost-effective supplement. The results of the European Commission (EC) tests supported the lifting of the ban on non-ruminant processed animal proteins

[5] Category 1 raw materials are defined the animals or parts of animal having a TSE risk and category 2 raw materials refer to animals or parts of animal which are unfit for human consumption for these reasons, first animals were dead on the farm, second animal contained veterinary residues, third animals failed health inspection (2002/1774/EC).

(Spongiform Encephalopathy Advisory Committee, 2008). The findings of these tests confirmed that the use of non-ruminant MBM from different species for feeding pigs and poultry is not related to BSE transmission and does not pose the risk to humans. Reinstating processed animal proteins derived from non-ruminant raw materials (category 3 raw materials) has significant impacts on the revenue and profitability of slaughterhouses and renders. The EU renders will benefit from processing non-ruminant animal by-products into proteins and fats, while slaughterhouses will obtain the additional revenue by selling category 3 animal by-products.

Figure 2.1: Animal by-products regulation based on 2002/1776/EC



Source: EC Regulation 2002/1774/EC

According to the market report by the European Fat Processors and Renderers Association (EFPRA) Congress (2006), reinstating processed animal proteins derived from non-ruminant animal by-products (category 3) needs to meet the following four conditions: (1) document control; (2) marker for category 1 and 2 raw materials; (3) species identity for processed animal proteins; and (4) control tool for ruminant feed. These four conditions are essential tools to avoid the use of ruminant animal proteins for feeding ruminant animals, eliminate the contaminated processed animal proteins in the feed chain, guarantee consumers' health protection at a high level, and maintain consumers' confidence in European meat products.

Document controls have entered into force for the administration of animal by-products in the EU (Woodgate et al., 2009). Category 3 raw materials to produce processed animal proteins require the accompaniment of a health certificate throughout the entire process (slaughterhouse, transportation, and rendering plants). The 2007/1432/EC regulation set rules for the marking and transport of animal by-products. These rules ensure that animal by-products of different species (pigs, poultry, and ruminants) and different risk levels (category 1, 2, and 3 raw materials) are identifiable and separated. Color-coded packaging of containers and vehicles are required for the transportation of animal by-products and processed animal proteins from one member state to another member state. For the preset colors, black is set for category 1 raw materials, yellow for category 2 materials, and green for category 3 materials. A marker for hazardous materials (category 1 and 2 materials) plays a crucial role in preventing the contamination of processed animal proteins, which are derived from non-ruminant category 3 raw materials.

Lifting the feed ban on non-ruminant processed animal proteins requires the sensitive methods to detect various processed animal proteins in animal rations. The classical microscopy method has been the only official method, which has a 0.1% sensitivity level, to differentiate fishmeal from land animal proteins, but it fails to discriminate between avian, porcine, and bovine origins (EC-Working Document, 2003). The classical microscopy method, which cannot produce the reliable results for validation tests within avian, porcine, and bovine species, has become the main restriction for lifting the ban on feeding non-ruminant animal proteins. Alternative methods have been developed to identify the species origin of various processed animal proteins in farm animal rations. However, these methods have not been approved and validated at the EU level (0.1% sensitivity level) by inter-laboratory studies (Fumiere et al., 2009). The lack of efficient methods has resulted in the waste of valued animal protein sources and extension of the feed ban. Indeed, a tool for the control of ruminant feed is highly dependent on the development of efficient methods for the determination of the species origin of various processed animal proteins.

Based on the development of control measures for the ban on feeding ruminant animals (document control, marker for hazardous material, species-species identity, and control tool for ruminant feed), the initial step to reinstate non-ruminant processed animal proteins is the use of porcine and poultry meal in aquaculture feed. Non-ruminant processed animal proteins derived from category 3 raw materials in registered plants are already available (Fumiere et al., 2009). The current official microscopy method can identify fishmeal from land animal proteins at the EU level. Therefore, the use of porcine and poultry meal derived from category 3 non-ruminant materials without contamination of hazardous materials (category 1, category 2 , and ruminant raw materials) in aquaculture feed will not present the risk of spreading the BSE disease. As early mentioned in this section, the technical constraint regarding the digestibility of processed animal proteins in aquaculture feed has already been resolved through progress in modern biotechnology and development of rendering technology. Processed animal proteins are valuable and cost-effective protein sources for the replacement of fishmeal in aquaculture feed.

The continually increased fishmeal price and resource constraints of fish meal have become critical for the sustainable development of aquaculture industry (Hishamunda et al., 2008). For Asian aquaculture farmers, the price of fishmeal is the primary concern. Non-ruminant processed animal proteins are in a good position for partial replacement of fishmeal in aquaculture feed.

Consumers' income, education level, personal preference, and the epidemic of BSE across different countries have significant influence on consumers' risk attitudes and perceptions toward consumption of livestock products from animals fed with ingredients containing processed animal proteins. The response of consumers to the relaxation of the feed ban and tolerance levels of animal proteins in animal feeds determinates the final status of processed animal proteins as feed ingredients in EU (EFPRA-Congress, 2006). For this reason, consumer risk based market segmentation can be implemented.

The BSE crisis has heightened concerns about food and feed safety in the EU. Consumers in the EU, particularly in Western European countries, are more averse to the potential food and feed risk and show less trust in government agents than the consumers in the U.S. (Haniotis, 2000). Against this background, it is expected that Western European consumers will not accept meat fed with processed animal proteins. For this reason, major retailers in Western European countries, as stated by Asda and Sainsbury, oppose the EU in lifting restrictions on feeding MBM to pigs and poultry and refuse to sell meat fed ingredients containing MBM (Syal, 2007). Because economic and social developments among the EU members still remain unbalanced, especially between new members and old members, the feed industry in the new member states will reutilize non-ruminant processed animal proteins for feeding pigs and poultry. There is a good chance for formation of an efficient market for non-ruminant animal proteins in these countries. In addition, if consumers in the EU accept the use of animal proteins for feeding aquaculture, animal proteins from the rendering industry may be a good substitute for fishmeal used in European aquaculture feed.

The demand for protein as animal feed has been fueled worldwide. China and Southeast Asian countries contribute the largest share of the global increased protein feed requirement. Exports of processed animal proteins to these countries have become more important to European renders. However, the main barriers include the BSE status in the EU, lack of an efficient domestic market in the EU, and potential the stance of the government and consumers against imports because of BSE transmission risk. The EC has initiated the geographical BSE risk assessment since 1998. These assessments have been used as the main indicator for evaluation of local BSE epidemics, and they have a strong influence on the trade of processed animal proteins.

The reaction of the EU on animal proteins (ban all animal proteins for feeding all farm animals) has been significantly affected by the attitudes of consumers toward the safety of meat, particularly the risk perception of consumers regarding the spread of BSE. The final status of processed animal proteins as a feed ingredient in the EU will be dependent on not only adequate legislations and a series of methods to ensure the safety of animal proteins but also if consumers accept feeding with animal proteins (USDA-FAS, 2002; Syal, 2007).

2.3 Structure changes in China's livestock production

Structure changes in China's livestock production (backyard, specialized, or commercial production) have significant impact on the demand for protein ingredients. According to FAOSTAT database, in 2008, China contributed 26.63% of the world total production of meat, 17.25% of production of poultry meat, and 45.75% of production of pig output. China is ranked as the world's largest pig meat producer and the world's second largest poultry meat producer. In terms of China's share in the world output of livestock products, shift of livestock production from traditional toward specialized and commercial production will bring a large increase in demand for feed grain and protein meals.

In the late 1970s and early 1980s, most of China's animals were raised by traditional farmers on a small scale basis (Fuller et al., 2002; Fisher et al., 2007). Traditional backyard farmers generally fed their animals with low amounts of purchased feed grain and protein meals that were mixed with all available low-cost feedstuffs or non-conventional feed, such as crop residue, grass, and food residue. Backyard production benefits from low-cost feedstuffs, but it often results in low productivity or inefficient feeding. Since the rural reform of 1978, farmers began to diversify their agricultural production by raising animals for additional income. More farmers have become specialized in livestock production and have increased their animal inventories. At the same time, the share of backyard livestock production has substantially fallen. In China, increased livestock production mainly comes from the contribution of specialized production. In contrast to backyard production, specialized and commercial production adopt advanced breeding technology and feed their animals with greater quantities of purchased grains, concentrates, protein meals, and formulated feeds (Ke, 2001). Commercial livestock production has emerged around China coastal provinces or around urban centers in the late 1980s, but it only accounts for a few percent of the total output. The share of livestock output from commercial operations is expected to accelerate in the future.

The main feed ingredients used by commercial operation are purchased grains and complete feed.

In China, non-conventional feed resources are widely used by traditional backyard and specialized farmers for feeding their animals, although the proportion of non-conventional feed use in traditional backyard production is higher than in specialized production. For commercial operation, non-conventional feed resources are rarely found. In China, nearly 50% of feedstuffs originate from non-conventional feed, which is mainly used by traditional backyard farmers (Fischer et al., 2007).

The shares of livestock production from different operation types vary greatly across different species. Table 2.9 shows the development of the pig inventory and transition of livestock production from 1993 to 2008 based on the survey jointly conducted by researchers at the Center for Agricultural and Rural Development (CARD) at Iowa State University and at the Chinese Center for Agricultural Policy (CCAP).

As early mentioned in this chapter, although the share of pig sector has continuously dropped, the pig sector still remains the largest component of China’s livestock industry. Table 2.9 shows that China’s pig inventory has substantially increased.

China has the world's largest pig inventory with approximately 504.5 million pigs at the end of 2008. In the early 1980s, backyard pig production accounted for over 90% of China's total production with an inventory of one to five pigs per rural household. The share of backyard pork production has declined sharply since the early 1980s, whereas the share of specialized and commercial pig production has steadily risen. According to an estimate of the Food and Agricultural Policy Research Institute (FAPRI database, various years), the share of pig output from specialized and commercial production increased from 14.0% in 1993 to 33.6% in 2008, whereas the share of pig output from traditional production decreased from 86.0% to 66.4% during the same period.

Table 2.9: Pig inventory and share of pig and poultry output by different livestock production types

Year	Pig Inventory (million head)	Pig Output from Traditional Production (%)	Pig Output from Specialized and Commercial Production (%)	Poultry Output from Traditional Production (%)	Poultry Output from Specialized and Commercial Production (%)
1993	384.2	86.0	14.0	65.0	35.0
1994	393.0	83.0	17.0	63.0	37.0
1995	414.6	86.4	13.6	61.0	39.0
1996	441.7	84.7	15.3	59.8	40.2
1997	362.8	83.0	17.0	58.6	41.4
1998	400.4	81.3	18.7	57.4	42.6
1999	422.6	79.7	20.3	56.3	43.7
2000	430.2	78.1	21.9	55.1	44.9
2001	446.8	76.5	23.5	54.0	46.0
2002	457.4	75.0	25.0	53.0	47.0
2003	462.9	73.5	26.5	51.9	48.1
2004	467.9	72.0	28.0	50.9	49.1
2005	473.0	70.6	29.4	49.8	50.2
2006	479.2	69.2	30.8	48.8	51.2
2007	491.1	67.8	32.2	47.9	52.1
2008	504.5	66.4	33.6	46.9	53.1

Source: Calculations based on joint survey conducted by the Centre for Agricultural and Rural Development (CARD) at Iowa State University and the Chinese Center for Agricultural Policy (CCAP) in Beijing, from Food and Agricultural Policy Research Institute (FAPRI) database, various years.

Compared to pig sector, poultry sector is more intensive, concentrated, and integrated (Pan, 2003). As shown in Table 2.8, the specialized and commercial production share rose from 35.0% in 1993 to 53.1% in 2008, whereas the traditional backyard production share declined from 65.0% to 46.9% in the same period.

The transition of pig and poultry production from traditional backyard production toward specialized and commercial production is expected to accelerate in the future. The ruminant sector is still underdeveloped in China. The majority of ruminant animals are either fed in small pens or on edges of fields, where they eat weeds and have less demand for manufactured feed, protein meals, and concentrates (Ke, 2001).

2.4 Agricultural policy changes affecting livestock industry, oilseed industry and national food security

2.4.1 Livestock industry development policy

Before the Rural Reform, livestock products, like other important agricultural products, were entirely administered and managed by all levels of China's government, where central government and its local representatives controlled all phases of production and consumption (Huang, 1998). As earlier mentioned in this Chapter, in the planned economy period, the scheme of China's livestock industry was designed to provide cheaper livestock products for urban residents and to export for earning hard currency that is used to import advanced technology and equipment for realization national industrialization (Jim et al., 2009). After the Rural Reform, policy goal was shifted to establish a fully market-based economic system. Specifically for the livestock industry, the current policy objective is to reduce discrimination against the livestock sector, increase farmers' income from livestock production, improve the quality and safety of livestock products, and protect the environment (Ke, 2001).

The major policies contributing to the development of livestock production are presented below:

Institutional reform

Similar to other sub-sectors in the agricultural industry, institution reform also plays a crucial role in the development of China's livestock industry. The right of decision-making for livestock production is transferred to individual households or farmers. The institution reform strongly stimulates production incentives resulting in the expansion of livestock inventory, output, and productivity.

Price and market reforms

The price and market reforms are crucial components of China's transition strategy to a market-oriented economy (Van Tongeren and Huang, 2004). It is also true for the livestock sector. Domestic trade in livestock products have been liberalized by eliminating procurement quotas and fixed procurement prices for livestock products sold to the central government.

Prior to price and market reforms, state-owned and collective-owned trade enterprises completely monopolized trade of livestock products. Since the late 1980s, private and cooperative traders have been allowed to be involved in the trade of livestock products. During the same period, the market shares of state and collective marketing agencies have substantially declined. The objective of the price and market reform in the livestock industry is to establish a market-based economic system to provide opportunities for farmers to improve their production efficiencies and increase off-farm incomes.

Promotion of specialized and commercial livestock production

To promote specialized and commercial livestock production, China's central and local governments invested in bioscience innovation including improvement of livestock genetics, management practices, and disease control (Fuller et al., 2002). Moreover, national technical assistance, disease, and breeding service programs have also been developed to assist livestock farmers.

Feed policy

The development of China's feed industry follows the rising demand of households for livestock products and expansion of specialized and commercial livestock production. China's output of feed jumped to 137 million metric tons in 2008 with an annual growth rate of 18.8% from 1980 to 2008 making China the world's second largest feed producer behind the U.S. (Lin, 2010). China initially establishes a complete feed industry consisting of a feed processing industry, feed additive industry, as well as the measures and regulations for the supervision and inspection of feed industry.

Before the Rural Reform, China did not have its own modern feed manufacturing industry. State-owned feed enterprises monopolized the feed industry in China at that time. China liberated its feed industry by encouraging joint private and foreign ventures involving the feed industry (USDA-ERS, 1999). To promote the development of its feed industry, China exempted import tariffs and value-added taxes (VAT) on imports of feed additive processing equipment.

2.4.2 Policy changes affecting the trade of oilseeds and their products

Trade policy reform prior to WTO accession

During the planned economy period, China's trade regime was highly centralized and plan-based (Martin 1999; Huang and Rozelle, 2002). A group of government agencies was involved in the administration of the grain and oilseed trade. Among these agencies, the State Grain Bureau (SGB) was the core component. Every year, the SGB and its subordinate provincial unit developed China's Grain Supply-Demand Balance Tables, which included information for predicted domestic production, consumption, import levels, export levels, and stock levels (De Gorter and Liu, 2002). The SGB set the quantities of grain (quotas) to be purchased at a fixed price for each province and allocated these quotas to each province.

SGB also planed the quantities of grain to be imported and exported (quotas). These imports and exports quotas were required to obtain the permission from the State Council (SC). Thereafter the approved quotas were passed to the Ministry of Commerce (MOC). The MOC required China's National Cereals, Oils, and Foodstuffs Import and Export Corporation (COFCO) to purchase or sell grains at the world market. The COFCO received a service fee (commission) for exports and imports of grain. The COFCO and its provincial units were the sole import and export agency for grain and oilseed trade. State grain trade created barriers and discriminated against domestic non-state-owned and foreign import and export companies. Except for state trading, other major barriers of grain trade included import licensing procedures, tariffs, VATs, and export subsidies.

The reform of China's agricultural trade regime prior to the WTO accession had the following four major dimensions: (1) increasing the number and type of enterprises eligible to trade agricultural products; (2) developing indirect trade policy instruments, which were absent under the planning system; (3) reducing and ultimately removing the exchange rate distortion; and (4) liberalizing markets so that prices had a role in guiding resource allocation (Martin, 2001).

These trade reforms reduced trade distortions in the agricultural sector. Grains, such as corn, wheat, and rice, have been treated as the strategic products in China. The trade of grain was tightly controlled by the central government. Because the self-sufficient ratio of grain was set at 95% by China's central government, import quotas were set in advance and were strictly managed (Zhang, 2005). State-owned import and export companies, which held licenses, were able to access these import quotas. The tariff rates for grains (wheat, corn, and rice) above the quota, which was set at 77%, made no over quota grain imported to China (Fuller et al., 2001).

In the 1980s and early 1990s, China was a net exporter of soybeans and their products (oil and meal). The domestic demand for soybeans and their products remained weak during this period. China's domestic soybean production was sufficient not only to meet the domestic consumption but also to have a surplus to export. China's government implemented export promotion and import restriction policy on the trade of soybeans.

The trade liberalization of agricultural commodities in China started from the liberalization of soybean trade. In the late 1990s, in anticipation of its accession to the WTO, China's government initially decided to fully liberalize the trade of soybeans. China reduced soybean tariffs from 114% to 3% and phased out import quotas on soybeans (Fuller et al., 2001; Tuan et al., 2004).

Impact of China's WTO accession on the trade of oilseeds

In December 2001, China became a full member of the WTO. As one of the world's largest agricultural economies in the world, the effects of China's membership in the WTO on its economy and world agricultural trade have been well documented (Colby et al., 2001; Fuller et al., 2001; Martin 2001; Huang and Rozelle 2002). China's WTO accession had the following fundamental implications for its economy: implementing WTO agreements; changing government's role in the management of economy and trade; and increasing engagement in the world economy and participation in world trade. Regarding the agricultural sector, the key commitments were to remove the policies and institutions that were in conflict with the WTO roles and to ensure that the updated agricultural trade regime fully comply with the WTO requirements. The main commitments included diminishing government use of state-owned trading enterprises to restrict imports and the state-run procurement system to monopolize the grain and cotton trade (Colby et al., 2001).

Based on the WTO agreements, China's agricultural trade system was required to be transparent and do not discriminate against imports. China made the concessions in all three key areas including market access (tariffs, tariff rate quotas, and other trade barriers), domestic support, and export subsidies. The critical component of China's WTO accession commitment was to increase foreign produced goods and service access China's market. China committed itself to reducing and limiting tariffs for all agricultural products and using a tariff-rate quota (TRQ) scheme for certain key commodities in response to increasing market accession. Under China's TRQ scheme, a specified quantity of imports, known as quotas, had minimal tariffs applied, whereas imports over quota were administered under higher tariffs. Non-state and foreign enterprises were encouraged to engage in international agricultural trade.

Trade policy changes affecting oilseeds and their products varied by commodity with soybean oil and rapeseed oil subject to TRQ and no TRQ for soybeans, soybean meal, and rapeseed. Tariffs on soybean oil were cut from 13% to 9% for within-quota imports, while the over-quota tariffs were cut from 74% in the first year to 9% in the fifth year during a five-year implementation period (Fuller et al., 2001). The amount of TRQ set for soybean oil increased from 1.7 million metric tons to 3.3 million metric tons after a five-year implementation period and was then abolished in the following year. In 2009, tariffs on soybeans, soy meal, and rapeseed were maintained at 3%, 5%, and 9%, respectively (FAPRI database, various years).

Use of valued added tax to manage soybean trade

Beginning in the mid-1990s, a VAT was launched by China's government as a key policy to increase tax revenue and manage trade flow (Fuller et al., 2001; Tuan et al., 2004). China's VAT scheme is quite flexible, and the VAT is frequently updated based on the government's preference. The government can raise, reduce, or even exempt a VAT for specific commodities, goods produced by a specific region, goods produced by a specific company, or commodities used for a specific purpose. For instance, a commodity for export can be charged at a low rate of VAT or even exempted, whereas the same commodity for import can be set at a high VAT rate. VAT does not conflict with the WTO agreement because the commitments of China's WTO accession did not specify a VAT scheme.

China's government has applied VAT to administer trade of soybeans and their products (Tuan et al., 2004). In response to a rapidly increased demand for soybean meal driven by the livestock industry, the 13% VAT on soybean meal was lifted in 1995 to stimulate imports. Because of the exemption of VAT, the imports of soybean meal largely increased in the mid-1990s. Simultaneously, a rising soybean meal supply caused a decrease in soybean meal price and reduced the domestic soybean crushing margin (price difference between selling soy oil and soybean meal after deducting the cost of buying soybeans). Consequently, the domestic soybean meal production fell. The demand and supply of soybean meal and soy oil are closely linked. The decline in soybean meal production led to a shortage of soybean oil. To correct the market imbalances, China's government re-imposed the VAT on imported soybean meal in July 1999. As expected, the soybean crushing margin increased, while the imports of soybean meal fell and imports of unprocessed soybeans increased. In 2004, China also waived the 13% VAT on exports of soybean meal in response to the promotion of soybean meal exports and development of the oilseed crushing industry. In 2009, the VAT on soybeans was set at 13% (FAPRI database, various years).

The tariff reduction and phase-out of import quotas on soybeans have promoted the trade of oilseeds and their products (soy oil and soybean meal). As a full member of the WTO, China uses non-tariff instruments, such as licensing, food safety standards, and VAT schemes, to manage the trade of oilseeds and oilseed meals.

2.4.3 Effects of regulations of Genetically Modified Organisms on the trade of oilseeds and oilseed meals

Because of resource restrictions, Genetically Modified (GM) engineering has been regarded as an alternative approach to enhancing China's food security, increasing agricultural productivity, increasing incomes of farmers, fostering sustainable development, and improving the country's competitive position in international agricultural markets (James, 2002; Huang et al., 2003; Song and Marchant, 2006). China was one of several large countries to commercially introduce GM crops, primarily GM cotton, since the mid-1980s (James, 2002).

China's government issued several regulations and standards applying to management, imports, and labeling of GM crops. The "Biosafety Administration Regulations on Genetic Engineering" was China's first legislation related to biosafety, which was issued and implemented on December 24, 1993 (State Science and Technology Commission, 19993). Shortly after China became a WTO member, the "Biosafety Administration Regulations on Agricultural Transgenic Products" legislation was launched on May 23, 2001, which was a landmark legislation addressing biosafety in China that requires testing and labeling of all food products containing biotech ingredients (MOA, 2001). Both imported and domestic GM crops are subject to this regulation. In addition, official safety certificates are also needed to obtain from China's MOA. In 2002, three implementing regulations were supplemented for domestic safety evaluation, import approval, and labeling (Petry and Wu, 2009).

In China, Sate Committee for the Safety of Agricultural Transgenic Living Things is responsible for evaluation and analysis of safety and risk. According to the "Biosafety Administration Regulations on Agricultural Transgenic Products" legislation (MOA, 2001) and its implementing regulations, three specific rules are applicable to control and manage imported GM crops. First, the test results or data are required by China's State Committee for the Safety of Agricultural Transgenic Living Things to show that considerable research was carried out on GM crops to be imported within exporting countries or a third country and to prove that GM crops to be imported are safe for human consumption and are not harmful to animals, other plants, and environment. Second, all imported GM crops are subject to labeling requirements, but China's labeling requirements do not specify a tolerance level. GM and non-GM products are required to be separated for transportation. Third, each shipment of GM products requires an individual safety certificate. An approval process for the application for an official safety certificate may take up to 270 days (Tuan et al, 2004; Song and Marchant, 2006).

Initially, the regulations seriously disrupted China's imports of soybeans between April and June of 2002. In response to the shortage of soybeans in the domestic market, China's government issued temporary import permits for GM soybeans (MOA, 2002). From March 2004, China decided to grant permanent safety certificates for imports of soybeans to replace temporary import permits, which had to be reevaluated after a five year implementation period (Chinese State General Administration for Quality Supervision, Inspection and Quarantine, 2004). The imports of soybeans were temporarily disrupted, but rebounded after permanent safety certificates were issued.

2.4.4 Impact of food security policies on meat, feed grain, and oilseed trade

Due to China's population (more than 1.3 billion), the per capita cultivated land in China is around 0.1 hectare, which is 50% less than world average (World Bank-World Development Indicators, 2010). Cultivated land is a scare resource in China. China's land scarcity combined with the increase in non-agricultural land use and land degradation causes rising concern about its ability to produce sufficient feed grain and protein feed to meet growing domestic demands driven by booming livestock industry without increasing imports from the world market (Fuller et al, 2001). As China's demand for animal protein continues to rise at a fast rate, there has been considerable debate about whether China will become a major importer of meat, grain, soybeans, or all three of them (Fischer et al, 2007). China's strategy to deal with the rising demand for livestock products has become the priority concern of policy makers and traders.

As mentioned earlier in this chapter, the trade of meat products, as reflected by the trade of pig and chicken meat, has rapidly grown since the 1980s, but the trade of meat products is still negligible compared to China's total meat output and consumption. As shown in Tables 2.6 and 2.7, China's meat consumption is almost entirely provided by domestic producers. The increased livestock production significantly relies on productivity growth (Nin et al., 2004; Rae et al., 2006). Against this background, it is assumed that China will need to import grain or soybeans to fill the deficit of feedstuffs for its livestock sector. Concern arises over what is China's capacity to increase its soybeans or grain production and what is its impact on national food security (grain self-sufficiency). Imported soybeans in China was 27 million metric tons in 2005, which would have required the farmland that is the equivalent to the total arable land area of four provinces - Heilongjiang, Jilin, Liaoning, and Inner Mongolia (Tian, 2006). If all farmland in these four provinces are converted to soybean farming, the production of grains would be significantly reduced (roughly 17% of the country's total) and would seriously challenge China's self-sufficient in grain. Consequently, China's policy is to encourage grain production and decrease soybean production for achieving long-term grain self-sufficient.

In principle, China has following strategies to respond to the increasing demand for livestock products. First, China will increase domestic production of soybeans, feed grain, and livestock to meet increased demand without reliance on imports. Second, when soybean demand cannot be met by increased domestic production, additional requirement of soybeans will be imported. Third, if the increased feed grain requirement cannot be provided by domestic producers, China will further relax imports of grain. Finally, rising demand for livestock products will be directly satisfied by imports.

3 State of Research

3.1 Studies focusing on China's demand for protein sources

Only a few studies (Simpson and Li 2001; Li, 2004) have explored China's demand for and supply of protein for feeding its farm animals and its implications for international agricultural trade. According to the approaches applied in these investigations, feed demand is calculated through multiplying fixed feed-meat conversion coefficients by meat output, whereby a certain proportion of animal feed is assumed to be protein feeds. These calculations dos not guarantee close-to-reality results because animal feed in China contains a large share of crop residuals, and protein practices and feed compositions vary significantly between traditionally raised and intensively raised animals (specialized and commercial livestock production).

Simpson and Li (2001) simulated China's long-term supply, demand and trade of feed ingredients (protein feeds and feed grain) based on requirement and domestic availability of metabolizable energy (ME) and CP for its livestock industry. A non-deterministic simulation spreadsheet model was developed. Feed-meat conversion ratios were fixed and proportions of livestock inventories between traditional production and specialized production were unclear throughout the projection period. Projection results indicate that China would remain self-sufficient in feedstuffs including both feed grain and protein feeds (soybean meal), and protein feeds (fish meal) for aquaculture needed to be imported. As imports of soybeans as protein sources have skyrocketed since the mid-1990s, recalculation of China's future demand for protein feeds (soybean meal) is required.

Li (2004) stated that projected crude protein deficit would be between 60 million metric tons to 80 million metric tons by 2030 based on the best feed-meat conversion ratios. The main weakness of Li's projection was that the calculation was simplistic from a technical point of view. Li's approach did not capture income effect, population growth, and feeding technological development. Furthermore, livestock feed in China contains a large share of non-conventional feed, and protein sources for animal feed in China differ significantly in traditional backyard production versus specialized production, which Li did not consider.

3.2 Studies on China's soybean demand and trade

In Jiang's dissertation (2001), Jiang developed a multi-market equilibrium displacement model to investigate and capture the impact of China's accession to the WTO, liberalization of vegetable oil trade, and increasing demand for protein meal on the U.S. soybean complex (joint soybean, oil and meal market). This study introduced development of China's soybean industry and change in demand, supply, and market equilibrium of soybeans, oil, and meal since the mid-1990s. The joint demand and supply characteristics of soybeans and their products were explained. The elasticities of supply and demand for soybeans, oil, and meal in China, the U.S., and the ROW were estimated. The simulation results indicated that China's WTO accession and the liberalization of China's vegetable oil would benefit soybean producers worldwide. China's expanded demand for soybean meal would result in increase in soybean production in China, the U.S. and the ROW and led a higher international soybean price. The soybean farmers in China, the U.S. and the ROW are beneficiaries, in which the largest beneficiary is the U.S. soybean producers.

Song et al. (2006) conducted a competitive analysis (comparison of export costs) of China's main soybean exporters (U.S., Brazil, and Argentina) in China's market. Their study presented the market structure of China's soybean import market and compared the export costs of the three exporters. The results show that the U.S. and South American countries became seasonal complementary soybean suppliers for China, with Brazil and Argentina dominating in the summer season and the U.S. dominating in the winter season. The exporters' costs were further divided into production cost, internal transportation cost, and international transportation cost. The lowest exporters' costs were in Brazil, whereas Argentina had the highest cost. Brazil had the greatest advantage in China's market followed by the U.S. and

Argentina. Accompanying development and improvement of infrastructure in Brazil and Argentina, the position of the U.S. in China's market has been challenged and eroded.

Song et al. (2007) analyzed market power between China and the U.S. in global soybean market. The market structure was that China became the largest importer and the U.S. has been one of the largest exporters. There were two possible circumstances regarding this market. Either China had more influence on the market compared to exporter (U.S.) or the U.S. had a strong impact on the market. The residual demand elasticity (RDE) model offered an effective method for measuring and determining market power of a single firm. According to the RDE model, a two-country partial equilibrium trade model was constructed to compare market power of soybean trade. Trade equilibrium was achieved, where residual demand and residual supply were equal. The price flexibilities (marketing margins) of residual demand and residual supply were used to compare market power. Empirical results show that China's soybean importer had stronger market power compared to the U.S. exporter.

Chen et al. (2009) developed a simultaneous equation system to determine the effect of changes in domestic prices of soybean by-products (soybean oil and meal), their substitutes (rapeseed oil, palm oil, and corn), and meat products (pig and chicken meat) on imports of soybeans. It is assumed that China's soybean processors import soybeans and soybean oil from the U.S., Brazil, and Argentina. China's domestic oilseed crushers sell soybean oil and soybean meal maximizing their crush profits. The imported soybeans and domestic produced soybeans are homogeneous. The soybean import demand function was derived from the profit maximization function. The generalized method of moment (GMM) was applied to estimate the system equations. The estimated elasticities imply that not only the import prices of soybeans but also the prices of domestic soybeans and their by-products (oil and meal), prices of other protein meals and vegetable oils, prices of meat products (pigs and poultry) had strong influence on imports of soybeans from the world market.

3.3 Studies focusing on the ROW available protein sources for feeding farm animals

Speedy (2002) addressed the global requirements and availabilities of protein sources for feeding world farm animals. This study stated that global livestock production has experienced fast growth in response to an expanded demand for livestock products driven by population growth, income growth, increased rural to urban migration, and change in world food consumption patterns. Increased global livestock output would mainly come from the contribution of intensive livestock production (specialized and commercial production). Rising livestock output and structural changes in livestock production toward intensive production systems have led to a rapid and increasing demand for feed, particularly high-quality protein feeds. Increasing global demand for protein feed is driven by low-and-middle income countries, in which several of them have appeared as major importers of protein meals and soybeans, especially China. The solution for easing the shortage of protein sources depends on use of alternative protein sources and development of biotechnologies. Because of BSE and dioxin contamination, feed and food safety issues have become a major concern of consumers and result in a growing demand for safety, quality assurance, and traceability in the food and feed supply chain. A global code of practice for production of proteins for animal feed is recommended.

The study, conducted by Chadd et al. (2002), emphasized use of a less popular protein plant for feeding farm animals. A number of less popular protein sources were introduced, including by-products of the food industry, oilseeds, legumes, and quality protein maize. The relationship between protein requirement and livestock production system was also addressed. The attention of this study was given to the improvement of protein utilization in a marginal environment. The authors suggested a long-term strategy for the provision of sufficient protein for feeding farm animals could be obtained through the development of novel supply crops, improvement in crop breeding, and advances in genetic technology.

Miller (2002) examined the relationship between energy and protein for different livestock species (poultry, pigs, fish, and ruminants). The author explained the effects of the animal digestive system, age, and environment on the utilization of dietary protein. Adequate energy must be provided in a balanced dietary ration, and a high energy to protein ratio is required to optimize the use of protein. Otherwise, protein in animal feed would turn into energy rather than body protein. Miller's study explained the effect of the requirement of indispensable and ileal digestible amino acids for formulation of monogastric and ruminant diets on different growth stages. In addition, the author also addressed the anti-nutritional characteristics of protein feeds.

Wanapat (2002) investigated the livestock production systems and available protein sources in Thailand. The contribution of the livestock sector to Thailand's economy has been significant. In general, the livestock production system in Thailand can be divided into three sub-categories-subsistence, semi-intensive, and intensive production system. Species, livestock production system, and local feed resources have strong influences on feed requirements. Empirical results indicated that livestock feeds account for up to 70% of the cost of livestock production in which the cost of protein sources has the priority consideration. Soybean meal and fishmeal have been major protein sources for Thailand's animal feed. Due to price factor, the quantity of imported soybeans and fishmeal are insufficient to meet the requirement of the feed industry. Therefore the development of alternative protein sources is urgently needed. Low cost and protein-rich cassava-based products (cassava leaf/hay) have potential to be used as alternative protein sources.

3.4 ROW studies on oilseeds and their products

Numerous studies have been performed on the ROW's oilseeds and their products (meal and oil). Early studies on the international soybean sector were concentrated on the U.S. market and its trade partners.

The study on the U.S. soybean sector conducted by Houck et al. (1972) is considered as a landmark study in this area. Their work explains the joint characteristics of soybeans and their products. Soybeans, soybean oil, and soybean meal serve for different markets, but the supply and demand dynamics of soybeans, soybean oil, and soybean meal are closely linked to each other. Moreover, soybean oil and soybean meal are produced together. Their study provided a basic model structure for analysis of the major agricultural commodities, which are used to produce outputs in a fixed proportion. The global export market for soybeans, soybean oil, and soybean meal from the U.S. was categorized into four geographic regions. Annual data from 1947/1948 to 1966/1967 was used to estimate parameters in their study. The model was estimated by ordinary least square (OLS), two-stage least squares (2SLS), and three-stage least squares (3SLS) for both the U.S. market and export market. The estimated elasticities of supply and demand for soybeans and their products were discussed. The important contribution of this study is that this model has been widely used for analysis world market of soybeans and oilseeds.

Liu (1985) investigated future trends of Japan's grain, oilseed, and livestock productions under different economic assumptions. Japan's livestock industry is highly dependent on imported feed grain and oilseeds as feedstuffs. A complete model of grain, oilseed, and livestock for Japanese market was built. The model included eight equation blocks as follows: 1) supply of grain and oilseeds; 2) supply of livestock products; 3) food and non-feed demand; 4) derived feed demand; 5) stock demand; 6) trade between Japan and the ROW; 7) market margins; and 8) price links between Japan and the ROW. The system equations examined the cross-community effects on demand, supply, and market equilibrium of Japan's grain, oilseed, and livestock products.

The policy analysis and model simulation were carried out.

Meyers et al. (1991) developed a complete econometric model for world soybean trade. The soybean trade model is one of three trade modeling system developed, updated, and maintained by CARD at Iowa State University, whereas the other two commodity trade models are for wheat and feed grains. The basic structure of the model was based on the work of Houck et al. (1972). In each region, equilibrium price, supply, demand, and net trade were endogenously determined. The model was connected through cross-price linkages between soybeans, soybean oil, and soybean meal. The model was a non-spatial and partial equilibrium model because trade flows in some regions could not be identified. Exogenous variables used for the policy analysis and simulation included yield change, income growth, currency exchange rate, tariffs, and subsidies. China's soybean sector was considered to be endogenous block in their model.

Tsai (1994) provided a qualitative assessment of the economic structure of Taiwanese livestock, meat, and feed grain market. A special emphasis was given to the impact of trade liberalization on the interaction between these markets. A theoretical model was developed, which connected household demand for livestock products with a dynamic feed grain demand and supply system, via various livestock inventories. The econometric model of Taiwanese livestock, meat, and feed grain markets consisted of three simultaneous blocks as follows: a livestock and meat supply system, a meat demand system, and a feedstuffs supply and demand system. Both the iterated seemingly unrelated regression (ITSUR) and the nonlinear three-stage least squares (N3SLS) were used to estimate model parameters. The consequence of exogenous shocks on Taiwanese livestock, meat, and feed grain markets were simulated, which include beef import restrictions, feed grain import restrictions, complete liberalization of beef trade, complete liberalization of feed grain trade, economic growth, and change currency exchange.

Perera (1996) developed a structural econometric model to identify and examine interdependencies and interrelationships of world fats and oils. Previous studies only investigated a few vegetable oils (by-products of oilseeds). This study not only extended to explore all vegetable oils and animal fats (butter, lard, and tallow) but also captured the interrelationship between vegetable oils and animal fats. The approach follows the basic structural model where the market equilibrium conditions (supply, demand, and price) for animal fats or vegetable oils are specified. A complete model of the world fats and oils was built by the incorporation of the bean/seed demand system, oilseed meal demand system, and fat/oil supply system. The model was divided into four simultaneous blocks as follows: fat and oil demand block, oilseed meal demand block, oilseed demand block, and fat and oil supply block. The three alternative policy scenarios were also simulated including a 25% increase in the soybean loan rate, 25% reduction in the butter support price, and 70% increase in the corn loan rate.

Persaud and Chern (2002) investigated the effect of meat trade liberalization on the soybeans and rapeseed competition in the Japanese import market. The Japanese oilseed crush industry is assumed to be completely dependent on imported soybeans and rapeseed. Their study assumed that imports of processed products (meals and oils) were negligible and the domestic production of soybeans and rapeseed was zero. The theoretical framework was based on small country assumption. The demand for soybeans and rapeseed was treated as a derived input demand by extending the production function. The results indicated that lower Japanese meat production would lead to rising rapeseed imports and decreasing soybean imports.

Kruse (2003) constructed the world oilseed model, which can be applied to policy simulations. Exogenous shocks included macroeconomic policy change, currency exchange rates, economic growth, and technology growth. Commodities in the model consist of soybeans, soybean meal, soybean oil, sunflowers, sunflower meal, sunflower oil, rapeseed, rapeseed oil, and palm oil. The world oilseed model was developed based on structural model, where the behavior identities on demand and supply side are identified. Market equilibriums of oilseeds, oils and meals are determined by interaction between their supply and demand. The crush demand for oilseeds and feed demand for oilseed meal are defined as the input demand. The input demand function was obtained by simultaneous solutions of first order condition for profit maximizing. A well constructed structural econometric model provided a general framework for analyzing world oilseed market and conducting policy simulations.

Mattson et al. (2004) analyzed the world oilseed sector, which includes the major world oil crops (soybeans, rapeseed and sunflower seeds) and their by-products (oil and meal). The demand for oilseeds, meal, and oil were estimated by using An Almost Ideal Demand System (AIDS). The situations of future production, consumption and trade of oilseeds and their products were simulated based on simple trend approach. Future oil crop yields and acreage harvested were also projected. The projected results indicated that the U.S remains the largest exporter in global oilseeds market, but the U.S. position has been challenged by its main competitors (Brazil and Argentina). China would continue to remain its leading position as the largest soybean importer in the world.

Masuda and Goldsmith (2009) emphasized the multiple uses of soybeans–food, feed, fuel and industrial use. This study investigated the demand for soybeans at both country and international levels. The long-term elasticity of demand for soybeans was estimated by an error correction mechanism (ECM) approach using the country level data, in which household income is measured by real GDP. The long-term elasticity was projected through 2030. World demand for soybeans was projected through incorporation the growth of meat output and increased fuel use. The result indicated world demand for soybeans and their products (oil and meal) would rise significantly.

4. Methodology and Conceptual Framework

4.1 Commodities in the model

The essential components of protein sources for animal rations include two separated parts as follows: plant protein meals (oilseed meals) and animal protein meals (fishmeal and MBM). For this study, both key plant protein meals (soybean meal, rapeseed meal, peanut meal, and sunflower seed meal) and animal protein meals (fishmeal and MBM) are considered. In addition, demand and supply dynamics of plant protein meals (soybean meal, rapeseed meal, and peanut meal) are closely connected to that of oilseeds (soybeans, rapeseed, and peanuts). Against this background, commodities to be investigated in this study extend beyond plant and animal protein meals. Oilseeds, which have close links with plant protein meals, are also included. Table 4.1 shows the protein meals and their associated oilseeds in the model.

Table 4.1: Protein meals and oilseeds in the model

	Meals/Cakes	**Seeds/Nuts/Beans**
Annual Crops		
Soybeans	**I**	**I**
Rapeseed	**I**	**I**
Peanuts	**I**	**I**
Sunflower seed	**I**	
Animal Products		
Fishmeal	**I**	
Meat and Bone Meal	**I**	

Note: I means commodity in the model

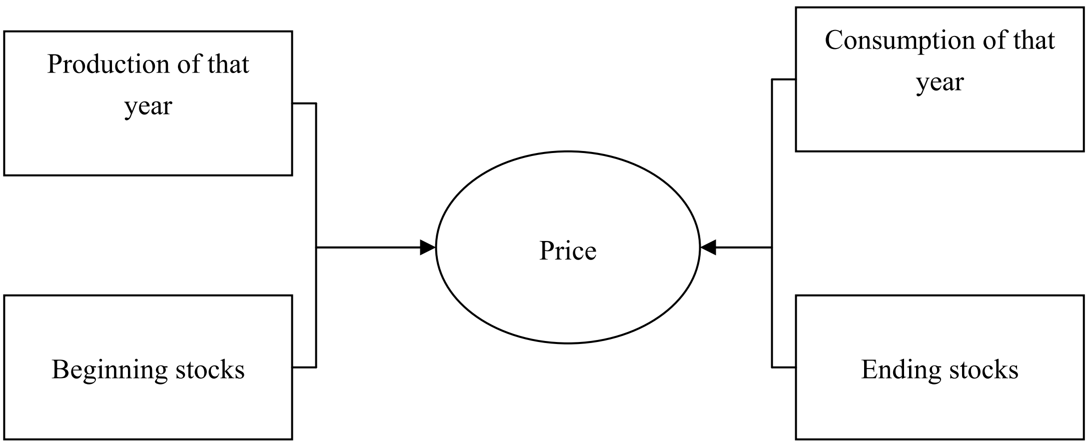
Source: Author

4.2 Conceptual framework

4.2.1 Basic framework of the model

The conceptual framework of this study followed the basic structural model, where the demand, supply, market equilibrium, and stock of specific commodity involved in this study are determined (Perera, 1996; Pothidee, 1999; Kruse, 2003; Sun et al., 2009). In this four equation system, the market equilibrium of the protein meals or their associated oilseeds is reached through a supply and demand automatic adjustment process. The equilibrium point states that the demand curve intersects the supply curve at the market clearing price, where the quantity demanded equals the quantity supplied. As shown in Figure 4.1, for a certain year, the supply identities are in the left side of the diagram, which include beginning stocks and production of that year, whereas the components in the right side of the diagram refer to demand identities, which consist of consumption of that year and ending stocks. Ending stocks equal beginning stocks plus the current year production minus the current year consumption.

Figure 4.1: Basic structural model of a specific protein meal for a certain year



Source: Author

4.2.2 Two-country partial equilibrium trade model of soybeans

The basic structural model is extended to a two-country partial equilibrium trade model, in which the linkages between China and the ROW connect through the trade of different types of commodities. The model framework connects household demand for livestock products to livestock requirements for protein meals through various types of livestock inventories (different species and different production types). The system equations of the extended structural model are designed to integrate the household demand for livestock products, livestock production, livestock inventories, requirement for protein meals, imports of protein meals, and imports of their jointed oilseeds.

As early introduced in Chapter 2, China's strategy to meet the increasing demand for livestock products can be achieved through importing livestock products, feed grain, protein meals, or all of them. In principle, imports of livestock products or live animals have significant impacts on the quantity of feed grain and protein meals to be imported. However, it is not a significant concern in China. First, the trade of various types of meats and live animals only accounts for a few percent of its total domestic livestock production and consumption (FAOSTAT database, various years). Second, the priority of its agricultural policy objective is given to country's food security, which is reflected as achieving self-sufficient in grain production and consumption. The targeted self-sufficient rate of grain is fixed at 95% for the long-term (Zhang, 2005). Under China's government tight control, the production and consumption of grain have remained in balance for several decades. Against these backgrounds, within the two-country partial equilibrium trade model, China and the ROW are linked through the trade of protein meals and their associated oilseeds not feed grain or livestock products.

In reality, due to country's expanded oilseed crushing capacity and the advantages of soybean meal compared to other oilseed meals in terms of protein value, protein utilization, price, quantity and safety concerns, the trade of protein meals between China and the ROW expresses primarily as China imports the soybeans from the

ROW, where China's imports equal the ROW exports. The price linkage of soybeans between China and the ROW is also subject to currency exchange rates and tariff rates.

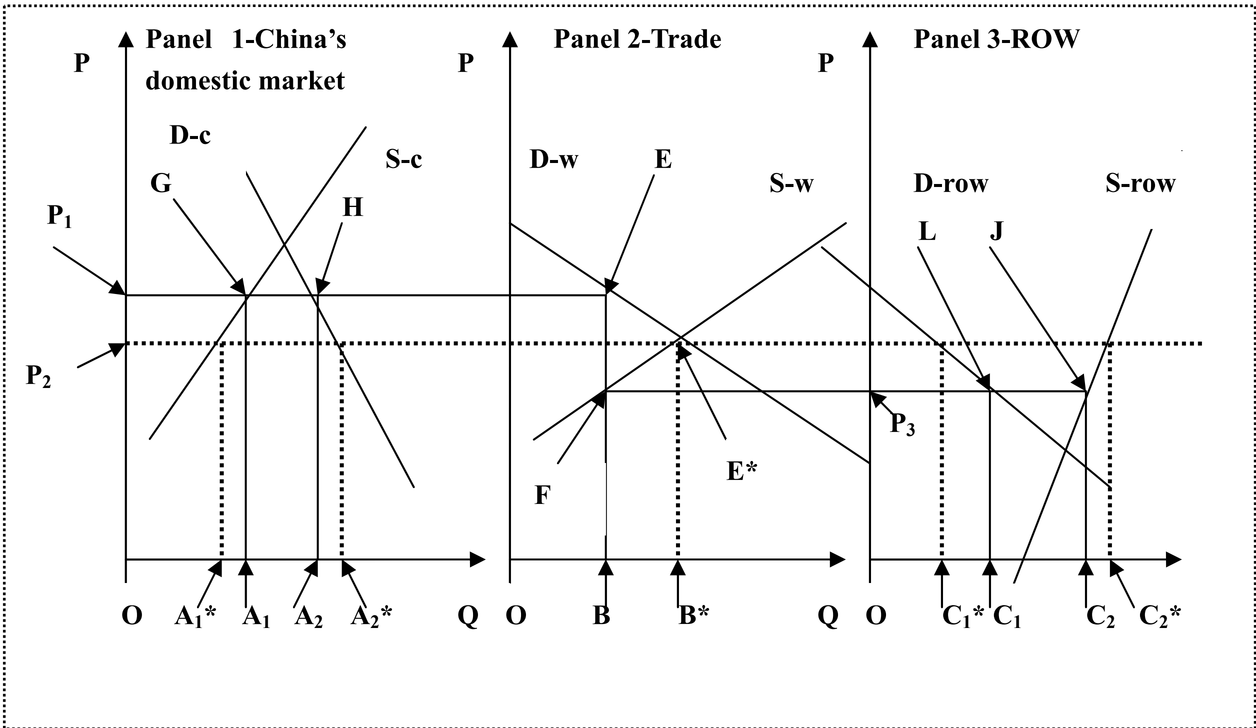
Before laying out the extended structural equations in details, the diagram of soybean trade between China and the ROW is presented. Figure 4.2 shows the effect of China's trade liberalization on soybean trade, where China is a net soybean import country, the ROW represents a net exporter, and China's imports equal to the ROW's exports.

Because China is the world largest importer of soybeans, changes in China's trade policy (trade liberalization and WTO accession) will affect the global soybean demand and supply. As shown in Figure 4.2, China is a net importer of soybeans (Panel 1). A tariff exists between China and the ROW, which equals P_1 minus P_3. The quantity of China's domestic supply is A_1 at point G. The quantity of China's domestic demand is A_2 at point H. China's import equals A_2 minus A_1. Panel 2 indicates the trade market between China and the ROW. Because of tariffs between China and the ROW, China's import price is P_1 at point E on the demand curve (D-w), while the ROW's export price is P_3 at point F on the supply curve (S-w). The trade volume is B. Panel 3 explains market equilibrium of the ROW. The quantity of the ROW's supply is C_2 at point J, the quantity of the ROW's demand is C_1 at point L, and the quantity of the ROW export equals C_2 minus C_1. The linkage of these three panels implies that China's imports or the ROW's exports equals international trade as follows: $(A_2 - A_1) = (C_2 - C_1) = B$.

To gain WTO membership, China liberalized its soybean trade by reducing its tariffs and phasing out its import quotas in the late 1990s. Under free trade, the tariff rate will be zero. This change causes equilibrium price and quantity of trade in Panel 2 to move from the interaction of E to the interaction of E*, which is determined by excess demand (D-w) and supply (S-w). China's domestic price falls from P_1 to P_2, while at same time, the ROW's price jumps up from P_3 to P_2. Consequently, the quantity of China's imports and the ROW's exports increase to $(A_2^* - A_1^*)$ and $(C_2^*$-

C_1*), respectively. Under new equilibrium, China's imports equal to the ROW's exports. The new equilibrium condition can be defined as follows: (A_2* -A_1*) = B* = (C_2*-C_1*).

Figure 4.2: Partial equilibrium trade model of soybeans



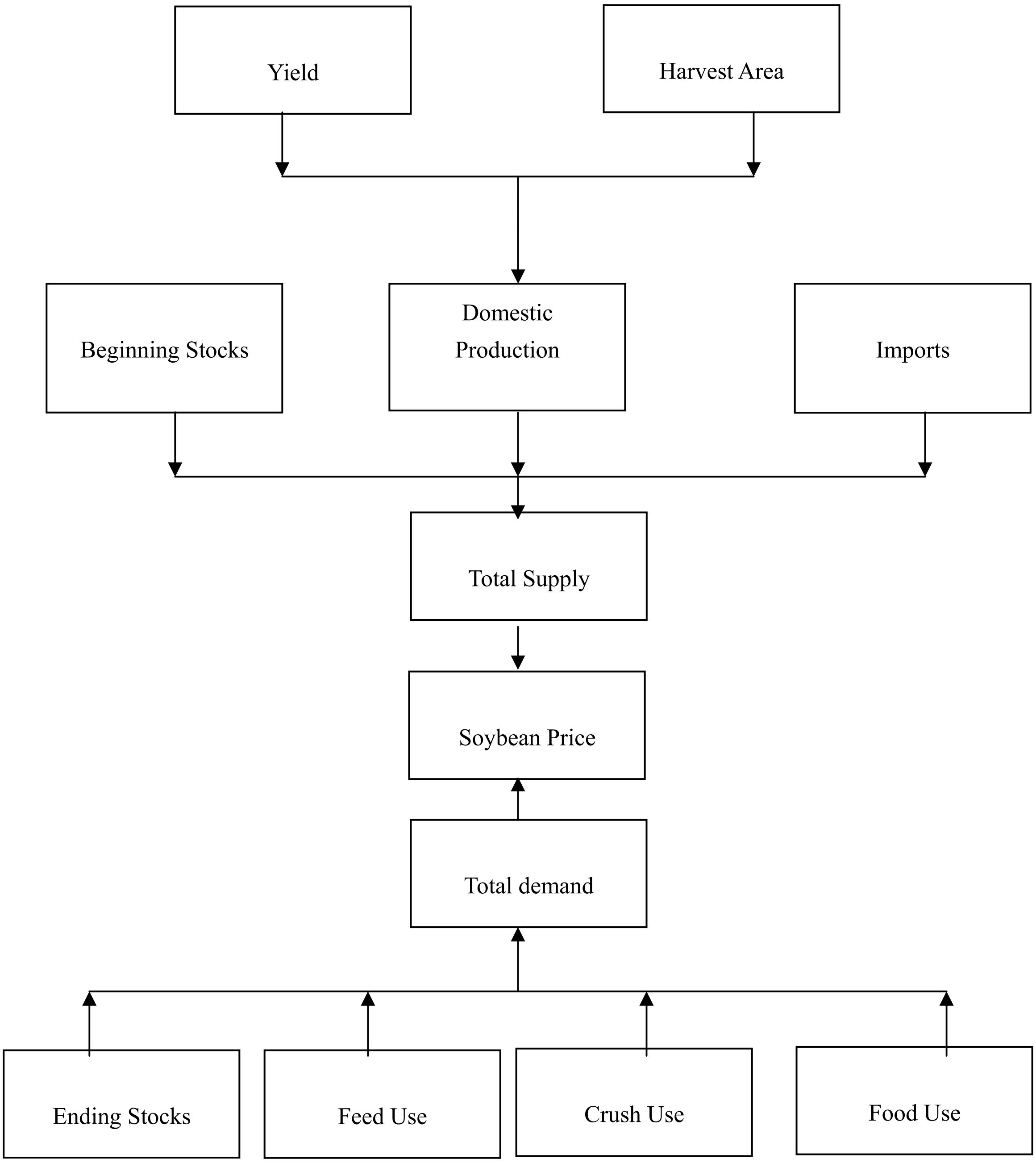
Source: Author

4.2.3 Joint demand and supply dynamics between soybeans and soybean meal

This section explains the joint demand and supply dynamics between soybeans and soybean meal. As explained by Houck et al. (1972), Perera (1996) and Kruse (2003), soybeans, meal, and oil focus on different market – crushing industry, feed industry and human consumption, respectively. All of them have their own supply and demand dynamics. However, supply and demand dynamics for soybeans and their products (oil and meal) are closely linked with each other. Meal and oil are outputs from soybean extraction process and they are joint products in strict scenes. Joint relationship implies that an increase in one component is associated with the rising availability of another component automatically. As a joint product, when soybean meal output is increased that is driven by expanded livestock production, the level of soybean oil production will rise as well.

The supply and demand dynamics for soybeans, oil and meal are presented in the Figure 4.3 and 4.4, respectively.

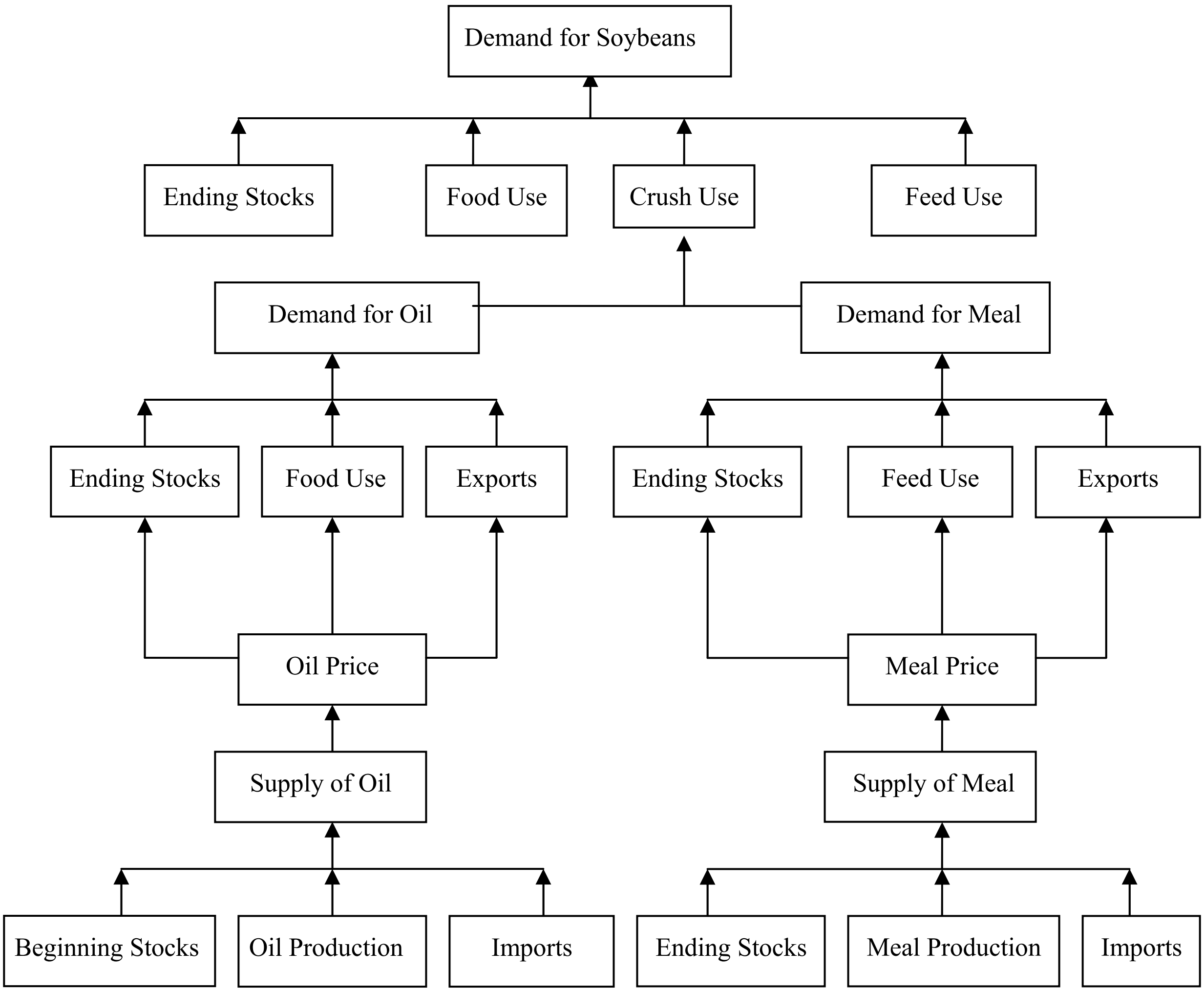
Figure 4.3: Basic structural model of China's soybeans



Source: Kruse, 2003

Figure 4.3 describes the basic market structure of soybeans. Each box in the diagram refers to a behavioral variable. The constructing diagram for China's soybean market follows the concept of the structural model. The equilibrium price is determined by the interaction of soybean supply and demand. The upper part of the figure identifies the behavioral identities affecting the supply of soybeans, while the lower part of the figure illustrates variables on the demand side. Total supply of soybeans consists of domestic production of that year, imports, and beginning stocks, in which domestic production is determined by the harvest areas and the yield. The components of soybean demand include food use, crush use, ending stocks, and feed use.

Figure 4.4: Detail market structure of soybean oil and meal



Source: Author

Figure 4.4 extends demand for soybeans (Figure 4.3) to supply and demand systems of soybean oil and meal. Each box in Figure 4.4 refers to a behavior identity. Crush demand for soybeans is expressed as derived demand (factor input demand), which is indirectly and jointly driven by oil and meal requirement. The demand for soybean oil is made up of food use, ending stocks and exports, while the demand for soybean meal is comprised of three main components including feed use, ending stocks and exports.

Because of joint characteristics, the influence of exogenous variables (increase in household income or livestock production) is represented by changes in demand for soybean oil and meal at same time in the same direction. The change in demand for soybean oil and meal results in reaching their new market equilibrium prices of oil and meal, respectively. The supply of soybean oil and soybean meal will respond in the same direction to the new market equilibrium conditions.

The supply of soybean meal includes beginning stocks, domestic meal production, and imported meal, while total supply of soybean oil consists of beginning stocks, domestic oil production, and imported oil.

4.2.4 Conceptual framework of China's soybean imports

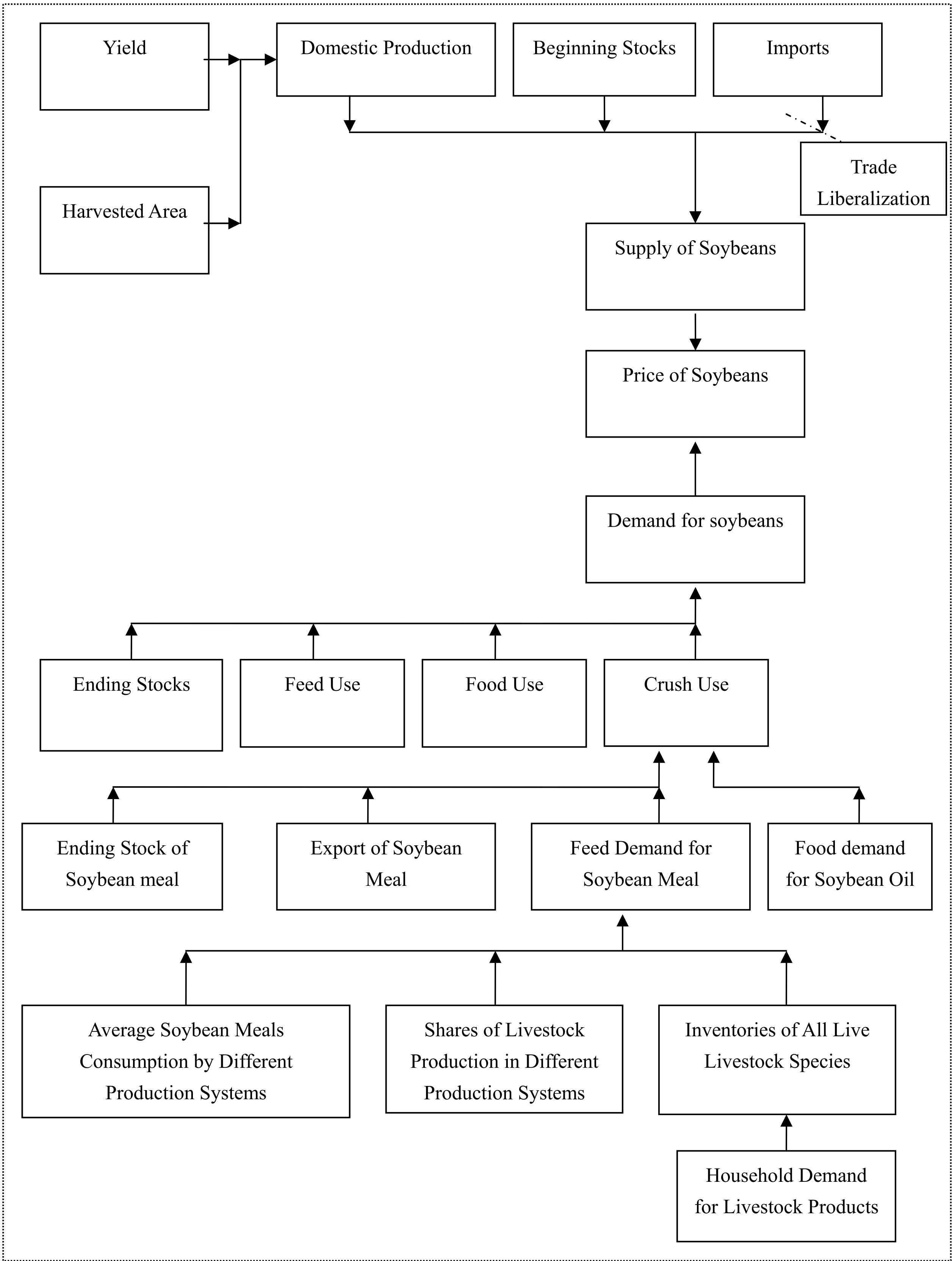
A conceptual framework is constructed for analyzing China's imports of soybeans, driven by expanded livestock production. It requires the incorporation of demand for livestock products, livestock output, livestock inventories, demand for soybean meal, supply of soybean meal, and imports of soybeans. Figure 4.5 integrates Figures 4.1, 4.2, 4.3 and 4.4 from household demand for livestock products to imports of soybeans through various livestock inventories.

As shown in Figure 4.5, the market equilibrium of soybeans in China's domestic market is dependent on interaction of two essential market forces (soybean demand and supply). The upper part of the figure presents the composition of domestic soybean supply, while lower part explains domestic soybean demand. As presented in Figure 4.3, current year domestic production, the beginning stocks and the imported from the ROW make up of total supply of soybeans. Trade liberalization (reducing tariffs and phase out import quotas) as exogenous shock causes the change in China's imports of soybeans.

The components of demand for soybeans include ending stocks, feed use, food use and crush use. The crush demand for soybeans is linked to the meal and oil requirement. The total meal demand is comprised of ending stocks, feed demand and exports.

Feed demand for soybean meal is derived from demand for livestock products. Demand for soybean meal is jointly determined by average use of soybean meal in different raised animal rations (traditional or specialized raised livestock), the shares of livestock production in different production systems, and the inventories of all livestock species (pig and poultry). Household demand for livestock products is an exogenous determinant. Livestock inventories are determined by household demand for livestock products.

Figure 4.5: Conceptual framework for analyzing China's soybean imports



Source: Author

4.3 Model development

The construction of the econometric model follows the basic structural model described in section 4.2.

The following common subscripts are used:

First subscript i for the commodity: i = 1,……, n;

Second subscript j, k for the country: j = China, k = the ROW;

Third subscript t for crop year: t = 1980/1981,…..,2006/2007.

Specific protein meal or oilseed demand at the period ***t*** is explained by its own price, other related commodity prices, quantity of livestock production, household's income or expenditure, and other exogenous variables.

(4.1) $$QCD_{i,j,t} = f(PC_{i,j,t}, PA_{i,j,t}, PA_{i,k,t}, EXP_{i,j,t} LP_{i,j,t}, Z_t)$$

where

EXP = household's income or expenditure

LP = livestock production

PA = price of alternative commodity

PC = price of oilseeds

QCD = quantity of oilseed demanded

Z = other exogenous variable

Oilseed domestic production at the period ***t*** can be calculated by multiplying harvest areas by average yield.

(4.2) $$QCS_{i,j,t} = HA_{i,j,t} * AY_{i,,j,t}$$

where

AY = average yield of oilseeds

HA = harvest areas of oilseeds

QCS = quantity of domestic oilseed production

Harvest area of oilseed at the period ***t*** is determined by its own lagged harvest areas, its lagged price, lagged other related commodity prices and other exogenous variables.

(4.3) $$HA_{i,j,t} = f(HA_{i,j,t-1}, PC_{i,j,t-1}, PA_{i,j,t-1}, V_t)$$

V = other exogenous variable

Hence, the price of oilseed at the period ***t*** is a result of the quantity of its demand and stocks, other related commodity prices, and other exogenous variables.

(4.4) $$PC_{i,j,t} = f(QCD_{i,j,t}, QCT_{i,j,t}, PA_{i,j,t}, PA_{i,k,t}, W_t)$$

where

QCD = quantity of oilseed stocks

W = other exogenous variable

The stocks of the certain year equate the stock of the previous year, plus domestic supply and import minus demand and export.

(4.5) $$QCT_{i,j,t} = QCT_{i,j,t-1} + QCS_{i,j,t} + QCM_{i,j,t} - QCD_{i,j,t} - QCE_{i,j,t}$$

where

QCM = quantity of oilseed imported

QCE = quantity of oilseed exported

Input demand

Crush demand for soybeans is classified as derived demand (factor input demand) since soybeans are the inputs to produce oil and meal in the fixed proportions for different markets. A demand function is developed to estimate crush demand for soybeans by extending production function (Persaud and Chern, 2002; Kruse, 2003). This production function includes two non-allocable inputs, soybeans and crushing machine, producing oil and meal as the joint outputs. It is assumed that an individual soybean crusher operates in a perfectly competitive environment. Then the production functions of soybean crush are given as:

(4.6) $QOS = f(QSC, K)$

(4.7) $QMS = f(QSC, K)$

where

QOS = quantity of soybean oil produced

QMS = quantity of soybean meal produced

QSC = quantity of soybean crush

K = units of oilseed crushing machinery

Total costs (TC), total revenues (TR), and profits (PR) are specified as:

(4.8) $TC = PS * QSC + C * K$

(4.9) $TR = PO * QOS + PM * QMS$

(4.10) $PR = (PO * QOS + PM * QMS) - (PS * QSC + C * K)$

where

C = cost of oilseed crushing machinery per unit

PM = price of soybean meal

PO = price of soybean oil

PR = profit of soybean crush

PS = price of soybean

TC = total cost of soybean crush

TR = total revenues of soybean crush

The production function is substituted into the profit function in order to obtain an unconstrained profit maximization function:

(4.11) $PR = PO * QOS(QSC, K) + PM * QMS(QSC, K) - PS * QSC - C * K$

First order conditions for maximizing profits are obtained by differentiating the profit function with respect to inputs:

(4.12) $$\frac{\partial PR}{\partial QSC} = PO*(\frac{\partial QOS}{\partial QSC}) + PM*(\frac{\partial QMS}{\partial QSC}) - PS = 0$$

(4.13) $$\frac{\partial PR}{\partial K} = PO*(\frac{\partial OOS}{\partial K}) + PM*(\frac{\partial QOM}{\partial K}) - C = 0$$

Simultaneous solutions of the first order conditions provide the demand function for the production factors:

(4.14) $$QSC = f(PS, PO, PM, C)$$

Price relationship between soybeans and their by-products (oil and meal)

According to Dalian Commodity Exchange Database (2009), the price relationship of soybean, meal and oil in China is defined as:

(4.15) $$PCSYS_t = PCSYM_t * SYSM + PCSYO_t * SYSO - COSTC$$

where

$PCSYS$ = soybean price in RMB per metric ton, China

$PCSYM$ = soybean meal price in RMB per metric ton, China

$SYSM$ = quantity of soybean meal produced from one tone soybean

$PCSYO$ = soybean oil price in RMB per metric ton, China

$SYSO$ = quantity of soybean oil produced from one tone soybean

$COSTC$ = cost of crushing one ton of soybean

Function of 4.15 states that prices of soybeans, oil and meal are closely related.

Adaptive expectations

The principle of adaptive expectation states that future values of economic variables can be formulated or predicated on the basis of previous values and their error terms (Evans and Honkapohja, 2001). Theory of adaptive expectation has widely been used for analyzing demand and supply dynamics of oilseeds and related products (Kruse, 2003; Liu, 2004). The actual production is dependent on the expected price rather than actual price.

The process of adaptive expectations can be described as:

(4.16) $$P^*_t - P^*_{t-1} = \gamma(P_{t-1} - P^*_{t-1}) + u_t$$

where

P^*_t = the expected price in year t

P^*_{t-1} = the expected price in year t-1

P_{t-1} = the actual price in year t-1

γ = the coefficient of adjustment ($0 \leq \gamma \leq 1$)

u_t = error term in year t

Function 4.16 states that the difference between expected price in year ***t*** and expected price in year ***t-1*** equals the difference between actual price and expected price in the previous period (error term), multiplied by γ, the partial-adjustment factor.

Function of 4.17 is developed based on function of 4.16:

(4.17) $$P^*_{t+1} = P^*_t + \gamma(P_t - P^*_t) + u_{t+1}$$

where:

P_t = the actual price in year t

u_{t+1} = error term in year t+1

Function of 4.17 implies that the expected price in year ***t+1*** reflects expected price in year ***t*** plus the difference between actual price and expected price in year ***t***.

Function of 4.18 explains that production in year ***t*** is determined by the expected price in year ***t+1***.

(4.18) $$Q_t = \beta_0 + \beta_1 P^*_{t+1}$$

where

Q_t = quantity of production in year t

β_i = production function parameters

By substituting function 4.17 into function 4.18 to replace the unobservable variable P^*_{t+1}, the following function is yielded:

(4.19) $$Q_t = \beta_0\gamma + \beta_1\gamma P_t + (1-\gamma)Q_{t-1} + u_t$$

Thus, current period production depends on lagged dependent variable and actual price. Function 4.19 is the final function, which shows an autoregressive procedure and all independent variable are known.

4.4 System equations

4.4.1 China's soybean sector

Crush demand function

As explained early in this Chapter, crush demand for soybeans is classified as an input demand, which depends on demand for soybean meal, derived from livestock production. Consequently, it is expected that the rising meat output has positive effect on crush demand for soybeans. Crush demand for soybeans is assumed to be negatively related to own-price.

It assumes a positive response of crush demand for soybeans to increase in output price (soybean meal price). Moreover, it is assumed that there is a substitute relationship between soybeans and rapeseed. For this reason, it is expected that the effect of the increasing rapeseed price on crush demand for soybeans is positive. The expected signs of dependent variables with respect to changes in explanatory variables are displayed in Table 4.2.

Table 4.2: Determinants of China's soybean crush demand and expected signs

Dependent variable: Quantity of China's soybean crushed

Explanatory variables		Expected signs on dependent variable
PCSYS	Soybean price, China	-
PCRAS	Rapeseed price, China	+
PCSYM	Soybean meal price, China	+
MEAT	Meat output, China	+

Source: Author's prediction

As shown in function 4.20a, crush demand for soybeans in China (*$QCSYSU_t$*) is defined as a function of soybean price (*$PCSYS_t$*), rapeseed price (*$PCRAS_t$*), soybean meal price (*$PCSYM_t$*), and meat output (*$MEAT_t$*). Since the per unit production costs (*C*) are assumed to be constant, they are not included in the extended function.

(4.20a) $QCSYSU_t = f(PCSYS_t, PCRAS_t, PCSYM_t, MEAT_t)$

Compared with linear regression, advantage of double logarithmic regression is that estimated parameters directly provide price and income elasticies. The function for soybean crush demand in China is estimated in double logarithmic form and partial adjustment. Therefore, the estimated function is specified as:

(4.20b)
$$Log(QCSYSU_t) = \beta_0 + \beta_1 Log(QCSYSU_{t-1}) + \beta_2 Log(PCSYS_t) + \beta_3 Log(PCRAS_t) + \beta_4 Log(PSCYM_t) + \beta_5 Log(MEAT_t)$$

where

β_0 = constant term

β_1,….., β_5 = regression coefficients

Price function

The explanations of the selected explanatory variables of soybean price in China are shown in Table 4.3. It is expected that soybean price is negatively related to soybean stock level and positively related to the amount of soybean crushed. In addition, the amount of soybean crushed is inversely proportional to its stock level. Against this background, stocks-to-crush ratio is set up to avoid the multicollinearity. It is expected a negative response of soybean price to increase in soybean stocks-to-crush ratio. In China, both soybeans and corn production area concentrate in the areas of Northeast and North Plain and they compete with each-other. For this reason, it is assumed that the effect of corn price on soybean price is negative.

Table 4.3: Determinants of China's soybean price and expected signs

Dependent variable: China's soybean price

Explanatory variables		**Expected signs on dependent variable**
PCRAS	Rapeseed price, China	+
SS/SC	Soybean stocks-to-crush ratio, China	-
PCCNS	Corn price, China	-
PCSYS (-1)	Lagged soybean price, China	+

Source: Author's predication

China's soybean price ($PCRAS_t$) is considered as a function of rapeseed price ($PCRAS_t$), soybean stocks-to-crush ratio $\left(\frac{SS}{SC}\right)_t$, and lagged corn price ($PCCNS_{t-1}$).

(4.21a) $PCSYS_t = f\,(PCRAS_t, (SS/SC)_t, PCCNS_{t-1})$

The function for China's soybean price is estimated in double logarithmic form and partial adjustment. Therefore, the estimated function is specified as:

$$(4.21b)\quad Log(PCSYS_t) = \beta_0 + \beta_1 Log(PCRAS_t) + \beta_2 Log(\frac{SS}{SC})_t + \beta_3 Log(PCCNS_t) + \beta_4 Log(PCSYC_{t-1})$$

Import demand function

In late 1990s, China reduced its tariff on soybeans in order to gain WTO membership. A dummy variable is introduced to capture the impact of WTO accession on imports of soybeans, which equal to 0 from 1978 to 1995, and equal to 1 afterwards. The imports of soybeans are expected to be positively related to domestic soybean price and negatively related soybean price in the ROW. To avoid the multicollinearity, the ratio of domestic soybean price to soybean price in the ROW is calculated. It is expected a positive response of imports of soybeans to increase in ratio of domestic soybean price to soybean price in the ROW. It is assumed that the rising meat output has the positive impact on imports of soybeans. The explanations of the selected explanatory variables are given in Table 4.4.

Table 4.4: Determinants of China's soybean imports and expected signs

Dependent variable: Quantity of China's Soybean Imported

Explanatory variables		**Expected signs on dependent variable**
MEAT	Meat output, China	+
PCSYS/ PWSYSR	Ratio of China's soybeans price to the ROW soybean price	+
DUMWTO	Dummy variable for China's WTO accession	

Source: Author's predication

China's import demand for soybeans ($QCSYSM_t$) is a function of meat output ($MEAT_t$), the ratio of domestic soybean price to the ROW soybean price $\left(\frac{PCSYS}{PWSYSR}\right)_t$, and the dummy variable ($DUMWTO_t$).

(4.22a) $QCSYSM_t = f\left(MEAT_t, \left(\frac{PCSYS}{PWSYSR}\right)_t, DUMWTO\right)$

Because the variable series of $QCSYSM_t$ contain the negative numbers, linear regression is used to estimate the parameters. Therefore, the estimated function is specified as:

(4.22b) $$QCSYSM_t = \beta_0 + \beta_1 MEAT_t + \beta_2 \left(\frac{PCSYS}{PWSYSR}\right)_t + \beta_3 DUMWTO$$

Production function

It is expected that soybean producers automatically adjust their plant areas to maximize profit through comparing the soybean price with competing crop prices. Table 4.5 presents the expected signs of domestic soybean production with respect to changes in explanatory variables. The lagged domestic soybean production is expected to have the positive impact on dependent variable. It is assumed that domestic soybean production is positively related to own price. It supposes that there is a substitute relationship between soybeans and rapeseed. Consequently, rapeseed price will be positively related to China's domestic soybean production. It is assumed that lagged corn price is negatively related to domestic soybean production. Trend variable is introduced as a proxy to determine the effect of technical change. Trend variable takes the value 1, 2, 3, ……, 26, 27. Trend variable likely has the positive effect on China's domestic soybean production.

Table 4.5: Determinants of China's domestic soybean production and expected signs

Dependent variable: Quantity of China's domestic soybean production

Explanatory variables		**Expected signs on dependent variable**
QCSYSP (-1)	Lagged quantity of domestic soybean production, China	+
PCSYS(-1)	Lagged soybeans price, China	+
PCRAS (-1)	Lagged rapeseed price, China	+
PCCNS(-1)	Lagged corn price, China	-
TREND	Trend variable	+

Source: Author's prediction

Domestic soybean production ($QCSYSP_t$) is represented in the function of lagged own production ($QCSYSP_{t-1}$), lagged soybean price ($PCSYS_{t-1}$), lagged rapeseed price ($PCRAS_{t-1}$), lagged corn price ($PCCNS_{t-1}$) and a trend variable *(TREND)*.

(4.23a) $QCSYSP_t = f\,(QCSYSP_{(t-1)}, PCSYS_{(t-1)}, PCRAS_{(t-1)}, PCCNS_{(t-1)}, TREND)$

Linear regression is applied to estimate the parameters of soybean production function. The function for domestic soybean production is estimated in the partial adjustment form. Therefore, the estimated function is specified as:

(4.23b) $$QCSYSP_T = \beta_0 + \beta_1(QCSYSP_{t-1}) + \beta_2(PCSYS_{t-1}) + \beta_3(PCRAS_{t-1}) + \beta_4(PCCNS_{t-1}) + \beta_5 TREND$$

Food demand function

Table 4.6 shows the expected signs of soybean food consumption with respect to changes in explanatory variables. It is expected that soybean food consumption is positively related to GDP per capita and negatively related to its price.

Table 4.6: Determinants of China's soybean food demand and expected signs

Dependent variable: Quantity of China's soybean food consumption per capita

Explanatory variables		**Expected signs on dependent variable**
GDPP	GDP per capita, China	+
PCSYS	Soybeans price, China	-

Source: Author's prediction

Soybean food consumption in China (*$QCSYSFP_t$*) is explained as a function of GDP per capita (*$GDPP_t$*) and soybean price (*$PCSYS_t$*).

(4.24a) $QCSYSFP_t = f\,(GDPP_t, PCSYS_t)$

The function for soybean food consumption in China is estimated in double logarithmic form and partial adjustment. Therefore, the estimated function is specified as:

(4.24b)

$$Log(QCSYSFP_t) = \beta_0 + \beta_1 Log(GDPP_t) + \beta_2 Log(PCSYS_t) + \beta_3 Log(QCSYSFP_{t-1})$$

4.4.2 ROW soybean sector

Crush demand function

Unlike the China's soybean crush demand function, world average GNI per capita is an exogenous variable. For consistent, the ROW soybean crushed is also updated to per capita level. The effects of the explanatory variables on crush demand for soybeans in the ROW are introduced in Table 4.7. It is supposed a positive response of crush demand for soybeans to increase in world GNI per capita. It is expected that crush demand for soybeans is positively related to rapeseed price.

Table 4.7: Determinants of the ROW soybean crush demand and expected signs

Dependent variable: Quantity of the ROW soybean crushed per capita

Explanatory variables		**Expected signs on dependent variable**
PWSYS	Soybean price, ROW	-
PWRAS	Rapeseed price, ROW	+
GNIP	World average GNI per capita	+

Source: Author's prediction

Crush demand for soybeans in the ROW ($QWSYSUP_t$) is assumed as a function of soybean price ($PWSYS_t$), rapeseed price ($PWRAS_t$) and GNI per capita ($GNIP_t$).

(4.25a) $QWSYSUP_t = f\,(PWSYS_t, PWRAS_t, GNIP_t)$

The function for the ROW soybean crush demand is estimated in double logarithmic form and partial adjustment. Therefore, the estimated function is specified as:

(4.25b)
$$Log(QWSYSUP_t) = \beta_0 + \beta_1 Log(PWSYS_t) + \beta_2 Log(PWRAS_t) + \beta_3 Log(GNIP_t) + \beta_4 Log(QWSYSUP_{t-1})$$

Price function

As shown in table 4.8, soybean price in the ROW is estimated to depend on rapeseed price and soybean stocks-to-crush ratio. Soybean price is assumed to be positively related to rapeseed price. Since the effects of soybean stocks and soybean crush on soybean price in the ROW show opposite sign, the soybean stocks-to-crush ratio is calculated. It is expected that the rising soybean stocks-to-use ratio has the negative effect on the ROW soybean price.

Table 4.8: Determinants of the ROW soybean price and expected signs

Dependent variable: the ROW Soybean price

Explanatory variables		**Expected signs on dependent variable**
PWRAS	Rapeseed price, ROW	+
RWSYSU	Soybean stocks-to-crush ratio, ROW	-

Source: Author's prediction

Soybean price in the ROW ($PWSYS_t$) is considered as a function of rapeseed price ($PWRAS_t$) and the ratio of soybean stocks-to-use ($RWSYSU_t$).

(4.26a) $PWSYS_t = f\,(PWRAS_t, RWSYSU_t)$

The function for soybean price in the ROW is estimated in double logarithmic form. Therefore, the estimated function is specified as:

(4.26b) $$Log(PWSYS_t) = \beta_0 + \beta_1 Log(PWRAS_t) + \beta_2 Log(RWSYSU_t)$$

Export function

Explanatory variables of export demand for soybeans in the ROW include the ratio of China's soybeans price to the ROW soybean price and GDP per capita in China. The expected effects of explanatory variables on dependent variable are presented in Table 4.9. The effect of per capita GDP on ROW soybean exports is assumed to be positive. It is assumed that the ROW export of soybeans is positively related to price development between China and the ROW.

Table 4.9: Determinants of the ROW soybean export demand and expected signs

Dependent variable: Quantity of the ROW soybean exported

Explanatory variables		**Expected signs on dependent variable**
PCSYS/ PWSYSR	Ratio of China's soybeans price to the ROW soybean price	+
GDPP	GDP per capita, China	+

Source: Author's prediction

Explanatory variables of export demand for soybeans in the ROW ($QWSYSE_t$) include the ratio of China's soybean price to the ROW soybean price $\left(\frac{PCSYS}{PWSYSR}\right)_t$ and GDP per capita in China ($GDPP_t$)

(4.27a) $$QWSYSE_t = f\left(\left(\frac{PCSYS}{PWSYSR}\right)_t, GDPP_t\right)$$

Function for the ROW soybean export demand is estimated in double logarithmic from. Therefore, the estimated function is specified as:

(4.27b) $$Log(QWSYSE_t) = \beta_0 + \beta_1 Log\left(\frac{PCSYS}{PWSYSR_t}\right) + \beta_2 * Log(GDPP_t)$$

Production function

The expected effects of explanatory variables on soybean production in the ROW are shown in Table 4.10. The effect of lagged dependent variable is assumed to be positive. It is supposed a positive response of soybean production in the ROW to increase in own price. The trend variable is involved to capture the impact of the technical change. The technology change is supposed to be positively related to soybean production.

Table 4.10: Determinants of the ROW soybean production and expected signs

Dependent variable: Quantity of the ROW soybean production

Explanatory variables		**Expected signs on dependent variable**
PWSYS(-1)	Lagged soybean price, ROW	+
QWSYSP(-1)	Lagged quantity of soybean production, ROW	+
TREND	Trend variable	+

Source: Author's predication

Soybean production in the ROW ($QWSYSP_t$) is given as a function of lagged own production ($QWSYSP_{t-1}$), lagged own price ($PWSYS_{t-1}$) and trend variable ($TREND$).

(4.28a) $QWSYSP_t = f(QWSYSP_{(t-1)}, PWSYS_{(t-1)}, TREND)$

The function for soybean production in the ROW is estimated in the partial adjustment. Therefore, the estimated function is specified as:

(4.28b) $$QWSYSP_t = \beta_0 + \beta_1(QWSYSP_{t-1}) + \beta_2(PWSYS_{t-1}) + \beta_3 TREND$$

4.4.3 China's rapeseed sector

Crush demand function

Crush demand function for rapeseed is formulated in a similar approach as soybean crush demand. The expected relationship between crush demand for rapeseed and explanatory variables are shown in Table 4.11. The effect of the rising meat output on crush demand for rapeseed is assumed to be positive. Crush demand for rapeseed is supposed to be negatively related to own price. It is assumed a positive response of dependent variable to rise in GDP per capita. The effect of increase in supply of substitute commodity (soybeans) is assumed to be positive.

Table 4.11: Determinants of China's rapeseed crush demand and expected signs

Dependent variable: Quantity of China's rapeseed crushed

Explanatory variables		Expected signs on dependent variable
MEAT	Meat output, China	+
PCRAS	Rapeseed price, China	-
PCSYS	Soybean price, China	+
GDPP	GDP per capita, China	+

Source: Author's prediction

Crush demand for rapeseed in China (*$QCRASU_t$*) is considered to depend on meat output (*$MEAT_t$*), rapeseed price (*$PCRAS_t$*), soybean price (*$PCSYS_t$*) and GDP per capita (*$GDPP_t$*).

(4.29a) $QCRASU_t = f(MEAT_t, PCRAS_t, PCSYS_t, GDPP_t)$

The function for rapeseed crush demand in China is estimated in double logarithmic form and partial adjustment. Therefore, the estimated function is specified as:

(4.29b)
$$Log(QCRASU_t) = \beta_0 + \beta_1 Log(QCRASU_{t-1}) + \beta_2 Log(MEAT_t) + \beta_3 Log(PCRAS_t) + \beta_4 Log(PCSYS_t) + \beta_5 Log(GDPP_t)$$

Price function

As presented in Table 4.12, it is assumed a positive response of rapeseed price to increase in corn price. Same as function for soybean price, the variable of rapeseed stocks-to-crush ratio is created. It is supposed that the effect of the rising rapeseed stocks-to-crush ratio on rapeseed price is negative.

Table 4.12: Determinants of China's rapeseed price and expected signs

Dependent variable: China's rapeseed price

Explanatory variables		Expected signs on dependent variable
RS/RU	Rapeseed stocks-to-crush ratio, China	-
PCCNS	Corn price, China	+

Source: Author's prediction

Function for rapeseed price in China is explained by China's rapeseed stocks-to-crush ratio and corn price in China.

(4.30a) $PCRAS_t = f\left(\left(\frac{RS}{RU}\right)_t, PCCNS_t\right)$

The function for rapeseed price in China is estimated in double logarithmic form and the partial adjustment. Therefore, the estimated function is specified as:

(4.30b) $$Log(PCRAS_t) = \beta_0 + \beta_1 Log\left(\frac{RS}{RU}\right)_t + \beta_2 Log(PCCNS_t) + \beta_3 Log(PCRAS_{t-1})$$

Production function

The expected effects of explanatory variables on rapeseed production in China are presented in Table 4.13. The effect of previous year production on current production is expected to be positive. It is assumed the positive responses of rapeseed production to increase in rapeseed price and soybean price. Effect of corn price is believed to be negative, while impact of technical change (trend variable) is assumed to be positive.

Table 4.13: Determinants of China's rapeseed production and expected signs

Dependent variable: Quantity of China's rapeseed production

Explanatory variables		**Expected signs on dependent variable**
QCRASP(-1)	Lagged quantity of rapeseed production, China	+
PCRAS(-1)	Lagged rapeseed price, China	+
PCSYS(-1)	Lagged soybean price, China	+
PCCNS(-1)	Lagged corn price, China	-
TREND	Trend variable	+

Source: Author's prediction

Rapeseed production in China (*$QCRASP_t$*) is determined by lagged own production (*$QCRASP_{t-1}$*), lagged own price (*$PCRAS_{t-1}$*), lagged soybean price (*$PCSYS_{t-1}$*), lagged corn price *$PCCNS_{t-1}$*, and trend variable.

(4.31a) $QCRASP_t = f(QCRASP_{(t-1)}, PCRAS_{(t-1)}, PCSYS_{(t-1)}, PCCNS_{(t-1)}, TREND)$

The function for rapeseed production in China is estimated in the partial adjustment.

Therefore, the estimated function is specified as:

(4.31b) $$QCRASP_t = \beta_0 + \beta_1 * (QCRASP_{t-1}) + \beta_2 * (PCRAS_{t-1}) + \beta_3 * (PCSYS_{t-1}) + \beta_4 * (PCCNS_{t-1}) + \beta_5 * TREND$$

4.4.4 ROW rapeseed sector

Crush demand function

The expected relationship between crush demand for rapeseed and explanatory variables are shown in Table 4.14. The effects of own price on crush demand for rapeseed is supposed to be negative. Since it is assumed there is a substitute relationship between soybeans and rapeseed in the ROW. There is a positive response of crush demand for rapeseed to increase in soybean price and average GNI per capita.

Table 4.14: Determinants of the ROW rapeseed crush demand and expected signs

Dependent variable: Quantity of the ROW rapeseed crushed per capita

Explanatory variables		Expected signs on dependent variable
PWRAS	Rapeseed price, ROW	-
PWSYS	Soybean price, ROW	+
GNIP	World average GNI per capita	+

Source: Author's prediction

Crush demand for rapeseed in ROW (*$QWRASUP_t$*) is explained as a function of rapeseed price (*$PWRAS_t$*), soybean price (*$PWSYS_t$*) and world average GNI per capita (*$GNIP_t$*)

(4.32a) $QWRASUP_t = f\,(PWRAS_t, PWSYS_t, GNIP_t)$

The function for rapeseed crush demand in ROW is estimated in double logarithmic form and partial adjustment. Therefore, the estimated function is specified as:

(4.32b)
$$Log(QWRASUP_t) = \beta_0 + \beta_1 Log(QWRASUP_{t-1}) + \beta_2 Log(PWRAS_t) + \beta_3 Log(PWSYS_T) + \beta_4 Log(GNIP_t)$$

Price function

The expected relationship between the ROW rapeseed price and explanatory variables are shown in Table 4.15. It is assumed that the response of the ROW rapeseed price to increase in the ROW soybeans price is positive. For the ROW, the stocks of rapeseed are calculated through the production of certain year minus crushed of that year. Then, the ratio of rapeseed stocks-to-crush is calculated to avoid the multicollinearity. It is expected the effect of this ratio on rapeseed price in the ROW is negative.

Table 4.15: Determinants of the ROW rapeseed price and expected signs

Dependent variable: The ROW Rapeseed price

Explanatory variables		Expected signs on dependent variable
RWRASU	Rapeseed stocks-to-crush ratio, ROW	-
PWSYS	Soybean price, ROW	+

Source: Author's predication

Rapeseed price in the ROW *($PWRAS_t$)* is defined as a function of rapeseed stocks-to-use ratio *($RWRASU_t$)* and soybean price *($PWSYS_t$)*.

(4.33a) $PWRAS_t = f\,(RWRASU_t, PWSYS_t)$

The function for rapeseed price in the ROW is estimated in partial adjustment.

Therefore, the estimated function is specified as:

(4.32b) $$(PWRAS_t) = \beta_0 + \beta_1(RWRASU_t) + \beta_2(PWSYS_1) + \beta_3(PWRAS_{t-1})$$

Production function

The expected impact of explanatory variables on rapeseed production in the ROW is shown in Table 4.16. The effect of lagged dependent variable is assumed to be positive. It is supposed a positive response of rapeseed production to increase in own price. Technical change has the positive impact on rapeseed production.

Table 4.16: Determinants of the ROW rapeseed production and expected signs

Dependent variable: Quantity of the ROW rapeseed production

Explanatory variables		Expected signs on dependent variable
QWRASP(-1)	Lagged quantity of rapeseed production, ROW	+
PWRAS(-1)	Lagged rapeseed price, ROW	+
TREND	Trend variable	+

Source: Author's prediction

The rapeseed production in the ROW (*$QWRASP_t$*) is determined by lagged own production (*$QWRASP_{t-1}$*), lagged own price (*$PWRAS_{t-1}$*), and trend variable (*TREND*).

(4.34a) $QWRASP_t = f\,(QWRASP_{(t-1)}, PWRAS_{(t-1)}, TREND)$

The function for rapeseed production in the ROW is estimated in the partial adjustment. Therefore, the estimated function is specified as:

(4.34b) $$QWRASP_t = \beta_0 + \beta_1(QWRASP_{t-1}) + \beta_2(PWRAS_{t-1}) + \beta_3 TREND$$

4.4.5 China's peanut sector

Crush demand function

Crush demand for peanuts in China is explained by meat output and corn price. The expected relationship between crush demand for peanuts and explanatory variables are shown in Table 4.17. Crush demand for peanuts is expected to rise following the growth of meat output. It is expected that the effect of China's corn price on peanut crush in China is negative.

Table 4.17: Determinants of China's peanut crush demand and expected signs

Dependent variable: Quantity of China's peanuts crushed

Explanatory variables		**Expected signs on dependent variable**
MEAT	Meat output, China	+
PCCNS	Corn price, China	-

Source: Author's prediction

As the price information of China's peanuts is unavailable (procurement system in 1980s), crush demand for peanuts in China ($QCPNSU_t$) is assumed as the function of meat output ($MEAT_t$) and corn price ($PCCNS_t$).

(4.35a) $QCPNSU_t = f(MEAT_t, PCCNS_t)$

The function for peanut crush demand in China is estimated in double logarithmic form and the partial adjustment. Therefore, the estimated function is specified as:

(4.35b) $$Log(QCPNSU_t) = \beta_0 + \beta_1 Log(QCPNSU_{t-1}) + \beta_2 Log(MEAT_t) + \beta_3 Log(PCCNS_t)$$

Production function

As shown in Table 4.18, it is expected that soybean price and trend variable are positively related to peanut production. It is assumed a negative response of peanut production to increase in corn price. The effect of technical change on peanut production is supposed to be positive.

Table 4.18: Determinants of China's peanut production and expected signs

Dependent variable: Quantity of China's peanut production

Explanatory variables		Expected signs on dependent variable
QCPNSP(-1)	Lagged quantity of China's peanut production	+
PCCNS(-1)	Lagged China's corn price	-
PCSYS(-1)	Lagged China's soybean price	+
TREND	Trend variable	+

Source: Author's predication

Peanut production in China ($QCPNSP_t$) is considered to depend on lagged own production ($QCPNSP_{t-1}$), lagged corn price ($PCCNS_{t-1}$), lagged soybean price ($PCSYS_{t-1}$), and trend variable ($TREND$).

(4.36a) $QCPNSP_t = f(QCPNSP_{t-1}, PCCNS_{t-1}, PCSYS_{t-1}, TREND)$

The function for peanut production in China is estimated in the partial adjustment. Therefore, the estimated function is specified as:

(4.36b) $$QCPNSP_t = \beta_0 + \beta_1(QCPNSP_{t-1}) + \beta_2(PCCNS_{t-1}) + \beta_3(PCSYS_{t-1}) + \beta_4 TREND$$

4.4.6 China's soybean meal sector

Demand function

As presented in Table 4.19, it is expected a positive response of demand for soybean meal in China to increase in meat output. The effect of own price is assumed to be negative. It is supposed that there is complementary relation between corn and soybean meal for feeding farm animals. Consequently, it is expected that demand for soybean meal is negatively related to corn price.

Table 4.19: Determinants of China's soybean meal demand and expected signs

Dependent variable: Quantity of China's soybean meal consumption

Explanatory variables		Expected signs on dependent variable
MEAT	Meat output, China	+
PCSYS	Soybean price, China	-
PCCNS	Corn price, China	-

Source: Author's prediction

Demand for soybean meal in China ($QCSYMC_t$) is considered as a function of meat output ($MEAT_t$), soybean price ($PCSYS_t$), and corn price ($PCCNS_t$).

(4.37a) $QCSYMC_t = f(MEAT_t, PCSYS_t, PCCNS_t)$

The function for soybean meal consumption in China is estimated in double logarithmic form and partial adjustment. Therefore, the estimated function is specified as:

(4.37b) $$Log(QCSYMC_t) = \beta_0 + \beta_1 Log(MEAT_t) + \beta_2 Log(PCSYS_t) + \beta_3 Log(PCNNS_t) + \beta_4 Log(QCSYMC_{t-1})$$

4.4.7 ROW soybean meal sector

Demand function

As indicated in Table 4.20, it is expected that the response of demand for soybean meal in the ROW to increase in own price is negative. The effects of world average GNI per capita on dependent variable is positive.

Table 4.20: Determinants of the ROW soybean meal demand and expected signs

Dependent variable: Quantity of the ROW soybean meal consumption per capita

Explanatory variables		Expected signs on dependent variable
PWSYM	Soybean meal price, ROW	-
GNIP	World average GNI per capita	+

Source: Author's prediction

Demand for soybean meal in the ROW ($QWSYMCP_t$) is given as a function of the ROW price of soybean meal ($PWSYM_t$) and world average GNI per capita ($GNIP_t$).

(4.38a) $QWSYMCP_t = f(PWSYM_t, GNIP_t)$

The function for soybean meal demand in the ROW is estimated in double logarithmic form and partial adjustment. Therefore, the estimated function is specified as:

(4.38b) $$Log(QWSYMCP_t) = \beta_0 + \beta_1 Log(QWSYMCP_{t-1}) + \beta_2 Log(PWSYM_t) + \beta_3 Log(GNIP_t)$$

4.4.8 China's rapeseed meal sector

Demand function

Demand for rapeseed meal in China is considered to depend on meat output, own price, soybean meal price and corn price. The demand for rapeseed meal with respect to changes in explanatory variables is displayed in Table 4.21. It is assumed there is substitute relationship between soybean meal and rapeseed meal. Thus, it is expected that demand for rapeseed meal is postively related to soybean meal price. The impact of meat output on dependent variable is assumed to be positive, while the effect of corn price is supposed to be negative.

Table 4.21: Determinants of China's rapeseed meal demand and expected signs

Dependent variable: Quantity of China's rapeseed meal consumption

Explanatory variables		Expected signs on dependent variable
MEAT	Meat output, China	+
PCRAM	Rapeseed meal price, China	-
PCSYM	Soybean meal price, China	+
PCCNS	Corn price, China	-

Source: Author's prediction

Demand for rapeseed meal in China ($QCRAMC_t$) is determined by meat output ($MEAT_t$), own price ($PCRAM_t$), soybean meal price ($PCSYM_t$) and corn price ($PCCNS_t$).

(4.39a) $QCRAMC_t = f(MEAT_t, PCRAM_t, PCSYM_t, PCCNS_t)$

The function for rapeseed meal demand in China is estimated in double logarithmic form and partial adjustment. Therefore, the estimated function is specified as:

(4.39b) $$Log(QCRAMC)_t = \beta_0 + \beta_1 Log(MEAT_t) + \beta_2 Log(QCRAMC_{t-1}) + \beta_3 Log(PCRAM_t) + \beta_4 Log(PCSYM_t) + \beta_5 Log(PCCNS_t)$$

4.4.9 ROW rapeseed meal sector

Demand function

Table 4.22 presented the expected signs of demand for rapeseed meal in the ROW with respect to changes in explanatory variables. It is assumed that demand for rapeseed meal is negative related to own price. The effects of the ROW soybean meal price and world average GNI per capita on dependent variable are positive.

Table 4.22: Determinants of the ROW rapeseed meal demand and expected signs

Dependent variable: Quantity of the ROW rapeseed meal consumption per capita

Explanatory variables		Expected signs on dependent variable
PWRAM	Rapeseed meal price, ROW	-
GNIP	World average GNI per capita	+
PWSYM	Soybean meal price, ROW	+

Source: Author's prediction

Demand for rapeseed meal in the ROW ($QWRAMCP_t$) is specified as a function of own price ($PWRAM_t$), world average GNI per capita ($GNIP_t$), and soybean meal price ($PWSYM_t$).

(4.40a) $QWRAMCP_t = f\,(PWRAM_t, GNIP_t, PWSYM_t)$

The function for rapeseed meal demand in the ROW is estimated in double logarithmic form and partial adjustment. Therefore, the estimated function is specified as (4.40b):

(4.40b)
$$Log(QCRAMCP_t) = \beta_0 + \beta_1 Log(PWRAM_t) + \beta_2 Log(GNIP_t) + \beta_3 Log(PWSYM_t) + \beta_4 Log(QCRAMCP_{t-1})$$

4.4.10 China's fish meal sector

Demand function

As displayed in Table 4.23, the response of fish meal in China to increase in meat out is assumed to be positive. Due to lack of fish meal resources, price of fish meal in China is assumed to equal to world fish meal price. For this reason, the effect of fish meal price in the ROW on demand for fish meal in China is assumed to be negative. It is assumed that the effect of soybean meal price in China on dependent variable is positive.

Table 4.23: Determinants of China's fish meal demand and expected signs

Dependent variable: Quantity of China's fish meal consumption

Explanatory variables		Expected signs on dependent variable
MEAT	Meat output	+
PWFHMR	Fish meal price in China's currency, ROW	-
PCSYM	Soybean meal price, China	+

Source: Author's predication

Demand for fish meal in China (*$QCFHMC_t$*) is determined by meat output (*$MEAT_t$*), fish meal price in the ROW (*$PWFHMR_t$*), and soybean meal price in China (*$PCSYM_t$*).

(4.41a) $QCFHMC_t = f\,(MEAT_t, PWFHMR_t, PCSYM_t)$

The function for China's fishmeal demand is estimated in double logarithmic form and partial adjustment. Therefore, the estimated function is specified as (4.41b):

(4.41b)
$$Log(QCFHMC_t) = \beta_0 + \beta_1 Log(MEAT_t) + \beta_2 Log(PWFHMR_t) + \beta_3 Log(QCFHMC_{t-1}) + \beta_4 Log(PCSYM_t)$$

Import demand function

The expected effects of explanatory variables on China's fish meal import are shown in Table 4.24. The effect of China's meat output on dependent variable is assumed to be positive. It is supposed a negative response of fish meal import to increase in the ROW fish meal price. It is assumed that fish meal imports in China are positively related to increase in soybean meal price.

Table 4.24: Determinants of China's fish meal import and expected signs

Dependent variable: Quantity of China's fish meal imported

Explanatory variables		Expected signs on dependent variable
PWFHM	Fish meal price, ROW	-
MEAT	Meat output, China	+
PWSYM	Soybean meal price, ROW	+

Source: Author's prediction

Fish meal import in China ($QCFHMM_t$) is expressed as a function of fish meal price in the ROW ($PWFHM_t$), meat output ($MEAT_t$), soybean meal price in the ROW ($PWSYM_t$).

(4.42a) $QCFHMM_t = f(PWFHM_t, MEAT_t, PWSYM_t)$

Therefore, the estimated function is specified as:

(4.42b) $$QCFHMM_t = \beta_0 + \beta_1(PWFHM_t) + \beta_2(MEAT_t) + \beta_3(PWSYM_t)$$

4.4.11 ROW fish meal sector

Demand function

Table 4.25 shows the expected reaction of fish meal demand in the ROW with respect to change in explanatory variables. The impact of lagged dependent variable is assumed to be positive. The effect of own-price is assumed to be negative. It is assumed that demand for fish meal is positively related to soybean meal price in the ROW. The demand for fish meal with respect to increase in world average GNI per capita is assumed to be positive.

Table 4.25: Determinants of the ROW fish meal demand and expected signs

Dependent variable: Quantity of the ROW fish meal consumption per capita

Explanatory variables		Expected signs on dependent variable
PWFHM	Fish meal price, ROW	-
PWSYM	Soybean meal price, ROW	+
GNIP	World average GNI per capita	+

Source: Author's prediction

Demand for fish meal in the ROW (*$QWFHMCP_t$*) is estimated to depend on fish meal price (*$PWFHM_t$*), soybean meal price (*$PWSYM_t$*), and world average GNI per capita (*$GNIP_t$*).

(4.43a) $QWFHMCP_t = f(PWFHM_t, PWSYM_t, GNIP_t)$

The function for fish meal demand in the ROW is estimated in double logarithmic form and partial adjustment. Therefore, the estimated function is specified as:

(4.43b) $$Log(QWFHMCP_t) = \beta_0 + \beta_1 Log(QWFHMCP_{t-1}) + \beta_2 Log(PWFHM_t) + \beta_3 Log(PWSYM_t) + \beta_4 Log(GNIP_t)$$

Table 4.26: Variables used in the model (China's sector)

Abbreviation	Item	Measurement unit
Jointed determined variable		
PCRAM	China's rapeseed meal price	RMB/mt
PCRAS	China's rapeseed price	RMB/mt
PCSYM	China's soybean meal price	RMB/mt
PCSYS	China's soybean price	RMB/mt
PCSYS/PWSYSR	China's soybean price and the ROW soybean price ratio	%
QCFHMC	Quantity of China's fish meal consumption	1,000 mt
QCFHMM	Quantity of China's fish meal imported	1,000 mt
QCPNSP	Quantity of China's peanuts production	1,000 mt
QCPNSU	Quantity of China's peanuts crushed	1,000 mt
QCPNMC	Quantity of China's peanuts meal consumption	1,000 mt
QCRAMC	Quantity of China's rapeseed meal consumption	1,000 mt
QCRASU	Quantity of China's rapeseed crushed	1,000 mt
QCRASP	Quantity of China's rapeseed production	1,000 mt
QCSYMC	Quantity of China's soybean meal consumption	1,000 mt
QCSYSM	Quantity of China's soybean imported	1,000 mt
QCSYSFP	Quantity of China's soybean food consumption per capita	kg
QCSYSU	Quantity of China's soybean crushed	1,000 mt
QCSYSP	Quantity of China's domestic soybean production	1,000 mt
SS/SC	China's soybean stocks-to-crush ratio	%
RS/RU	China's rapeseed stocks-to-crush ratio	%

Note: ha = hectare, mt = metric ton, kg = kilogram RMB = ren min-bi (Chinese currency)

Table 4.26 (continued): Variables used in the model (China's sector)

Exogenous variable		
CCPI	China's consumer price index, 1980-2006	Index with base of 1980=100
CPOP	China's population estimates, 1980-2006	10,000
DUMWTO	Dummy variable for China's WTO accession	Indicator variable equal to 0 from 1978 to 1995, and equal to 1 afterwards
GDPP	China's GDP per capita	RMB
MEAT	Quantity of China's meat output	1,000 mt
PCCNS	China's corn price	RMB/mt
PWFHM	the ROW fish meal price	U.S. $/mt
PWFHMR	the ROW fish meal price in China's currency	RMB/mt
PWSYM	the ROW soybean meal price	U.S. $/mt
TREND	Trend variable	1,2,3……26, 27

Note: ha = hectare, mt = metric ton, kg = kiogram RMB = ren min-bi (Chinese currency)

Table 4.27: Variables used in the model (ROW sector)

Abbreviation	**Item**	**Measurement unit**
Jointed determined variable		
PWFHM	the ROW fish meal price	U.S. $/mt
PWRAM	the ROW rapeseed meal price	U.S. $/mt
PWRAS	the ROW rapeseed price	U.S. $/mt
PWSYM	the ROW soybean meal price	U.S. $/mt
PWSYS	the ROW soybean price	U.S. $/mt

Note: ha = hectare, mt = metric ton, kg = kiogram RMB = ren min-bi (Chinese currency)

Table 4.27 (continued): Variables used in the model (ROW Sector)

QWFHMCP	Quantity of the ROW fish meal consumption per captia	kg
QWRAMCP	Quantity of the ROW rapeseed meal consumption per capita	kg
QWRASP	Quantity of the ROW rapeseed production	1,000 mt
QWRASUP	Quantity of the ROW rapeseed crushed per capita	kg
QWSYMCP	Quantity of the ROW soybean meal consumption per capita	kg
QWSYSE	Quantity of the ROW soybean exported	1,000 mt
QWSYSP	Quantity of the ROW soybean production	1,000 mt
QWSYSUP	Quantity of the ROW soybean crushed per capita	1,000 mt
RWSYSU	the ROW soybean stocks-to-crush ratio	%
RWRASU	the ROW rapeseed stocks-to-crush ratio	%
Exogenous variable		
GDPP	China's GDP per capita	RMB
GNIP	World average GNI per capita	U.S. dollar
MEAT	Quantity of China's meat output	1,000 mt
PWSYSR	the ROW soybean price in China's currency	RMB/mt
USCPI	U.S. Consumer price index, 1980-2006	Index with base of 1980 = 100
WPOP	World population estimates, 1980-2006	person
TREND	Trend variable	1,2,3……26, 27

Note: ha = hectare, mt = metric ton, kg = kiogram RMB = ren min-bi (Chinese currency)

5 Empirical estimation

5.1 Data sources and methodology

This section summarizes estimated results of structural equations presented in the previous chapter. The system equations of structural model are constructed for determining the interrelationship between livestock production and demand for protein meals as well as their associated oilseeds.

The OLS method is applied to estimate the parameters of system equations. Preliminary results suggest autocorrelation occurs. It expresses as the error terms in the regression equations are not independently distributed across the observations (Greene, 2001). The autocorrelation violates the basic assumption of OLS estimation.

Since forms of autocorrelation are different, various methods have been suggested regarding the correction of the error term. Modern economic theory emphasizes autocorrelation caused by the omitted exogenous variables. When autocorrelation is caused by the omitted exogenous variable, the lagged dependent variable can be a good proxy for ridding autocorrelation (Baker, 2007). Adding lagged dependent variable therefore mitigates the specification bias. But, when the regression function contains the lagged dependent variable on the right-side of the model, Durbin-Watson statistic is no longer valid and Durbin h-test is required to test for first-order autocorrelation (Greene, 2001). Cochrane-Orcutt iterative approach is a traditional method to deal with correction for autocorrelation caused by effects of standard errors (Wang, 2004). For this study, both adding lagged dependent variable as a proxy and Cochrane-Orcutt iterative approach are employed for correcting autocorrelation.

Consider the regression model:

(5.1) $Y_t = \beta_0 + \beta_1 * X_t + e_t$

Where

Y_t = dependent variable at time t

β = vector of coefficient

X_t = matrix of explanatory variables

e_t = error term

Cochrane-Orcutt iterative approach estimation is carried out by the following procedures. First, by using OLS method, the parameters of the constructed regression model can be estimated. Since the error terms are serially correlated across the observations, an estimate of ρ can be obtained from the regression of the OLS residuals e_t.

(5.2) $e_t = \rho * e_{t-1} + V_t$

where

ρ = vector of coefficient ($-1 \leq \rho \leq 1$)

V_t = error term

Estimate of ρ is used to transform regression model:

(5.3) $Y_t - \rho * Y_{t-1} = \beta_0(1-\rho) + \beta_1 * (X_t - \rho * X_{t-1}) + V_t$

Then, consistent estimates can be obtained based on regression of transformed model.

The secondary data used for the calculations are obtained from the United States Department of Agriculture's (USDA) Data Series on Production, Supply and Demand (PS&D). US Consumer Price Index (CPI) is available from US Bureau of Labor Statistics. World average Gross National Income (GNI) per capita is drawn from World Bank World Development Indicators (WDI) Data Source. Estimates of World population are taken from International Data of U.S. Census Bureau. Annual time series data from 1980/1981 to 2006/2007 are used to estimate the parameters of the model. Domestic prices of China's oilseeds, oil, and meals are taken from publications of China's Ministry of Agriculture (MOA). Data of China's GDP per capita, China's meat output and China's consumer price index (CPI) are adopted from MOA, China's Rural Development Reports. Since the supply of China's fish meal largely depends on the imports from world market, China's fish meal price is calculated from the ROW fish meal price by adjusting exchange rates. Since peanut, peanut meal, sunflower seed meal were in procurement system, values of these products were set by local and central government, national market for these products did not formulate in 1980s, and the market prices of these products cannot be obtained.

The estimations of system equations are done with the statistical program-Eviews. The lag period is one year. The expected explanatory variables impact on dependent variables, R^2, Durbin-Watson statistic (D-W stat.) or Durbin-h statistic (D-h stat.) and t-statistic are provided for each estimated equation.

5.2 Estimation of the parameters of the system equations

5.2.1 China's soybean sector

Crush demand

Table 5.1 illustrates the estimated results of China's soybeans crush demand. The fitness of China's soybean crush demand function is good with a high R^2 (0.98). Estimated coefficients of lagged dependent variable and China's meat output are all statistically significant. Estimated elasticity implies that a 10% increase in meat output is associated with a 6.4% increase in quantity of China's soybean crushed. The effects of soybean price and soybean meal price, in contrast, move into the opposite direction with insignificant ***t***-statistics. Contrary to theory, the response of crush demand for soybean to increase in the price of rapeseed price show the opposite sign and is statistically insignificant.

China's soybean price

Econometric estimation for China's soybean price is reported in table 5.2. Three explanatory variables explain 72% variation in the function of soybean price in China. The elasticity of lagged dependent variable is 0.67 and statistically significant at 1% level. The effect of the stocks-to-crush ratio on soybean price is negative with insignificant ***t***-statistics. The effect of China's corn price on China's soybean price is opposite and significant at 10% level.

Table 5.1: Determinants of China's soybean crush demand
(Dependent variable: Log of quantity of China's soybeans crushed)

Variable log of	**Estimated coefficient**	**Standard error**	**t-ratio**	**p-value**
Lagged quantity of soybean crushed, China	0.6524***	0.1336	4.8824	0.001
Soybean price, China	-0.4468	0.4231	-1.0562	0.3035
Rapeseed price, China	-0.1717	0.3112	-0.5519	0.5871
Soybean meal price, China	0.1884	0.2695	0.6989	0.4927
Meat output, China	0.6419**	0.2406	2.6678	0.0148
Constant	-0.6607	2.0161	-0.3277	0.7465
R^2= 0.9762 Durbin – h Statistic = 1.5125				

Note: *** 1% significance level, ** 5% significance level
Source: Author's calculation

Table 5.2: Determinants of China's soybean price
(Dependent variable: Log of China's soybean price)

Variable log of…	**Estimated coefficient**	**Standard error**	**t-ratio**	**p-value**
Rapeseed price, China	-0.1641	0.1805	-0.9091	0.3736
Soybean stocks-to-crush ratio, China	-0.0158	0.0564	-0.2800	0.7822
Corn price, China	0.3748*	0.1887	1.9867	0.0602
Lagged soybeans price, China	0.6708***	0.1415	4.7396	0.0001
Constant	1.0888	1.0892	0.9996	0.3289
R^2= 0.72 Durbin –h Statistic = 0.6941				

Note: *** 1% significance level, *10% significance level
Source: Author's calculation

Import demand

Cochrane-Orcutt approach is used to correct for auto correlation. A new estimate of ρ (0.3531) is computed and statistically significant at 10% level. Table 5.3 presents import demand for soybeans. The regression function shows a fair fitness result with R^2 at 0.75. As demonstrated by the dummy results, the impact of China's WTO accession on its soybean imports is not significant. Effect of domestic meat output and ratio of domestic soybean price to world market price on imports of soybeans are significant at 1% level and 5% level, respectively. Estimated elasticity demonstrates that imports of soybeans are sensitive to soybean price difference between domestic and international. A 10% growth of ratio of price difference causes rising imports of soybeans by 11.6%. The elasticity of soybean import with respect to China's meat out is elastic and statistically significant at 1% level. The result indicates that a 10% increase in China's meat output is associated with 32.8% increase in soybean imports.

Table 5.3: Determinants of China's soybean imports
(Dependent variable: Quantity of China's soybean imported)

Variable of…	**Estimated coefficient**	**Standard error**	**t-ratio**	**p-value**	**Elasticity**
Meat output, China	0.4963***	0.1026	4.8355	0.0001	3.2812***
Ratio of China's soybean price and the ROW soybean price	6577.77**	3219.40	2.0432	0.0532	1.1614**
Dummy	-1664.67	3937.12	-0.4228	0.6765	
Constant	-20907.2***	3770.24	-3.5873	0.0016	
R^2= 0.7481 Durbin – Watson Statistic = 1.6038					

Note: ***significant at 1% level, **significant at 5% level
Source: Author's calculation

Soybean production

As shown in Table 5.4, the estimated function has a good fitness regression result with R^2 at 0.87. The effect of soybean price on china's domestic soybean production is not significant. Estimated supply elasticity with respect to increase in China's rapeseed price shows unexpected sign and is statistically significant at 5% level.

Rapeseed price has negative impact on China's domestic soybean production. Estimated elasticity suggests that an increase in rapeseed price by 10% results in a decline of soybean production by 4.5%. Trend variable positively affect China's domestic soybean production and is statistically significant at 10% level.

Table 5.4: Determinants of China's domestic soybean production

(Dependent variable: Quantity of China's domestic Soybean production)

Variable of…	**Estimated coefficient**	**Standard error**	**t-ratio**	**p-value**	**Elasticity**
Lagged soybean domestic production in China	0.4137**	0.1940	2.1325	0.0455	0.4137**
Soybeans price, China	4.4562	2.8400	1.5691	0.1323	0.2791
Rapeseed price, China	-8.1242**	3.2729	-2.4823	0.0221	-0.4483**
Corn price, China	-1.9648	6.2637	-0.3137	0.7570	-0.0516
Trend variable	136.0639*	80.2564	1.6954	0.1055	0.1483*
Constant	8562.557	2270.111	3.7719	0.0012	
R^2= 0.8664 Durbin – Watson Statistic = 1.7249					

Note: **significant at 5% level, *significant at 10% level

Source: Author's calculation

China's Soybean food demand function

As displayed in Table 5.5, the estimated coefficients of all explanatory variables indicate the expected signs, but only lagged dependent variable is statistically significant. Food demand for soybeans with respect to changes in GDP per capita and soybean price are inelastic and insignificant.

Table 5.5: Determinants of China's soybean food demand

(Dependent variable: Log of quantity of China's soybean food consumption per capita)

Variable of log…	**Estimated coefficient**	**Standard error**	**t-ratio**	**p-value**
GDP per capita, China	0.0488	0.0361	1.3526	0.1899
Soybeans price, China	-0.0473	0.1445	-0.3274	0.7464
Lagged quantity of soybean food consumption per capita, China	0.9001***	0.1106	8.1357	0.0000
Constant	0.1345	0.8998	0.1495	0.8826
R^2= 0.7933 Durbin – h Statistic = -0.2989				

Note: ***significant at 1% level

Source: Author's calculation

5.2.2 ROW soybean sector

Crush demand

Table 5.6 presents estimated results of crush demand for soybeans in the ROW. The estimated function fits well with a high R^2 (0.96). The response of crush demand for soybeans to change in soybean price is highly inelastic and statistically insignificant. Estimated cross-price elasticity of crush demand for soybeans with respect to rapeseed price displays the opposite sign and is also statistically insignificant.

Table 5.6: Determinants of the ROW soybean crush demand
(Dependent variable: Log of quantity of the ROW soybean crushed per capita)

Variable log of …	Estimated coefficient	Standard error	t-ratio	p-value
Soybeans price, ROW	-0.0677	0.0869	-0.7785	0.4459
Rapeseed price, ROW	-0.0486	0.0724	-0.6706	0.5106
World average GNI per capita	0.3296***	0.1059	3.1119	0.0057
Lagged quantity of soybean crushed per capita, ROW	0.4251**	0.1601	2.6558	0.0156
Constant	-0.3916	0.6535	-0.5992	0.5561
R^2= 0.96 Durbin – h Statistic = -0.9650				

Note: *** 1% significance level, ** 5% significance level
Source: Author's calculation

The crush demand for soybeans with respect to increase in world average GNI per capita is fair (0.33) and statistically significant at 1% level.

Soybean price

Cochrane-Orcutt iterative method is used to correct for autocorrelation. A new estimate of ρ (0.6301) is obtained. It is statistically significant at 1% level. Estimated parameters are shown in Table 5.7. Estimated coefficients display the expected signs. The response of soybean price to increase in rapeseed price is significant at 1% level. The effect of the soybean stocks-to-crush ratio on soybean price is inelastic (-0.20) and statistically insignificant.

Table 5.7: Determinants of the ROW soybean price

(Dependent variable: Log of the ROW soybean price)

Variable log of…	Estimated coefficient	Standard error	t-ratio	p-value
Rapeseed price, ROW	0.6530***	0.1669	3.9123	0.0009
Soybean stocks-to-crush ratio, ROW	-0.2034	0.1303	-1.5613	0.1341
Constant	1.4420*	0.3066	1.7397	0.0973
R^2= 0.48 Durbin – Watson Statistic = 1.3503				

Note: *** significant at 1% level, * significant at 10% level

Source: Author's calculation

ROW soybean export demand

Cochrane-Orcutt iterative method is also applied to correct for autocorrelation. A new estimate of ρ (0.3972) is calculated. It is statistically significant at 5% level. Table 5.8 presents estimated elasticities of experts of soybeans in the ROW. The fitness of regression function is fair with R^2 (0.67). As assumed, the effect of China's GDP per capita on ROW soybean export is positive and significant at 1% level. Estimated elasticity suggests that a 10% rising China's GDP per capita causes the increase in the ROW soybean export by 6.7%. The ROW soybean exports with respect to increase in the ROW soybean price is inelastic (0.09) and statistically insignificant.

Table 5.8: Determinants of the ROW soybean export demand

(Dependent variable: Log of quantity of the ROW soybean exported)

Variable log of…	Estimated coefficient	Standard error	t-ratio	p-value
Ratio of China's soybean price and the ROW soybean price	0.0934	0.1296	0.7206	0.4784
GDP per capita, China	0.6732***	0.0801	8.4008	0.0000
Constant	3.3865***	0.3496	9.6882	0.0000
R^2= 0.7786 Durbin – Watson Statistic = 1.8640				

Note: ***significant at 1% level

Source: Author's calculation

Soybean production

Table 5.9 explains soybean production in the ROW. The effect of soybean price on soybean production is inelastic (0.12) and statistically insignificant. The estimated result shows that trend variable has positive impact on soybean production and is significant at 1% level.

Table 5.9: Determinants of the ROW soybean production

(Dependent variable: Quantity of the ROW soybean production)

Variable of…	Estimated coefficient	Standard error	t-ratio	p-value	Elasticity
Lagged soybean price, ROW	94.5695	75.9346	1.2454	0.2261	0.1243
Lagged quantity of soybean production, ROW	0.5457***	0.1904	2.8658	0.0090	0.5457***
Trend variable	3497.961***	1211.784	2.8619	0.0091	0.4092***
Constant	-6563.346	18342.64	-0.3578	0.7239	
R^2= 0.97 Durbin – Watson Statistic = 2.2382					

Note: ***significant at 1% level

Source: Author's calculation

5.2.3 China's rapeseed sector

China's rapeseed crush demand

Table 5.10 examines China's rapeseed crush demand. Regression function fits well with higher R^2 at 0.93. The effect of rapeseed price on China's rapeseed demand indicates the contrary sign and is statistically insignificant. Estimated demand elasticity suggests that a 10% rising meat output results in increase in rapeseed crush by 6.2%. The crush demand for rapeseed to increase in soybean price shows the contrary sign and statistically significant at 10 % level.

China's rapeseed price

Table 5.11 shows estimated parameters of function of rapeseed price in China. The fitness of estimated function is at 0.53. As expected, the effect of corn price on rapeseed price is modest (0.35) and statistically significant at 10% level. The response of China's rapeseed price to increase in rapeseed stocks-to-crush ratio is inelastic (-0.07) and insignificant.

Table 5.10: Determinants of China's rapeseed crush demand

(Dependent variable: Log of quantity of China's rapeseed crushed)

Variable log of …	Estimated coefficient	Standard error	t-ratio	p-value
Lagged rapeseed crushed, China	0.0775	0.1776	0.4364	0.6672
Meat output, China	0.6185**	0.2324	2.6614	0.0150
Rapeseed price, China	0.0221	0.2250	0.0980	0.9229
Soybean price, China	-0.5178*	0.2777	-1.8645	0.0770
GDP Per capita, China	0.0979	0.2152	0.4547	0.6542
Constant	4.3417**	1.7451	2.4879	0.0218
R^2= 0.93 Durbin – h Statistic = 0.4322				

Note: ** significant at 5% level, * significant at 10% level

Source: Author's calculation

Table 5.11: Determinants of China's rapeseed price

(Dependent variable: Log of China's rapeseed price)

Variable log of…	Estimated coefficient	Standard error	t-ratio	p-value
China's rapeseed stocks-to-crush ratio	-0.0653	0.0693	-0.9417	0.3566
China's corn price	0.3543*	0.1898	1.8671	0.0753
Lagged China's rapeseed price	0.5129**	0.1903	2.6955	0.0132
Constant	0.9882	1.1213	0.8813	0.3877
R^2= 0.53 Durbin – Watson Statistic = 1.5143				

Note: ** significant at 5% level, * significant at 10% level

Source: Author's calculation

China's rapeseed production

Table 5.12 displays the estimated parameters of function of rapeseed production in China. The effects of lagged own price, lagged soybean price, and lagged corn price on rapeseed production are inelastic and statistically insignificant. The effect of technical change measured by trend variable on China's rapeseed production is statistically significant at 1% level.

Table 5.12: Determinants of China's rapeseed production

(Dependent variable: Quantity of China's rapeseed production)

Variable of …	Estimated coefficient	Standard error	t-ratio	p-value	Elasticity
Lagged quantity of rapeseed production, China	-0.0304	0.2338	-0.1302	0.8977	-0.0304
Lagged rapeseed price, China	0.5047	2.6447	0.1908	0.8506	0.0450
Lagged soybean price, China	-3.0495	2.4271	-1.2565	0.2234	-0.3087
Lagged corn price, China	3.1919	5.1278	0.6225	0.5407	0.1355
Trend variable	387.7167***	99.8602	3.8826	0.0009	0.6832***
Constant	3784.333**	1679.200	2.2537	0.0356	
R^2= 0.91 Durbin – Watson Statistic = 1.9827					

Note: *** significant at 1% level, ** significant at 5% level
Source: Author's calculation

5.2.4 ROW rapeseed sector

ROW rapeseed crush demand

The estimated result of function of rapeseed crush demand in the ROW is presented in Table 5.13. The estimated coefficients have the correct signs, but only the variable of world average GNI per capita is statistically significant at 1% level. A 10% increase in world average GNI per capita would cause an increase in the ROW rapeseed crush demand per capita by 5.9%.

Table 5.13: Determinants of the ROW rapeseed crush demand

(Dependent variable: Log of quantity of the ROW rapeseed crushed per capita)

Variable log of …	Estimated coefficient	Standard error	t-ratio	p-value
Lagged quantity of rapeseed crushed per capita, ROW	0.0111	0.2696	0.0411	0.9676
Rapeseed price, ROW	-0.0906	0.1100	-0.8231	0.4207
Soybean price, ROW	0.0301	0.1103	0.2726	0.7881
World average GNI per capita	0.5869***	0.1694	3.4694	0.0026
Constant	-3.1831***	1.0822	-2.9412	0.0084
R^2= 0.9224 Durbin – Watson Statistic = 1.8337				

Note: *** significant at 1% level
Source: Author's calculation

Rapeseed price

Estimated parameters of function of rapeseed price in the ROW are presented in Table 5.14. They display the expected signs. The response of rapeseed price to increase in soybean price is positive (0.25) and is statistically significant at 10% level. The effect of rapeseed stocks-to-crush ratio on rapeseed price is inelastic (-0.07) and statistically insignificant.

Table 5.14: Determinants of the ROW rapeseed price

(Dependent variable: the ROW Rapeseed price)

Variable of…	Estimated coefficient	Standard error	t-ratio	p-value	Elasticity
Rapeseed stocks-to-crush ratio, ROW	-92.7808	55.5273	-1.6709	0.1111	-0.0687
Soybean price. ROW	0.2534*	0.1436	1.7640	0.0938	0.2536*
Lagged rapeseed price, ROW	0.4744***	0.0906	5.2386	0.0000	0.4744***
Constant	45.7025	20.6216	2.2163	0.0391	
R^2= 0.7951 Durbin – h statistic = 1.5204					

Note: *** significant at 1% level, * significant at 10% level

Source: Author's calculation

Rapeseed production

The estimated results are displayed in Table 5.15. The fitness of function is satisfactory with R^2 at 0.88, but weaker statistical significance on lagged the ROW rapeseed price. The estimated parameters all have the correct sign. The estimated parameter on the lagged dependent variable is at 0.38 and statistically significant at 5% level. The effect of trend variable is found to be positive and statistically significant from zero at 1% level.

Table 5.15: Determinants of the ROW rapeseed production

(Dependent variable: Quantity of the ROW rapeseed production)

Variable of…	Estimated coefficient	Standard error	t-ratio	p-value	Elasticity
Lagged quantity of rapeseed production, ROW	0.3836*	0.2144	1.7895	0.0895	0.3836**
Lagged rapeseed price, ROW	15.5910	16.5075	0.9445	0.3568	0.1039
Trend variable	636.7582***	212.2258	3.0004	0.0074	0.3586***
Constant	1921.827	4356.810	0.4411	0.6641	
R^2= 0.8829 Durbin – Watson Statistic = 1.7312					

Note: *** significant at 1% level, * significant at 10% level
Source: Author's calculation

5.2.5 China's peanut sector

China's peanuts crush demand

As indicated in Table 5.16, three explanatory variables explain 94% of variation in crush demand for peanuts in China. As expected, meat output is positively and significantly related to crush demand for peanuts. Estimated coefficient implies that a 10% rising meat output would induce an increase in amount of China's peanuts crush by 3.9%. The effect of corn price on crush demand for peanuts is inelastic (-0.09) and insignificant.

Table 5.16: Determinants of China's peanut crush demand

(Dependent variable: Log of China's quantity of peanut crushed)

Variable log of…	Estimated coefficient	Standard error	t-ratio	p-value
Lagged quantity of peanuts crushed, China	0.4559**	0.1953	2.3342	0.0291
Meat output, China	0.3912**	0.1557	2.5125	0.0198
Corn price, China	-0.0878	0.1928	-0.4555	0.6532
Constant	0.9703	1.0254	0.9462	0.3543
R^2= 0.9415 Durbin – Watson Statistic = 1.6718				

Note: ** significant at 5% level
Source: Author's calculation

Peanut production

As presented in Table 5.17, the fitness of regression function is at 0.95. The estimated parameters all show the correct signs. The estimated parameter on the lagged dependent variable is fair (0.71) and statistically significant at 1% level.

Table 5.17: Determinants of China's peanut production

(Dependent variable: Quantity of China's peanut production)

Variable of…	Estimated coefficient	Standard error	t-ratio	p-value	Elasticity
Lagged quantity of China's peanut production	0.7115***	0.2592	2.7450	0.0121	0.7115***
Lagged China's corn price	-6.9512	4.9409	-1.4069	0.1741	-0.2643
Lagged China's soybean price	2.0151	3.3280	0.6055	0.5513	0.1827
Trend variable	121.4262	161.8191	0.7504	0.4613	0.1916
Constant	1837.608	2234.546	0.82236	0.4201	
R^2= 0.9477 Durbin – Watson Statistic = 1.8357					

Note: *** significant at 1% level
Source: Author's calculation

The effects of soybean price and corn price on peanut production are inelastic and insignificant. It is found that the impact of technical change on China's peanut production is not significant.

5.2.6 China's soybean meal sector

Soybean meal demand

As shown in Table 5.18, estimated parameters get the expected sign, but parameters of soybean price and corn price suffer from statistically insignificant. The demand for soybean meal with respect to increase in meat output is at 0.77 and statistically significant at 10% level. Estimated demand elasticity indicates that a 10% rising meat output induce an increase in soybean meal consumption by 7.7%. The effect of soybean price on soybean meal demand is inelastic (-0.08) and statistically insignificant.

Table 5.18: Determinants of China's soybean meal demand

(Dependent variable: Log of quantity of China's soybean meal consumption)

Variable log of…	Estimated coefficient	Standard error	t-ratio	p-value
Meat output	0.7703*	0.3826	2.0132	0.0571
Soybean price, China	-0.0816	0.5186	-0.1573	0.8765
Corn price, China	-0.3346	0.4546	-0.7360	0.4699
Lagged soybean meal consumption, China	0.6654***	0.1553	4.2845	0.0003
Constant	-2.6889	3.2626	-0.8241	0.4191
R^2= 0.9756 Durbin – h Statistic = 1.9317				

Note: *** significant at 1% level, * significant at 10% level
Source: Author's calculation

5.2.7 ROW soybean meal sector

ROW soybean meal demand

Table 5.19 explains estimated results of demand for soybean meal in the ROW. Estimated parameters all show expected sign. The estimated parameter on the lagged dependent variable is 0.82 and statistically significant at 1% level. Demand for soybean meal with respect to increase in soybean meal price is inelastic (-0.10) and statistically significant at 1% level. The effect of world average GNI per capita on demand for soybean meal is inelastic (0.03) and insignificant.

Table 5.19: Determinants of the ROW soybean meal demand

(Dependent variable: Log of quantity of the ROW soybean meal consumption per capita)

Variable log of …	Estimated coefficient	Standard error	t-ratio	p-value
Lagged soybean meal consumption per capita, ROW	0.8156***	0.0882	9.2474	0.0000
Soybean meal price, ROW	-0.1004***	0.0309	-3.2527	0.0036
World average GNI per capita	0.0309	0.0378	0.8166	0.4229
Constant	0.7739	0.3136	2.4673	0.0219
R^2= 0.9678 Durbin – H Statistic = 0.7770				

Note: *** significant at 1% level
Source: Author's calculation

5.2.8 China's rapeseed meal sector

Rapeseed meal demand

As displayed in Table 5.20, the estimated function fits well (0.95). The response of China's rapeseed meal demand to increase in meat output and rapeseed meal price are at 1.04 and -1.96, which are statistically at 5% level and 1% level, respectively. A 10% increase meat output results in increase in rapeseed meal consumption by 10.4%, while a 10% rising rapeseed meal price causes the rapeseed meal consumption down by 19.6%.

Table 5.20: Determinants of China's rapeseed meal demand

(Dependent variable: Log of quantity of China's rapeseed meal consumption)

Variable log of…	Estimated coefficient	Standard error	t-ratio	p-value
Meat output, China	1.0372**	0.4056	2.5574	0.0188
Lagged quantity of rapeseed meal consumption, China	0.5541***	0.1409	3.9315	0.0008
Rapeseed meal price, China	-1.9635***	0.6149	-3.1935	0.0046
Soybean meal price, China	1.0493	0.6542	1.6039	0.1244
Corn price, China	0.9103	0.8675	1.0493	0.3065
Constant	-8.1549	4.0824	-1.9976	0.0595
R^2= 0.9462 Durbin – h Statistic = 0.0044				

Note: *** significant at 1% level, ** significant at 5% level
Source: Author's calculation

5.2.9 ROW rapeseed meal sector

ROW rapeseed meal demand

As shown in Table 5.21, estimated parameters have the expected signs and are all statistically significant. Own price elasticity is at -0.30. The response of demand for rapeseed meal to increase in soybean meal price is positive and statistically significant at 5% level. The estimated cross-price elasticity indicates that a 10% increase in soybean meal price brings a rise in rapeseed meal consumption by 2.9%. Demand for rapeseed meal is significantly influenced by world average GNI per capita. The elasticity shows that an increase in world average GNI per capita by 10% increases in rapeseed meal consumption by 3.5%.

Table 5.21: Determinants of the ROW rapeseed meal demand

(Dependent variable: Log of quantity of the ROW rapeseed meal consumption per capita)

Variable log of…	**Estimated coefficient**	**Standard error**	**t-ratio**	**p-value**
Rapeseed meal price, ROW	-0.3004**	0.1152	-2.6082	0.0173
World average GNI per capita	0.3547***	0.1008	3.5175	0.0023
Soybean meal price, ROW	0.2859**	0.1182	2.4176	0.0258
Lagged quantity of rapeseed meal consumption per capita, ROW	0.3287**	0.1536	2.1402	0.0455
Constant	-2.3912***	0.8220	2.9088	0.0090
R^2= 0.9306 Durbin – h Statistic = -0.7833				

Note: *** significant at 1% level, ** significant at 5% level
Source: Author's calculation

5.2.10 China's fish meal sector

China's fish meal demand

Table 5.22 identifies demand for fish meal in China. The fish meal demand elasticity with respect to increase in meat output is at 0.78 and statistically significant at 5% level. The estimated result suggests that a 10% rising meat output causes an increase in meat output by 7.8%. The demand for fish with respect to increase in soybean meal price shows contrary sign and is statistically significant at 10% level.

Table 5.22: Determinants of China's fish meal demand

(Dependent variable: Log of quantity of China's fish meal consumption)

Variable log of …	**Estimated coefficient**	**Standard error**	**t-ratio**	**p-value**
Meat output	0.7846**	0.3102	2.5295	0.0204
Fish meal price in China's currency, ROW	0.4316*	0.2216	1.9478	0.0664
Lagged fish meal consumption, China	0.1331	0.1953	0.6816	0.5037
Soybean meal price, China	-0.5132*	0.2692	-1.9060	0.0719
Constant	-2.4027	1.9734	-1.2175	0.2383
R^2= 0.9175 Durbin – Watson Statistic = 2.4330				

Note: ** significant at 5% level, * significant at 10% level; Source Author's calculation

Fish meal import demand

Table 5.23 shows estimated result of function of import demand for fish meal. Estimated parameters all have expected sign and are statistically significant. The response of import demand for fishmeal to fish meal price is at -0.94. The effect of meat output displays that a 10% increase in meat output causes an increase in fish meal import by 14.6%. The estimated significantly positive sign of cross-price elasticity affirms fish meal import in China is positively related to increase in soybean meal price.

Table 5.23: Determinants of China's fish meal import

(Dependent variable: Quantity of China's fish meal imported)

Variable of …	Estimated coefficient	Standard error	t-ratio	p-value	Elasticity
Fish meal price, ROW	-2.2513**	1.0245	-2.1974	0.0399	-0.9387**
Meat output	0.0224***	0.0037	6.0788	0.0000	1.4641***
Soybean meal price, ROW	6.1732**	2.6851	2.2991	0.0324	1.1029**
Constant	-425.9801	330.8691	-1.2875	0.2126	
R^2= 0.7742 Durbin – Watson Statistic = 2.1948					

Note: ** significant at 1% level, **significant at 5% level
Source: Author's calculation

5.2.11 ROW Fish Meal Sector

ROW fish meal demand

Table 5.24 shows estimated result of demand for fish meal in the ROW. The estimated coefficient on the lagged dependent variable is at 0.68 and statistically significant at 1% level. Own-price elasticity is at -0.32 and statistically significant at 1% level. The own elasticity indicates that a 10% increase in fish meal price declines fish meal demand by 3.2%. The effect of soybean meal price displays the correct sign and is statistically significant. This confirms that demand for fish meal is positively related to increase in soybean meal price in the ROW.

Table 5.24: Determinants of the ROW fish meal demand

(Dependent variable: Log of quantity of the ROW fish meal consumption per capita)

Variable log of…	Estimated coefficient	Standard error	t-ratio	p-value
Lagged quantity of fish meal consumption per capita, ROW	0.6751***	0.08787	7.6830	0.0000
Fish meal price, ROW	-0.3249***	0.0782	-4.1560	0.0005
Soybean meal price, ROW	0.2678***	0.0822	3.2587	0.0041
World average GNI per capita	-0.0927	0.0601	-1.5426	0.1394
Constant	1.3344**	0.5984	2.2299	0.0380
R^2= 0.9629 Durbin – h Statistic = 0.7255				

Note: ***significant at 1% level, ** significant at 5% level
Source: Author's calculation

5.3 Summary of estimate results

This chapter presents empirical estimated results, which was based on the conceptual framework developed in previous chapter. Among the 24 functions, the majority of estimate equations have the expected signs, the reasonable parameters and R^2. This displays the overall fitness of the equations are satisfactory. Estimated elasticites explain the interrelationship between livestock production and demand for protein meals as well as their associated imports of oilseeds.

5.3.1 Estimated elasticities for China

Table 5.25 shows the summary of estimated elasticities for China's soybeans, rapeseed and peanut crush demand. The elasticities of demand for soybeans and rapeseed with respect to increase in meat output in China are at 0.64 and 0.62, respectively. The effect of meat output on demand for peanuts is only at 0.39. Compared to estimated demand elasticities, demand for soybeans and rapeseed responds more proportionately to change in China's meat output than peanuts. This implies that the demand for soybeans and rapeseed is more closely associated with livestock production than that of peanuts.

Table 5.25: Estimated elasticities for China's soybeans, rapeseed and peanuts crush demand

	Dependent variables		
Explanatory variables	**Soybean crush demand**	**Rapeseed crush demand**	**Peanut crush demand**
Lagged dependent variable	0.6524***	0.0775	0.4559**
Soybean price, China	-0.4468	-0.5178*	--
Rapeseed price, China	-0.1717	0.0221	--
soybean meal price, China	0.1884	--	--
Meat output, China	0.6419**	0.6185**	0.3912**
GDP per capita, China	--	0.0979	--
Corn price, China	--	--	-0.0878

Note: ***significant at 1% level, ** significant at 5% level, * significant at 10% level, -- not applicable
Source: Author's calculations

Table 5.26 displays elasticities of soybeans, rapeseed, and peanut production in China. The effect of rapeseed production in pervious year shows the contrary sign. The positive and significant effect of lagged dependent variable for function of soybean and rapeseed production reveals that there are constraints on increase in their production in China. The effects of own prices on soybeans and rapeseed production are not significant. The statistically significant trend variables for functions of soybean and rapeseed production reflect the positive impact of technical changes.

Table 5.26: Estimated supply elasticities for domestic soybean, rapeseed and peanut production in China

	Dependent variables		
Explanatory variables	**Soybean production**	**Rapeseed production**	**Peanut production**
Lagged dependent variable	0.4137**	-0.0304	0.7115***
Lagged soybeans price, China	0.2791	-0.3087	0.1827
Lagged rapeseed price, China	-0.4483**	0.0450	--
Lagged corn price, China	-0.0516	0.1355	-0.2643
Trend variable	0.1483*	0.6832***	0.1916

Note: ***significant at 1% level, ** significant at 5% level, * significant at 10% level, -- not applicable
Source: Author's calculations

Elasticities of demand for protein meals in China are summarized in table 5.27. The own price elasticity of demand for rapeseed meal is elastic. Effect of soybean price on demand for soybean meal is not significant. All elasticities of demand for protein meals with respect to increase in meat output in China are positive and statistically significant. The effect of corn price on demand for soybean meal and rapeseed meal is not significant.

Table 5.28 illustrates China's import elasticities for soybeans and fish meal. The soybean and fish meal import demand elasticities with respect to China's meat output are elastic (more than 1). These are consistent with that rising meat output is the main driving force to boost imports of soybeans and fishmeal. Soybean imports respond more proportionately to meat output growth than that of fish meal import.

Table 5.27: Estimated demand elasticities for protein meal in China

	Dependent variables		
Explanatory variables	**China's soybean meal demand**	**China's rapeseed meal demand**	**China's fishmeal demand**
Lagged dependent variable	0.6654***	0.5541***	0.1331
Meat output, China	0.7703*	1.0372*	0.7846**
Soybean price, China	-0.0816	--	--
Soybean meal price, China	--	1.0493	-0.5132*
Rapeseed meal price, China	--	-1.9635***	--
Fish meal price in China's currency, China	--	--	0.4316*
Corn price, China	-0.3346	0.9103	--

Note: *** significant at 1% level, ** significant at 5% level, * significant at 10% level, -- not applicableSource: Author's calculations

Table 5.28: Estimated import demand elasticities for soybeans and fish meal in China

	Dependent variables	
Explanatory variables	**China's soybean imports**	**China's fish meal imports**
Meat output, China	3.2812***	1.4641***
Ratio of soybean price in China to ROW soybean price	1.1614**	--
Fish meal price, ROW	--	-0.9387**
Soybean meal price, ROW	--	1.1029**
Dummy		--

Note: *** significant at 1% level, ** significant at 5% level, -- not applicable,
Source: Author's calculations

5.3.2 Estimated elasticities for the ROW

The summary of elasticities of demand for soybeans and rapeseed in the ROW are presented in the Table 5.29. The effects of world average GNI per capita on crush demand for soybean and rapeseed are positive and significant. In the ROW, rapeseed crush demand is more elastic with respect to change in world average GNI per capita than soybean crush demand.

The effects of own prices on demand for soybeans and rapeseed are inelastic and insignificant.

Table 5.29: Estimated crush demand elasticities for soybean and rapeseed in the ROW

	Dependent variables	
Explanatory variables	**Soybean crush demand**	**Rapeseed crush demand**
Lagged dependent variable	0.4251**	0.0111
Soybean price, ROW	-0.0677	0.0301
Rapeseed price, ROW	-0.0486	-0.0906
World average GNI per capita	0.3296***	0.5869**

Note: *** significant at 1% level, ** significant at 5% level, -- not applicable
Source: Author's calculations

The summary of elasticities for soybean and rapeseed production in the ROW is shown in Table 5.30. The effects of lagged depnd variables are positive and statistically significant. The results imply that previous year's soybean and rapeseed production have strong impact on the current year production. Effects of own-prices are positive, but not statistically significant. The positive and significant trend variables reveal that technical improvement has positive impact on soybeans and rapeseed production in the ROW.

Table 5.30: Estimated supply elasticities for soybeans and rapeseed production in the ROW

	Dependent variables	
Explanatory variables	**Soybean production**	**Rapeseed production**
Lagged dependent variable	0.5457***	0.3836**
Lagged soybean price, ROW	0.1243	--
Lagged rapeseed price, ROW	--	0.1039
Trend variable	0.4092***	0.3586**

Note: *** significant at 1% level, ** significant at 5% level, -- not applicable
Source: Author's calculations

6. Derived Protein Meal Demand and its Implications for International Agricultural Trade

The objective of this chapter is to project China's total consumption of livestock products (pork, poultry, and eggs), predict corresponding requirement for protein meals, estimate the shortage of protein meals and their joint oilseeds, and simulate its implications for international agricultural trade.

6.1 Approaches for forecasting derived protein meal demand

Generally, two approaches, "trend approach" and "demand approach", can be used to forecast the long-term requirement for feed grain and protein meals, derived from the increasing livestock production (Islam, 2003; Zhou et al., 2006). "Trend approach" is assumed that demand for protein meals is consistent with livestock inventory. "Demand approach" is based on the assumption that demand for protein meals for feeding farm animals is expected to increase along with the growth in household consumption of livestock products, driven by increased household income. Consequently, forecasting household consumption of livestock products is the first step for projection national total requirement for protein meal. As introduced in Chapter 2, the income disparity between rural and urban household in China causes the average per capita consumption of livestock products by urban households is approximately two-to-three times greater than that of rural household. Taking this disparity into consideration, the projection of China's total consumption of livestock products is required to describe in a more disaggregated style, rather than by average analysis. Moreover, rural-urban migration is another key factor, which has a strong and direct impact on China's total demand for livestock products. Rural-urban migrants, particularly younger generations, apparently increase their consumption of livestock products after they settle in urban areas. China has experienced a remarkable massive rural-urban migration since the late 1980s. Given these concerns (income disparity between rural and urban household and migration), the estimate of

China's total demand for livestock products through "demand approach" requires the incorporation of separated data for rural and urban households with respect to average per capita consumption of livestock products, real income growth, the household income elasticity of demand for livestock products, with the respective numbers of the urban and rural populations.

Thereafter, the requirement for livestock feed can be calculated through multiplying the projected total requirement for livestock products by feed-meat conversion ratios. Livestock feed provides sufficient protein and energy, in which energy and protein are measured by grain and protein meal, respectively. Feed composition and contents of protein meals vary widely cross different livestock species, livestock production systems (traditional or specialized) and local available feed resources. The information of average uses of protein meals in animal rations was taken from the MOA survey. Finally, "demand approach" estimates China's total requirement for protein meals through the incorporation of projected total demand for livestock products, feed-meat conversion ratios, and the average uses of protein meals in different animal rations. Lack of detail and reliable livestock consumption and production data is the main obstacle for projection derived demand for protein meals.

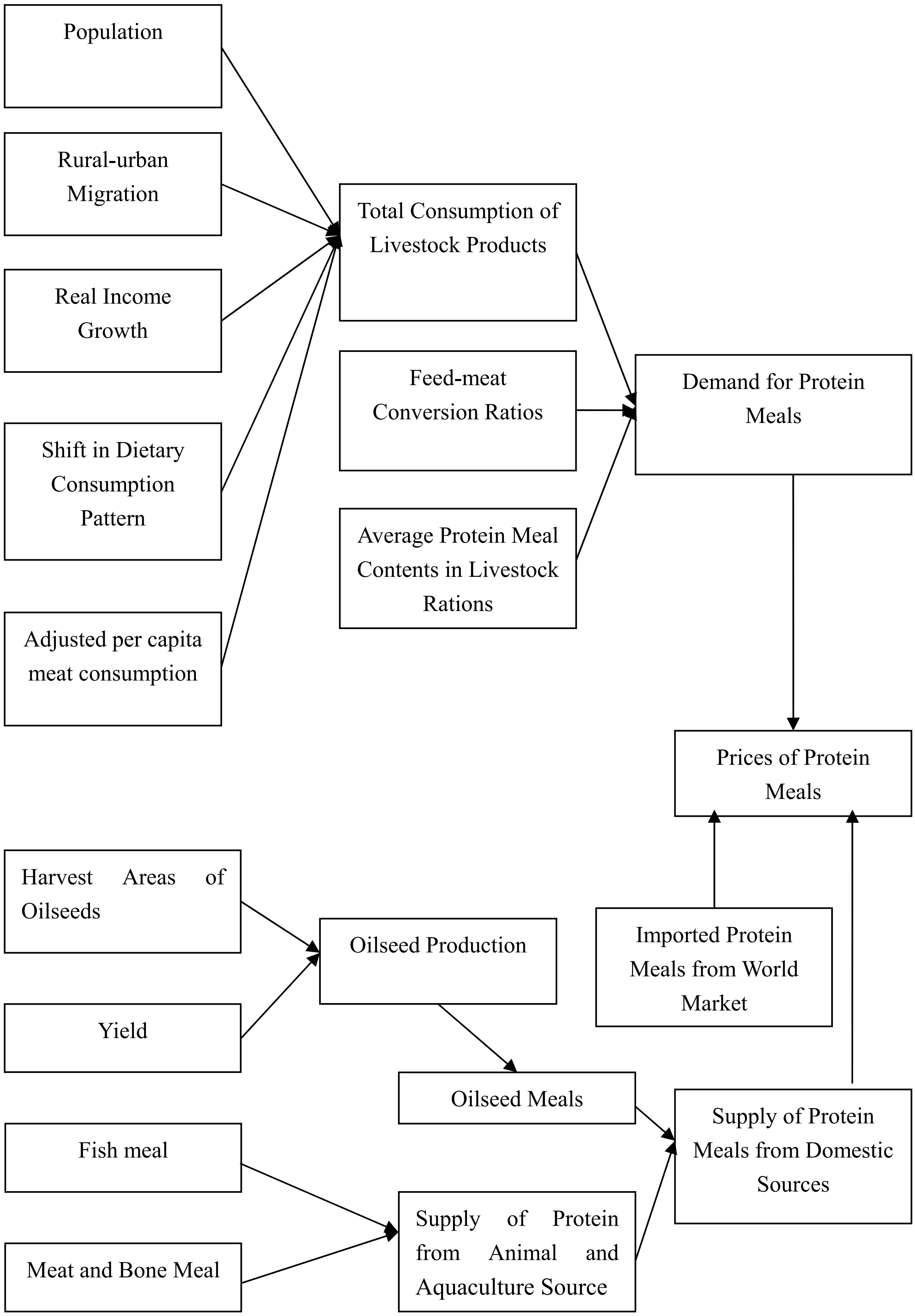
As early mentioned in Chapter 2, the discrepancy between China's livestock production and the consumption data has become larger since late 1980s (SSB-China's Statistical Year Book, various years). By 2008, production series reached a level that was two-to-three times higher than consumption series. The production data are report data. Central and local representatives of the MOA added up the estimated numbers of livestock slaughtered and average carcass weight, collected by village accountants (Ma et al., 2004). The problem of the production data is that there is no general standard for livestock statistics and local representative of the MOA at all levels has incentives to over-report their production levels to show their achievements. The consumption data gathered through the national household surveys annual conducted by the SSB. For these reasons, reported data (production data) have larger error and bias than survey data (consumption data). Because consumption data is more accurate, this study intends to employ "demand approach" to project China's national consumption of livestock products and their corresponding protein meal requirement.

Consumption data, collected through household survey, only included consumption of livestock products at home and did not consider livestock product consumed outside the home (restaurants) and increased consumption from rural-urban migrants (SSB, China's Statistical Year Book, various years). Both of them contribute somewhat to overall consumption of livestock products. Further data problem of SSB data, the quantities of the production and consumption of feed grain, derived from official livestock production and consumption data, are inconsistent with availabilities of feed gain and protein meals.

Data discrepancies and inconsistency between livestock production and consumption series have become the main constraints for predicting future requirements of protein meals. Therefore, to accurately project China's future supply, demand, and trade of protein meals, livestock consumption data are adjusted to compensate for the missing outside home consumption and additional consumption by rural-urban migrants.

Figure 6.1 presents the basic framework to calculate China's protein meal supply, demand, and trade. The equilibrium of protein meal can be reached through the interaction between supply and demand. The trade of protein meals equals the total demand minus the domestic supply. The demand for protein meals is jointly determined by the total projected consumption of livestock products, the feed-meat conversion ratios and the average uses of protein meals in different livestock rations. The factor variables used to project China's total consumption of livestock products are adjusted per capita meat consumption, real per capita income growth, rural-urban migration, population, and shifts in dietary consumption patterns. The total supply of protein meals includes imported protein meals and domestically produced protein meals. Oilseed meals produced from imported oilseeds are also considered as imported protein meals. China's domestic supply of protein meals comes from two separated sources - plant sources (soybean meal, rapeseed meal, peanut meal and sunflower seed meal) and animal sources (MBM and fish meal). The domestic production of oilseeds depends on the average yield and harvest areas of oilseeds.

Figure 6.1: Structure of simulation model: China's future trade in protein meals



Source: Author

6.2 Income elasticities of demand for livestock products

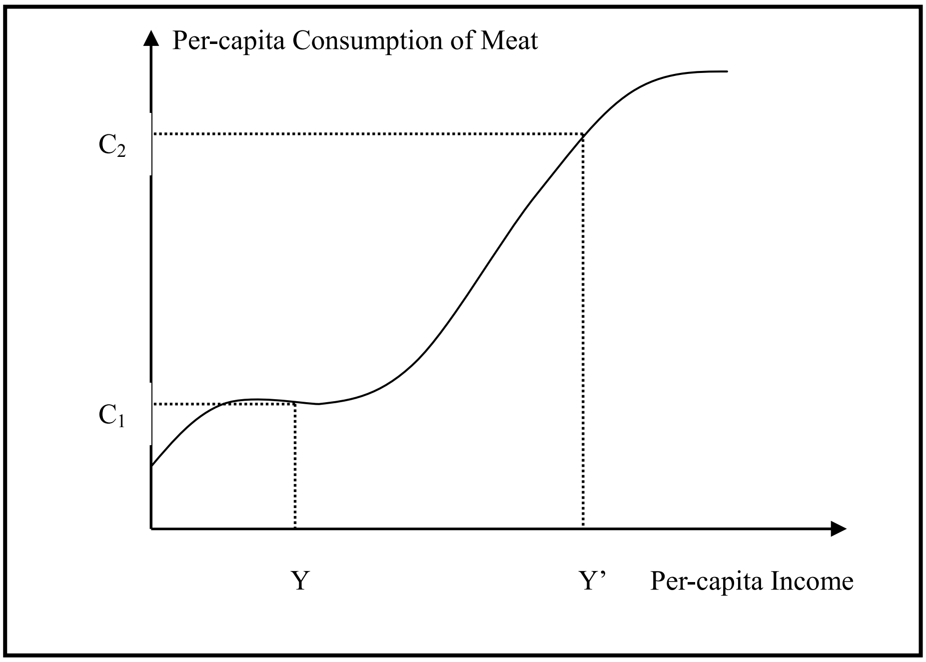
Rising per capita consumption of livestock products is influenced by a number of socio-economic factors including income growth, price factor, and consumer preferences, in which income growth plays the leading role. China has achieved extraordinary income growth since the early 1980s (SSB-China's Statistical Year Book, various years). China's fast household income growth has strong impact on per capita consumption of livestock products.

Engel's Law explains the relationship between food consumption and disposable income and demonstrates that the proportion of income devoted to food declines as income grows, even if actual expenditure on food increases. Global rising consumption of livestock products (Livestock Revolution) can be partially explained by Engel's Law (Lattimore, 2000).

The response of demand for livestock products to income growth shows wide variations among the countries at different income levels. In high-income countries (North America and the EU), livestock products are normal goods. For these countries, income elasticities of demand for livestock products range between 0 and 1. Income growth mainly causes shifts in consumer spending toward non-food items, and consumption of non-food items grows at a faster rate than livestock products. In contrary, livestock products, in low and middle income countries, are sometimes classified as luxury commodities (income elasticities more than 1) and have higher income elasticities than high-income countries. Higher proportion of increased consumer income will be devoted to livestock products. Consequently, income growth in these countries has bigger impact on consumption of livestock products than high-income countries. It implies that "Livestock Revolution" is driven up by low-and-middle income countries, rather than high-income countries.

Keyzer and Merbis (2002) investigated the relationship between per-capita meat consumption and disposal income. They found that Engel Curve for analyzing meat consumption can be divided into three different stages. In the first stage, when per capita income is below a certain lower threshold, demand for meat is low and barely increases. The effect of disposal income growth on per capita meat consumption is slight and minor. In the second stage, after the per capita income jumps to ***Y***, income growth has a strong effect on per capita meat consumption. In the third stage, when the per capita income reaches ***Y'***, the slope of the Engel curve becomes low again.

Figure 6.2: Engel curve of meat consumption



Source: Keyzer and Merbis (2002)

The extended piecewise linear demand system was developed by Keyzer and Merbis (2002). Cross country data for 125 countries between 1975 to 1997 were used to estimate this demand system. The estimated results support that the slope of the second stage is significant from first and third stage and the Engel Curve is convex in the first and second stages and concave in the third stage. As demonstrated by dummy variables, China was in the second stage moving from a low income country to middle income country, a stage in which income growth has a strong impact on meat demand.

In China, proportion of disposal income devoted to food items keeps decreasing trends. From 1990 to 2008, the shares of food spending in total disposal income have declined from 54% to 38% for urban household and from 59% to 44% for rural household (SSB-China's Statistical Year Book, various years).

In contrast, the shares of urban and rural household spending on livestock products in total disposal income have steadily increased since 1980s (Ma et al., 2003).

Accurate understanding detail information about the household demand for various livestock products with respect to income growth across different socio-economic groups plays a central role in projecting China's total consumption of livestock products. Differentiated analysis of demand for livestock products will provide better projection. However, most empirical studies on China's consumer demand for livestock products focused either on a broad group of commodities, such as food, clothing, and housing, or on whole food groups. Studies by Ma et al (2003) and FAPRI (2010) provided better and detail income elasticities of various livestock products across different socio-economic groups.

Table 6.1 shows estimated household income elasticities of demand for various livestock products from 1980 to 2000 (Ma et al, 2003). The rural and urban income elasticities for the 1980s and 1990s were separately estimated to capture the changes between these two decades. Estimated income elasticities demonstrated that rural and urban households' meat consumption pattern kept constant in the 1980s and 1990s. Most estimated income elasticities were greater than 1 and suggested that livestock products were luxury for China's consumers, with the exception of pork. Pork became the normal good (income elasticities less than 1) for both rural and urban household. Urban income elasticities (except pork) were larger than rural income elasticities, reflecting that the rising household income has stronger impact on demand for livestock products in urban area. Income elasticities of demand for poultry were the highest. This was consistent with that poultry meat was the favorite meat product.

Table 6.2 displays the income elasticities and own-prices of demand for livestock products estimated by FAPRI (2010). The significant differences of estimated income elasticies between FAPRI (2010) and Ma et al (2003) reflect the time interval and China's economic development. Study by FAPRI (2010) shows that there are no apparent differences in meat consumption pattern between rural and urban household.

All rural and urban income elasticities are smaller than 1 and indicate meat products are normal goods. Income elasticities of demand for pork are the lowest at 0.12 and 0.10 for rural and urban household, respectively. This implies that household demand for pork becomes inelastic with respect to income growth. Rural and urban income elasticities of demand for poultry and ruminant meat are higher than that of pork. The response of rural and urban demand for ruminant meat to increase in income is closed to that of poultry. All own-price elasticities are negative and modest. Rural household demand for poultry and ruminant meat are more price elastic than that of urban household. Income elasticities estimated by FAPRI (2010) explains meat consumption patterns in the 2000s. FAPRI-estimated income elasticities are used to project China's per capita meat consumption.

Table 6.1: Estimated household income elasticities of demand for livestock products

	Income elascities 1980-1990		Income elascities 1990-2000	
	Rural Household	Urban Household	Rural Household	Urban Household
Pork	0.7954	0.6821	0.7644	0.6594
Beef	1.0854	1.6837	1.1212	1.4114
Mutton	0.4542	1.2929	0.7491	1.2463
Poultry	1.6941	1.9542	1.3887	1.4119
Eggs	1.6425	1.2447	1.6967	1.3338

Source: Ma et al., 2003

Table 6.2: FAPRI-estimated household income and own-price elasticities of demand for livestock products in 2010

	Income elasticities		Own-price elasticities	
	Rural	Urban	Rural	Urban
Pork	0.12	0.10	-0.30	-0.30
Beef and mutton	0.45	0.40	-0.50	-0.37
Poultry	0.46	0.45	-0.44	-0.40

Source: FAPRI database (2010)

6.3 Forecasting per capita demand for livestock products

As early explained in this chapter, forecasting per capita demand for livestock products is the starting point for projection the demand-derived protein meal requirement, which involves the incorporation of estimated income elasticities of the demand for livestock products, the real per capita income growth, and the base-year per capita consumption of livestock products.

As early mentioned in this Chapter, China's official livestock production series were overestimated that had large error and significant bias, while on the other hand, consumption series omitted the out-of-home consumption (SSB-China's Statistical Year Book, various years). To accurately project China's future demand for livestock products, China's base-year per capita consumption of livestock products are adjusted to compensate the missing values of out-of-home consumption. CCAP survey in 1999 found that 34% of pork consumption for urban household was consumed outside the home in restaurants or other places, while 12% for rural household (Ma et al., 2004). This survey also found a similar out-of-home consumption pattern for poultry and ruminant meat. The year 2008 is defined as the base year.

The formulas used to adjust rural and urban household's per capita consumption of livestock products can be written as (6.1) and (6.2), respectively:

(6.1) $APRM_i = PRM_i/(1-0.12)$

(6.2) $APUM_i = PUM_i/(1-0.34)$

where, per capita consumption of livestock, products in the base year is expressed as

$APRM_i$ = adjusted rural household's per capita consumption

$APUM_i$ = adjusted urban household's per capita consumption

PRM_i = official rural household's per capita consumption

PUM_i = official urban houshold's per capita consumption

In the adjustment equations, ***i*** refers to pork, poultry, or eggs.

The adjusted base year rural and urban household per capita consumption of livestock products are shown in Table 6.3.

Table 6.3: Adjusted base year rural and urban household per capita consumption of livestock products in 2008

	Rural households (kg/capita)			Urban households (kg/capita)		
	pork	poultry	eggs	pork	poultry	eggs
Official per capita consumption of …….	12.65	4.36	5.43	19.26	8.00	10.74
Adjusted per capita consumption of …….	14.38	4.95	6.17	29.18	12.12	16.27

Source: The official base year per capita consumption of livestock products is available from SSB data source. The adjusted per capita consumption of livestock products is calculated by author.

Per capita income growth

Per capita income growth has been the main force driving the rising consumption of livestock products. Consequently, the assumption of per capita income growth plays the crucial role in projection per capita and national demand for livestock products. The assumption of per capita income growth from previous projection studies vary greatly. Liu (2004) assumed that per capita income growth was at 3.0 to 3.5% per annum. From 1990 to 2008, the average real per capita income growth rates for rural and urban household were at 5% and 8%, respectively (SSB-China's Statistical Year Book, various years).

Per capita consumption of livestock products in 2009 is calculated based on adjusted per capita consumption of livestock products in 2008 (base year). It is assumed that the real prices of pork, poultry, and eggs remain unchanged throughout the entire projection period. The functions used to determine the projected rural and urban household per capita consumption of livestock products in 2009 can be defined as (6.3) and (6.4), respectively:

(6.3) $PPRM_i = APRM_i * (1 + INR_i * 5\%)$

(6.4) $PPUM_i = APUM_i * (1 + INU_i * 8\%)$

where

$PPRM_i$ = projected per capita consumption of livestock products for rural household in the 2009

INR_i = rural income elasticity of demand for livestock products

$PPUM_i$ = projected per capita consumption of livestock products for urban household in the year 2009

INU_i = urban household's income elasticity of demand for livestock products

i = category of livestock products

The functions used to estimate the projected rural and urban household per capita consumption of livestock products from 2010 to 2020 can be defined as (6.5) and (6.6), respectively:

(6.5) $PPRM_{i,t} = PPRM_{i,t-1} * (1 + INR_i * 5\%)$

(6.6) $PPUM_{i,t} = PPUM_{i,t-1} * (1 + INU_i * 8\%)$

where

$PPRM_{i,t}$ = projected per capita consumption of livestock products for rural household

$PPUM_{i,t}$ = projected per capita consumption of livestock products for urban household

t = year

It is assumed that income elasticities of demand for livestock products hold constant during the projection period. Income leasticities are taken from the estimated income elasticies, as shown in Table 6.2. Income elasticities of eggs for rural and urban household are set at 0.455 and 0.491, based on IFPRI estimate (Huang et al., 1997). The projected results for the per capita consumption of pork, poultry, and eggs from 2010 to 2020 are presented in Table 6.4. Projected annual rural per capita consumption of pork, poultry and eggs increases to 15.44, 6.47 and 8.08 kg by 2020, respectively. For the urban household, projected annual per capita consumption of pork, poultry and eggs reaches to 32.11, 18.70 and 25.84 kg by 2020, respectively.

Table 6.4: Projected annual per capita consumption of livestock products: 2010-2020

	Rural household (kg/capita)			Urban household (kg/capita)		
	Pork	**Poultry**	**Eggs**	**Pork**	**Poultry**	**Eggs**
2010	14.55	5.18	6.45	29.65	13.03	17.58
2015	14.99	5.79	7.22	30.86	15.61	21.31
2020	15.44	6.47	8.08	32.11	18.70	25.84

Source: Author's calculations

6.4 Forecasting total consumption of livestock products by demand approach

Total consumption of livestock products can be calculated through multiplying projected rural and urban per capita consumption of livestock products by respective numbers of rural and urban population. The numbers of the population and structure of population (ratio of urban to rural population) are decisive factors for projection of total consumption of livestock products.

Rural-to-urban migration

Rural-to-urban migration has a significant impact on increase in overall consumption of livestock products. The income disparity between rural and urban households has been one of distinct features of China's economy. Income disparity is the primary factor causing inequity consumption of livestock products between rural and urban household. Moreover, poor market development and lack of infrastructure and transportation in rural areas aggravate this inequity consumption. With the development of China's economy, the income disparity and inequity consumption show rising trend. Rural-to-urban migration is the primary means for rural households to change their income disparity and inequity consumption.

The rising income disparity between rural and urban household combined with a large number of surplus labor in rural areas has brought about the world largest internal rural-urban migration. Migrate workers have made the fundamental changes in their food consumption patterns including increasing the animal protein intake level and expenditure devoted to livestock products. This study assumes that the per capita consumption of livestock products of the rural-urban migrant is equivalent to the average level of urban residents.

Rapid rural-urban migration has changed the structure of the population and ratio of urban to rural population has changed substantially, from 18% in 1978 to 46% in 2008 (SSB-China's Statistical Year Book, various Years). Based on the speed of rural-to-urban migration from 1978 to 2008, the baseline proportion of the population living in urban areas is set at 50 % for 2010, 55% for 2015, and 60% for 2020.

Population

Population is another decisive determinant in the projection of China's total demand for livestock products. As the world's most populous country (1.3 billion people), China's population has the large impact on projection result of total demand for livestock products.

According to data from National Population and Family Planning Commission of China (2009), China's population growth rate peaked in the late 1960s and early 1970s. Since then, due to China's birth control policy, the population growth rate has dropped. It was about 1.08 % in 1990-2000. National Population and Family Planning Commission (2009) estimated that the population growth rate would be 0.7% annually between 2005 and 2010 and 0.6% between 2010 and 2020. China's population is expected to reach 1.36 billion in 2010 and 1.40 billion in 2020. China's population will reach its peak in 2030 and then drop.

Throughout the projection period (2010-2020), the differences in annual population growth rates are small. According to the projection by National Population and Family Planning Commission of China (2009), the average annual population growth rate is assumed at 0.7% from 2010 to 2020. Rising demand for livestock products is highly dependent on the per capita real income growth and change in structure of population (ratio of urban to rural population).

Three alternative scenarios are designed to simulate China's total demand for livestock products. For proportion of the population between rural and urban, the gap between low bound and high assumption is 6%. The baseline assumption of real per capital income growth for rural and urban household follows the calculation by SSB data, 5% for rural household and 8% for urban household. The higher growth rates are set at 7% for rural household and 10% for urban household, while the lower growth rates are 3% for rural household and 6% for urban household. Table 6.5 presents socioeconomic variables used to project China's total consumption of livestock products including population growth rates, per capita real income growth rates, and the share of urban and rural population.

Table 6.5: Assumptions of factors affecting China's total demand for livestock products in China

	Low	**Baseline**	**High**
		Growth rate (%)	
Population			
2008-2010	0.7	0.7	0.7
2010-2020	0.6	0.6	0.6
Per capita real income			
Rural household	3	5	7
Urban household	6	8	10
		Percent (%)	
Ratio of Urban to Rural Population			
2010	47/53	50/50	53/47
2015	52/48	55/45	58/42
2020	57/43	60/40	63/47

Source: The population growth rates are based on the projection by National Population and Family Planning Commission of China (2009). The baseline per capita real income growth rates for rural and urban household and share of urban population are based on calculated real growth rates from SSB-China's Statistical Yearbook, various years.

The functions for determining China's rural population and urban population are expressed as (6.7) and (6.8), respectively:

(6.7) $POPR_t = POP*(1+RP_t)*SRP_t$

(6.8) $POPU_t = POP*(1+RP_t)*SUP_t$

where

$POPR_t$ = rural population

$POPU_t$ = urban population

POP = population in base year of 2008

RP_t = the real population growth rate

SRP_t = the share of rural population

SUP_t = the share of urban population

t = year

China's national consumption of livestock products is calculated by multiplying the projected urban and rural per capita consumption of livestock products by their respective population numbers. The equations for calculation of total rural and urban household consumption of livestock products of category ***i*** can be written as (6.9) and (6.10), respectively:

(6.9) $MEATR_{it} = PPRM_{it}*POPR_t$

(6.10) $MEATU_{it} = PPUM_{it}*POPU_t$

where

$MEATR_{it}$ = the total rural household consumption of livestock products

$MEATU_{it}$ = the total urban household consumption of livestock products

China's total consumption of livestock products is made up of total rural and urban household consumption of pork, poultry and eggs. The total rural and urban consumption of livestock products can be expressed as (6.11) and (6.12), respectively:

(6.11) $$TMEATR_t = \sum_i MEATR_{it}$$

(6.12) $$TMEATU_t = \sum_i MEATU_{it}$$

where

$TMEATR_t$ = the total rural household consumption of livestock products

$TMEATU_t$ = the total urban household consumption of livestock products

China's total pork, poultry, and egg consumption is projected by incorporating of forecasted per capita pork, poultry and eggs consumption, change in structure of population, and population growth. Projected per capita consumption of livestock products is shown in Table 6.4. As explained in Table 6.5, three scenarios are simulated and discussed under three alternative real income growth rates for rural and urban households. Table 6.6 displays the quantities of projected pork, poultry, and egg consumption.

Table 6.6: Projected China's total consumption of livestock products through demand approach (Million Metric Tons)

	Projected Consumption of Livestock products through 2020		
Basic Scenario	**2010**	**2015**	**2020**
Projected Pork Consumption	29.76	32.91	36.38
Projected Poultry Consumption	12.26	15.53	19.74
Projected Egg Consumption	16.18	20.77	26.79
Total	**58.20**	**69.21**	**82.91**
Low Scenario			
Projected Pork Consumption	29.03	31.77	34.78
Projected Poultry Consumption	11.73	14.21	17.27
Projected Egg Consumption	15.44	18.91	23.25
Total	**56.20**	**64.89**	**75.30**
High Scenario			
Projected Pork Consumption	30.50	34.06	38.02
Projected Poultry Consumption	12.80	16.95	22.53
Projected Egg Consumption	16.94	22.80	30.81
Total	**60.24**	**73.81**	**91.36**

Source: Calculation by Author

6.5 Derived protein meal demand for China's pig and poultry sector

This section forecasts future protein meal requirement for feeding farm animals derived from projected China's total consumption of livestock products. The trade of livestock products accounts for only a few percent of total production and consumption (SSB-China's Statistical Year Book, various years). Consequently, projected total consumption of livestock products is assumed to be entirely provided by domestic producers.

Feed requirement is calculated through multiplying projected household consumption for pork, poultry, and eggs by their respective feed-meat conversion ratios, in which protein requirement of animal feed is measured by protein meals.

It is assumed that animal rations provide sufficient energy and protein for animal growth. Based on animal diet formation system in China, feed grains provide most of the energy for both specialized and traditional raised animals, while protein meals (oilseed meals, fish meal, and MBM) contribute most of the protein supply for specialized raised animals and a part of the protein supply for traditional raised animals.

To project derived protein meal demand requires for detailed, precise, separated technical parameters and indicators of both specialized and traditional raised animals with respect to livestock inventories, feed-meat conversation ratios, the shares of outputs, and feeding practices.

Table 6.7 presents the slaughtered numbers and yield per carcass of pig and poultry in China. The slaughtered numbers of pigs and poultry have increased steadily since 1978 and jumped to 576.38 million and 10.23 billion in 2008, respectively. Their average annual growth rates were at 4.13% and 7.23%. Technical parameter (yield/carcass) has also made significant progress in late 1970s and in the 1980s, but it remained constant in 1990s and 2000s.

Table 6.7: Slaughtered numbers and yield/carcass of China's pig and poultry sector

Year	Pig Slaughtered (Million)	Pig Yield/Carcass (Kg/Head)	Poultry Slaughtered (Billion)	Poultry Yield/Carcass (Kg/Head)
1978	171.08	51.28	1.26	1.21
1979	198.85	54.66	1.31	1.21
1980	210.14	57.70	1.37	1.22
1985	233.65	69.44	1.64	1.23
1990	304.79	73.79	2.72	1.38
1991	325.45	74.70	3.15	1.42
1992	345.73	75.11	3.46	1.48
1993	368.08	75.65	4.38	1.46
1994	394.39	76.35	4.81	1.49
1995	427.16	76.16	5.75	1.51
1996	438.54	76.91	5.89	1.49
1997	429.26	77.60	6.99	1.46
1998	478.82	77.56	7.45	1.51
1999	514.47	75.12	8.20	1.43
2000	531.17	76.74	8.48	1.50
2001	531.05	76.34	8.33	1.50
2002	545.67	76.42	8.48	1.50
2003	553.78	76.37	8.89	1.48
2004	568.75	76.09	8.87	1.49
2005	584.56	75.77	9.40	1.49
2006	615.33	76.30	9.34	1.53
2007	623.77	76.22	9.75	1.54
2008	576.38	76.05	10.23	1.55

Source: FAOSATA database, various years

Chicken and duck are the most important poultry species in China. Table 6.8 shows slaughtered numbers and yield per carcass for China's Chicken and Duck Sector. The slaughtered numbers of chicken reached 7.76 billion in 2008, more than 7 times increase over 1978. Chicken yield per carcass increased an average of 0.91% annually from 1978 to 2008. The slaughtered numbers of duck reached to 1.91 billion in 2008, an increase of 9 times. Duck yield per carcass remained constant.

Table 6.8: Slaughtered numbers and yield/carcass of China's chicken and duck sector

Year	Chicken Slaughtered (Billion)	Chicken Yield/Carcass (Kg/Head)	Duck Slaughtered (Billion)	Duck Yield/Carcass (Kg/Head)
1978	1.00	1.08	0.21	1.32
1980	1.08	1.08	0.23	1.32
1985	1.32	1.11	0.26	1.32
1990	2.13	1.25	0.44	1.35
1991	2.43	1.31	0.53	1.25
1992	2.68	1.34	0.59	1.33
1993	3.43	1.33	0.74	1.33
1994	3.75	1.37	0.82	1.33
1995	4.44	1.36	0.97	1.32
1996	4.54	1.35	1.00	1.28
1997	5.50	1.32	1.11	1.32
1998	5.81	1.37	1.22	1.31
1999	6.26	1.31	1.51	1.24
2000	6.63	1.37	1.42	1.32
2001	6.45	1.37	1.44	1.33
2002	6.64	1.38	1.41	1.31
2003	6.96	1.36	1.49	1.29
2004	6.90	1.37	1.52	1.29
2005	7.24	1.38	1.67	1.29
2006	7.20	1.41	1.65	1.32
2007	7.46	1.42	1.77	1.32
2008	7.76	1.42	1.91	1.32

Source: FAOSTAT database, various years

Although the feed-meat conversion ratios are essential for estimate the feed requirements, information about feed-meat conversion ratios regarding different species (pigs and poultry) and different production systems (specialized and traditional production) are unclear, particularly traditional production (Zhou et al., 2006). Available estimated feed-meat conversion ratios show considerable variation because of farm size, survey's methods, survey's locations, as well as assumptions. Table 6.9 summarizes the major studies on China's feed conversion ratios for pigs, poultry and eggs. The feed conversion rates for pigs range from a maximum of 7 to a minimum 3, for broilers from a maximum of 4 to a minimum 2, and eggs have the smallest variation ranging from 2.5 to 3.5. Due to transition of livestock production toward more specialized operation and progress in farm management, breeding technology, and feeding practices, feed-meat conversion ratios show a declining trend.

Table 6.9: Summary of estimated feed-meat conversion ratios between 1990 and 2001

Author	Production type	Pork	Poultry	Eggs
Gao (1990)	Average	6-7	2	
Yu (1991)	Average	5.1	3	2.8-3
Food Study Group (1991)	Average	5.5-6.4	2.5-3.8	3-3.5
Editing Committee of MOA (1991)	Average	4-4.5	2.5	
Zhou (1993)	Average	5	2.2	2.8
RGCFDS (1993)	Average	5.5-6	2.5-3.5	3-3.5
Wang and Huo (1996)	Feeding practice	3.1	1.9	2.7
	Average	3.2	2.2	3
Cheng et al (1997)	Average	3.5	2.1	3
NORHS (1998)	Feedlots	3.3-3.5	2.36	2.96
	Specialized farms	3.24		
	Backyard farms	3.47		
Guo et al. (2001, p. 23)	Average	4	4	2.5

Source: Liu (2004) and Zhou et al (2006)

The appropriate feed-meat conversion rates are required for projection feed demand. The feed-meat conversion rates are adopted the estimates conducted by Tuan and Dyck (2001). The feed conversion ratio for backyard pig production is set at 6 and for specialized pig production at 4. The feed conversion ratio for backyard broiler production is set at 4 and specialized broiler production at 2.4. The feed conversion ratio for egg production is set at 2.6. These feed-meat conversion ratios are within the range listed in Table 6.9.

Table 6.10: Projected shares of backyard and specialized pig and poultry production by FAPRI

	Projections for Years		
	2010	2015	2020
Pig production share (%)			
Traditional production	63.81	57.96	52.96
Specialized production	36.19	42.04	47.04
Poultry production share (%)			
Traditional production	54.40	58.90	63.40
Specialized production	45.60	41.10	36.60

Source: The progress of structural change of various livestock production incorporates the projection data from FAPRI database, various years.

For projection the demand for protein meals derived from feed requirements, understanding the proportions of livestock outputs from different production systems is unavoidable. It is hard to obtain the accurate and detail information on distribution of livestock outputs from different production systems because of China's large size livestock sector (million specialized and traditional livestock farmers) and diverse geographic condition. Table 6.10 presents proportions of livestock output from backyard and specialized production in pig and poultry sector estimated by FAPRI.

Animal feeding practices and feed compositions is jointly determined by livestock species, production systems (traditional or specialized) and local available feed resources. As previously mentioned in Chapter 2, a distinct feature of feed compositions is that feed residues or non-conventional feed sources constitute a large share of the farm animal feed, including crop residues, sorghum, grass, and household waste. Feed compositions of animal rations consist of compound feed, protein meals and/or concentrate, unprocessed grain, and residual feed for both traditional and specialized livestock, although in specialized production, residues are used only to a minor extent. Protein meals in animal rations generally come from two separated parts, supplemented protein meals and protein meals from compound feed.

To compute the requirements for protein meals as animal feed, a feed technology function is applied to distinguish protein meals, feed grain, and residual feeds. The function is given as (6.13):

(6.13) $\alpha_{it} M_{it} = P_{it} + R_{it} + U_{it} + C_{it}$

where

α_{it} = the feed-meat conversion ratio for livestock product i;

M_{it} = the amount of projected demand for livestock product i;

R_{it} = the quantity of residual feeds in animal feed i;

P_{it} = the quantity of protein meals or concentrates in animal feed i;

U_{it} = the quantity of unprocessed grain in animal feed i;

C_{it} = the quantity of compound feed i;

i refers to pork, poultry or eggs. Technical and management progress can lead to a reduction of α. In this study, it is assumed that α improves by 12 % during 1998-2020.

As early introduced in this section, because of wide variation in components of livestock rations and local available feed sources, the detail information about livestock feeding practices and compositions of livestock ration across different production system is unclear and hard to obtain. Table 6.11 presents general feeding practises and feed compositions of pig, broiler, and layers rations. The quantities and types of ingredients used in traditional pig production are quite different from these in specialized pig production. The raw feed and bran account for 18.5 and 26.9% of traditional raised pig ration, respectively. Few raw feed and bran are used in specialized raised pig ration. Specialized raised pig frequently consumes large amounts of compound feed and cakes (protein meals). The main compositions of specialized raised broiler and layer rations are cereals and compound feed. The compound feed and cakes account for 69.7% and 7.2% of specialized raised broiler feed, respectively, while in specialized raised layer feed, their shares are 52.3% and 6.2%. Compared to specialized raised pig rations, specialized raised broiler and layers rations contain more compound feed and cakes. These imply that feeding specialized raised broiler and layers require more protein meals.

Table 6.12 presents the approximate proportions of complete feed and protein meals in backyard and specialized raised pig, poultry, and layer rations. These percentages will be used to project the demand for protein meals as animal feed. In average, China's feed manufacturing mills produce pig feed consisting of 80% grain and 15% protein meal, broiler feed with 75% grain and 20% protein meal (Zhou, 2002). Layer feed has a similar formulation to broiler feed, but with more minerals such as calcium and phosphorus.

Table 6.11: General feeding practises and feed compositions in China (%)

Feed type	Pigs		Broiler	Layers
	Traditional production	Specialized production	Specialized production	Specialized production
Cereals	41.2	38.5	20.9	33.9
Compound feed	8.6	34.6	69.7	52.3
Cakes	1.4	6.9	7.2	6.2
Bran	26.9	14.0	0.2	4.2
Concentrates	0.6	3.5	1.9	1.9
Fish meal	0.0	0.0	0.2	1.5
Other farm by products	1.9	2.6	0.0	0.0
Green/raw feed	18.5	0.0	0.0	0.0

Note: The compound feed is a mixture of all ingredients, which is produced based on animal nutritional formulations, to provide the specific nutrients requirement of animals. Concentrate feed refers to the mixture of all necessary ingredients, except grains. The main contents of concentrate are the protein meals. Source: MOA internal report taken from Ke (2001).

Table 6.12: Share of complete feed and protein meals in animal rations (%)

Feed type	Pigs		Broiler		Layers
	Backyard production	Specialized production	Backyard production	Specialized production	Specialized production
Complete feed	10	35	30	70	53
Protein meals	5	10	5	9	10

Source: The shares of complete feed and protein meals in animal rations are based on survey conducted MOA, as shown in Table 6.11 and China's Feedstuff Books (Zhou, 2002).

China's protein meal requirement is measured as demand for soybean meal. It is calculated by incorporating of the projected demand for pork, poultry and eggs, feed-meat conversion ratios, carcass yield rates, and the average protein meal used in pig, broiler, and layer rations. As early mentioned in this section, feed conversion ratios are based on the surveys conducted by Tuan and Dyck (2001). It is assumed a 70% carcass yield for broiler and a 60% carcass yield for pigs, respectively. Function 6.14 indicates that projected total requirement for protein meals include three components, meal requirement for pig production, broiler production and egg production, respectively.

(6.14) $PMT_t = PMP_t + PML_t + PME_t$

where

PMT_t = projected total protein meal requirement

PMP_t = projected protein meal requirement for pig production

PML_t = projected protein meal requirement for broiler production

PME_t = projected protein meal requirement for egg production

t = year

The compositions of protein meals in pig rations are from two separated parts, concentrates (protein meals) and complete feed. Based on formulation of China's pig feed, the proportion of protein meals is around 15% in compound feed. The carcass yield of pig is 60%. Total protein meals requirements as pig feed can be calculated by adding protein meal requirements derived from both traditional and specialized raised pigs. The function for calculation the protein meals in pig ration is given as (6.15):

(6.15) $PMP_t = (PMEAT_t/0.60)* FPT_t*SPT_t*(CPT*0.15+PPT)+(PMEAT_t/0.60)* FPS_t*SPS_t* (CPS*0.15+PPS)$

where

$PMEAT_t$ = projected pig production

FPT_t = traditional raised pig feed conversion rate

FPS_t = specialized raised pig feed conversion rate

SPT_t = share of pork production from traditional backyard production

SPS_t = share of pork production from specialized production

CPT = share of compound feed in traditional raised pig's ration

CPS = share of compound feed in specialized raised pig's ration

PPT = share of protein meal in traditional raised pig's ration

PPS= share of protein meal in specialized raised pig's ration

t = year

Same as pig feed, protein meals in poultry feed also come from two parts, concentrates (protein meals) and complete feed. The proportion of protein meals in poultry complete feed is about 20%. The carcass yield of poultry is 70%. Total protein meal requirement as poultry feed can be estimated by combined protein meal requirement derived from traditional operation as well as specialized operation. The equation for calculating the protein meal requirement in poultry ration is given as (6.16):

(6.16) $PML_t = (MEAT_t/0.70)^* \; EBT_t \; {}^*SBT_t \; {}^*(CBT^*0.20 + PBT) + (MEAT_t/0.70)^* \; EBS_t \; {}^*SBS_t \; {}^*(CBS^*0.20 + PBS)$

where

$BMEAT_t$ = projected broiler production;

EBT_t = traditional backyard raised poultry feed conversion rate;

EBS_t = specialized raised poultry feed conversion rate;

SBT_t = share of poultry production from traditional backyard production;

SBS_t = share of pork production from specialized production;

CBT = share of compound feed in traditional raised broiler's ration;

CBS = share of compound feed in specialized raised broiler's ration;

PBT = share of protein meal in traditional raised broiler's ration;

PBS = share of protein meal in specialized raised broiler's ration;

t = year.

It is assumed that the output of eggs is completely from specialized layer production. The making up of protein meals in layer rations are also from concentrates (protein meals) and complete feed. The proportion of protein meals in lay complete feed is same as poultry feed (20%). The equation for estimate the protein meal requirement in layer ration is specified as (6.17):

(6.17) $PME_t = (EGG_t)^* \; FET_t \; {}^*(CE^*0.20+PE)$

where

EGG_t = projected egg production;

FET_t = feed conversion rate of specialized egg production;

CE = share of compound feed in specialized raised layer's ration;

PE = share of protein meal in specialized raised layer's ration.

t = year.

Table 6.13: Projected protein meal requirement for pig, poultry and eggs feed

Protein feed requirement by livestock types	**Projected protein meal for livestock productions (Million Metric Tons)**		
	2010	2015	2020
Basic Scenario			
Pig	22.83	24.67	26.55
Broiler	7.40	8.72	10.29
Eggs	8.50	10.35	12.69
Total	**38.72**	**43.74**	**49.53**
Low Scenario			
Pig	22.27	23.81	25.38
Broiler	7.08	7.98	9.00
Eggs	8.11	9.43	11.02
Total	**37.46**	**41.22**	**45.39**
High Scenario			
Pig	23.39	25.53	27.74
Broiler	7.72	9.52	11.74
Eggs	8.90	11.37	14.60
Total	**40.02**	**46.42**	**54.08**

Source: Author's Calculations

As shown in Table 6.13, the possible outcomes of derived protein meal requirement are based on three alternative consumption levels of livestock products, which show in Table 6.6. China's demand for protein meal is projected by the incorporation of projected meat and egg consumption, feed conversion ratios, carcass yield rates, and average protein meal using in pig, broiler, and layer rations.

6.6 China's domestic production of protein meals

The supply of protein meals (soybean meal, fish meal, and MBM) is highly dependent on import sources. A high dependence on imported sources has become the bottleneck of the development of China's livestock industry.

6.6.1 China's production, consumption and trade of oilseeds, oilseed Meals, fish meal and MBM

According to FAOSTAT database, the global production of soybeans concentrated in a relatively few countries (Argentina Brazil, China and U.S.) and in 2008 the outputs from these four countries accounted for 90% of world supply. At same time, they are also the leading consumers of soybeans. China has become the largest importer in the world, while Argentina, Brazil and U.S are the top three exporters. The combined export share for Argentina and Brazil in the global market grows and displaces U.S. market share.

In 2008, based on FAOSTATA database, China was the largest producer of rapeseed, followed by Canada, India, and Germany. China's rapeseed consumption level resembles its production level. The increased rapeseed production is mainly driven by the rising demand for vegetable oil. The quantities of the sunflower seed and rapeseed production have remained constant.

China's annual production and consumption of soybeans and their products (meals and oils) remained in balance until the early 1990s. Thereafter, consumption has greatly exceeded domestic production. China produced 14 million metric tons of soybeans in 2007, and an additional 33 million metric tons was imported (FAOSTATA database, various years). As previously explained, due to increased household oil consumption and expanded domestic crushing capacity, China imports of soybeans rather than soybean meal (Tuan et al., 2004). The higher soybean crushing margins in the 1990s have stimulated the expansion of oilseed crushing industry.

As shown in Table 6.14, despite the rapidly rising market demand for oilseeds, during 1997 to 2008, the supply of the main oilseeds (soybeans, rapeseed and sunflower seeds) increased from 14.7 million metric tons to 15.0 million metric tons, gaining 0.3 million metric tons for soybeans; increased by 2.5 million metric tons for rapeseed and 0.5 million metric tons for sunflower seeds. In 2008, market structure of oilseed supply in China was that soybeans accounted for 52% of the total supply of oilseeds, rapeseed for 42%, and sunflower seeds for 6%, respectively.

Table 6.14: Domestic production of oilseeds in China (Thousand Metric Tons)

Commodity	1997	2000	2005	2006	2007	2008
Soybeans						
Beginning stocks	990	3,170	4,700	4,473	3,122	2,772
Ending stocks	3,018	4,910	4,473	3,122	2,772	2,910
Domestic production	14,728	15,400	16,350	16,000	14,300	14,975
Import	2,772	13,037	27,963	28,297	33,700	34,735
Crush use	8,450	18,900	34,500	35,500	38,100	39,279
Feed use	1,100	1,575	1,740	1,700	1,700	1,702
Food use	5,912	6,222	8,300	8,430	8,550	8,590
Rapeseed						
Domestic production	9,578	11,381	13,050	12,700	11,600	12,055
import	288	2,361	676	961	1,250	954
Crush use	8,950	12,530	13,056	12,981	12,200	12,322
Other use	916	1,212	670	680	650	687
Sunflower seed						
Domestic production	1,176	1,954	1,927	1,900	1,800	1,745
Crush use	730	950	972	958	842	788
Food use	383	860	749	754	750	787
Other use	60	113	95	95	95	90

Source: FAPRI database, various years.

Table 6.15 shows the development of harvest areas and per hectare yield of major oilseeds (soybeans, rapeseed and sunflower seeds) from 1978 to 2008. The soybean planted area increased slightly from 7.17 million hectares in 1978 to 9.13 million hectares in 2008. The average annual growth rate of soybean plant area was only at 0.81%. In contract, during the same period, rapeseed and sunflower seed planted areas significantly rise, from 2.60 million hectares to 6.59 million hectares, and 0.32 million hectares to 1.04 million hectares, respectively. The average annual growth rates of rapeseed and sunflower seed plant areas were at 3.15% and 4.01%, respectively. These figures imply that rapeseed and sunflower seed planted areas are growing at the much faster rates than that of soybeans.

Between 1978 and 2008, China's average per-hectare yields of soybeans, rapeseed and sun-flower seed increased from 1.06 metric ton to 1.70 metric ton, from 0.72 metric ton to 1.84 metric ton, and from 0.87 metric ton to 1,78 metric ton, respectively. The average annual growth rates of per-hectare yield of rapeseed and sunflower seed were at 3.18% and 2.42%. They are higher than that of soybeans (1.59%).

Several economic factors have limited the increase in its domestic soybean production and the maintenance its international competitive advantage. First, the government's strategy to achieve national food is through encouragement grain production and crowding out other crops including soybeans. Second, China's soybean production is concentrated in the Northeast and the North China plain. In the Northeast, soybeans are usually planted as the primary crop, while in the North China plain, arable land is suitable for planting two important crops - soybeans and grain (wheat and maize). Farmers decide whether to plant grain or soybeans based on their expected revenue. Government's subsidy, the advanced technology investment, reduced agricultural taxes were primarily targeted to grain producers (Tuan et al, 2004). These factors have caused that planted soybeans has been less profitable than planted grain and China's average per-hectare soybean yield is too low competed with its competitors. In 2008, average per-hectare soybean yield for China, Argentina, Brazil, and U.S were at 1.70, 2.82, 2.82, 2.67 metric ton and China's level was about 40%, 40%, and 36% lower than that of Argentina, Brazil, and U.S respectively (FAOSTAT database, various years).

Table 6.15: Harvest area and average yield of soybeans, rapeseed and sunflower seed in China

Year	Soybeans Harvest Area (Million Ha)	Soybeans Yield (Ton/Ha)	Rapeseed Harvest Area (Million Ha)	Rapeseed Yield (Ton/Ha)	Sunflower Seed Harvest Area (Million Ha)	Sunflower Seed Yield (Ton/Ha)
1978	7.17	1.06	2.60	0.72	0.32	0.87
1979	7.26	1.03	2.76	0.87	0.37	0.92
1980	7.23	1.10	2.84	0.84	0.84	1.08
1985	7.73	1.36	4.49	1.25	1.47	1.18
1990	7.56	1.46	5.50	1.26	0.71	1.88
1991	7.05	1.38	6.13	1.21	0.79	1.80
1992	7.22	1.43	5.98	1.28	0.81	1.83
1993	9.46	1.62	5.30	1.31	0.72	1.77
1994	9.23	1.74	5.78	1.30	0.80	1.70
1995	8.13	1.66	6.91	1.42	0.81	1.56
1996	7.48	1.77	6.73	1.37	0.69	2.06
1997	8.35	1.77	6.48	1.47	0.72	1.64
1998	8.50	1.78	6.53	1.27	0.89	1.65
1999	7.96	1.79	6.90	1.47	1.13	1.56
2000	9.31	1.66	7.49	1.52	1.23	1.59
2001	9.48	1.62	7.09	1.60	1.02	1.45
2002	8.72	1.89	7.14	1.48	1.13	1.72
2003	9.31	1.65	7.22	1.58	1.17	1.49
2004	9.58	1.82	7.27	1.81	0.93	1.66
2005	9.59	1.70	7.28	1.79	1.02	1.89
2006	9.30	1.67	5.98	1.83	0.99	1.83
2007	8.75	1.45	5.64	1.87	0.72	1.65
2008	9.13	1.70	6.59	1.84	1.04	1.78

Source: FAOSTATA database, various years

During 1997-2008, China's domestic oilseed meal production has grown significantly, in which the rising soybean meal supply accounted for the most increased oilseed meal production. Table 6.16 shows that between 1997 to 2008 China's soybean meal production grew from 6.7 million metric tons to 31.1 million metric tons, an increase of more than 4 times. As early explained in this section, the domestic soybean production remained unchanged. It can be drawn that the increased soybean meal supply was from the crush of imported soybeans. The domestic productions of rapeseed meal, peanut meal, and sunflower meal increased slightly. The consumption of peanut meal and sunflower seed meal accounts for a small share of total oilseed meal consumption.

Table 6.16: Domestic production of oilseed meals in China (Thousand Metric Tons)

Production of oilseed meals	1997	2000	2005	2006	2007	2008
Soybean meal	6,717	15,050	27,296	28,100	30,150	31,083
Rapeseed meal	5,549	7,800	8,208	8,130	7,675	7,752
Peanut meal	2,000	2,660	2,834	2,840	2,722	2,622
Sunflower meal	400	517	526	519	456	427

Source: FAPRI database, various years.

Because of resource constraint of fish meal and poor development of rendering industry in China, fish meal and protein animal proteins rely on imports from international market. China has been one of the largest import countries of fish meal. Compared to main protein meals, MBM only account for a small percent of total consumption of protein meals. In late 1990s, MBM was introduced to China as a protein supplement. Feed mills and farmers are unfamiliar with processed animal proteins and nutrition values of processed animal proteins have been underestimated (Li, 2009). Since it is widely believed that Mad Cow Disease comes from feeding contaminated processed animal proteins to ruminant animals, the status of imports of processed animal protein is unstable and unclear.

Table 6.17 presents the amount of MBM was imported to China during 2000-2007. As explained in Chapter 2, following the EU’s ban on MBM, China’s government took same action against MBM, imported from the EU. In 2004 and 2005, after the BSE was confirmed in North America, the global reaction was that ruminant processed animal proteins from North America were not allowed to use in animal rations. China’s government decided to take far-reaching measures on imports of processed animal proteins, ban on the imports and use of all MBM regardless of species from the U.S. and Canada. These actions caused the amount of the imports of MBM declined sharply since the 2000s.

Table 6.17: Imported MBM in China, 2000-2007 (Metric Tons)

	Year							
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Quantity of imported MBM	135,972	75,314	130,932	73,561	21,097	37,323	82,451	68.762

Source: National Renderers Association (NRA) Essential Rendering – Global Market 2008

6.6.2 Projection of major supply of protein meal from domestic sources

The total protein meal supply from domestic sources is calculated by adding up domestic production of oilseed meals (fish meal, rapeseed meal, sunflower seed meal, peanut meal and soybean meal), measured by the soybean meal equivalent. The oilseed meals, produced from imported oilseeds, are treated as imports.

Based on the nutritional standards of Feedstuffs Handbook (Zhou, 2002), the protein content of fish meal is set at 63%, rapeseed meal at 32%, sunflower seed meal at 28%, peanut meal at 44%, and soybean meal at 48%, respectively. The calculation of the supply of protein meals does not consider the effect of limiting amino acids. The equation for calculating China's total supply of protein meals in soybean meal equivalent is defined as (6.18):

(6.18) $TSBME_t = (FM_t*0.63)/(0.48)+ (RM_t*0.32)/(0.48)+ (SFM_t*0.28)/(0.48)+ (PM_t*0.44)/(0.48) +SBM_t$

where

$TSBME_t$ = China's total protein meals supply in soybean meal equivalent

FM_t = China's total domestic fish meal production

RM_t = China's domestic rapeseed meal production

SFM_t = China's domestic sunflower meal production

PM_t = China's domestic peanut meal production

SBM_t = China's domestic soybean meal production

t = year

Table 6.18 displays China's projected major protein meal supply from domestic sources in 2020. Then, these protein meals are converted into soybean meal equivalents. The projected supply of protein meals from domestic sources measured by soybean equivalents increases slightly from 23.2 million metric tons in 2010 to 25.0 million metric tons in 2020.

Table 6.18: Projected China's major protein meals supply from domestic sources by 2020

	Project Major High Protein Meals Supply (million metric tons)					
Year	Fish meal	Rapeseed meal	Sunflower seed meal	Peanut meal	Soybean meal	Total high protein meal supply in soybean meal equivalent
2010	0.500	8.565	0.446	2.798	14.02	23.21
2015	0.500	9.079	0.445	2.935	14.71	24.37
2020	0.500	9.500	0.450	3.000	15.00	25.00

Source: Major protein meals supply using FAPRI database, various years, the last column total high protein meal and fish meal supply in soybean meal equivalent calculated by author, based on protein contents.

6.7 China's protein meal balance sheets and their trade implications

According to three alternative levels of protein meal requirements projected in section 6.5, three different scenarios are constructed to discuss China's protein meal balances and their trade implications. Table 6.19 presents the results of baseline, upper-bound, and lower-bound projections of protein meal availability and requirements, as well as the requirements of the imports. The deficit of protein meals is equal to total requirement for protein meal minus total domestic supply of protein meals produced by domestically planted oilseeds. The deficit of protein meals is converted into corresponding soybean imports, based on soybean crush ratio.

Generally, soybean crush rates in China have two well accepted standards. Based on U.S. standard, when a bushel of soybeans (60 pounds) is crushed, the conventional result is 11 pounds of soybean oil, 44 pounds of 48% protein soybean meal (Chicago Board of Trade, 2010). China's standard, when 1 ton soybean is crushed, 16% soybean oil and 78.5% soybean meal will be produced (Dalian Commodity Exchange Database, 2009). The different processing methods have resulted in the variations in meal output rates. For this study, the calculation of imported soybeans is based on China's standard.

The projected total supply of protein meal in soybean meal equivalents shows only slight growth. Under the baseline scenario analysis, the total requirement for protein meals is projected to grow from 38.72 million metric tons in 2010, to 43.74 in 2015, and 49.53 in 2020, respectively. The corresponding soybean meal deficit will be 15.51 million metric tons in 2010, 19.38 in 2015, and 24.52 in 2020, respectively. Due to China's sufficient oilseed crush capacity, China is expected to directly import soybeans rather than import soybean meal or oil. Based on China's soybean crushing rate (78.5%), the imports of soybeans will be 19.76 million metric tons in 2010, 24.68 by 2015, and 31.24 by 2020, respectively.

Scenario outcomes demonstrate that the gap between the domestic supply and demand of protein meal derived from livestock production will continue to widen and the dependency on imports of protein meal or their associated oilseeds is expected to rise considerably.

Table 6.20 indicates the results of three different scenarios for the imports of soybeans as a protein source for China's animal feed. According to the baseline scenario result, China's soybean import dependency rate will rise from 40% in 2010 to 50% in 2020.

China's rising household animal protein intake and shift livestock production system toward more specialized and commercial operation will intensify China's shortage of protein meals and China's dependency rates on imported protein sources has steadily increased.

Table 6.19: Baseline, high bound and low bound projection of protein meal supply and demand by 2020 (Million Metric Tons)

Year	Total local availability of protein meals in soybean meal equivalent (1)	Total requirements for protein meals in soybean meal equivalent (2)	Protein meal deficit in soybean meal equivalent (2)-(1)	Soybean import needs
Basis Scenario				
2010	23.21	38.72	15.51	19.76
2015	24.37	43.74	19.38	24.68
2020	25.00	49.53	24.52	31.24
Low Scenario				
2010	23.21	37.46	14.24	18.14
2015	24.37	41.22	16.85	21.47
2020	25.00	45.39	20.39	25.98
High Scenario				
2010	23.21	40.02	16.80	21.24
2015	24.37	46.42	22.05	28.09
2020	25.00	54.08	29.08	37.04

Source: Author's Calculation.

Table 6.20: Dependency rates of soybeans imports based on three different scenarios

	2010	2015	2020
Low Scenario	0.38	0.41	0.45
Basic Scenario	0.40	0.44	0.50
High Scenario	0.42	0.48	0.54

Source: Author's Calculation.

7. Summary and Conclusions

The objectives of this study is to provide an in-depth analysis of China's supply, demand, and trade of protein meals, an interrelationship between livestock production and demand for protein meals, and the impact of rising demand for protein meals on global agricultural trade. In addition, this investigation suggests recommendations for appropriate policies to deal with the shortage of protein sources for feeding its farm animals.

7.1 Study overview

Protein sources for China's livestock sector vary significantly with the opportunity for further development. In China, oilseed meals, fish meal and MBM contribute most of the protein for feeding specialized and commercial raised animals, while they also provide a part of the protein for feeding traditional raised animals.

The commodities involved in this study consist of three key protein sources (oilseed meals, fish meal, and MBM) and their associated oilseeds (soybean, rapeseed, sunflower seed and peanuts). The conceptual framework of the model followed the basic structural model for analyzing the agricultural commodity. In the four-equation system (demand, supply, price and stocks), the market equilibrium condition of supply and demand of specific protein meal or oilseeds can be reached through interaction between supply and demand. The theory of joint products was also presented to explain supply and demand dynamics between oilseeds and their products (oil and meal).

Because of different types of the commodities trading between China and the rest of the world, the basic structural model was extended to the two-country partial equilibrium trade model. The extended structural model was designed to connect household demand for livestock products with the requirements of protein meals via various types of livestock inventories. The extended structural model constructed a complete system equation for determining the interrelationship between livestock production and demand for protein meals as well as their associated oilseeds, particularly soybeans.

The trade of livestock products and feed grain can affect the projection results for demand, supply and trade of protein meals. Since the trade of livestock products accounting for a small proportion of total domestic production and consumption, country's long term food security policy, expanded oilseed extraction capacity, the advantages (protein value, quantities, price, and safety factors) of soybeans compared with other oilseed meals, the trade between China and the rest of the world is primarily expressed as imports of soybeans. For these reasons, this study assumes that the trade of soybeans represents the linkage in the two-country partial equilibrium trade model, in which China's imports of soybeans equal the rest of the world's exports.

Soybean crush demand is defined as an input demand, derived from soybean production function. Soybean crush demand function incorporates the basic structural economic model with input demand theory. Moreover, the partial adjustment theory was also applied in the system equations.

The deficit status and trade situation of protein meals were simulated. "Demand approach" was used to determine the deficit status of protein meals. Forecasting derived demand for protein meals was based on the projected China's total demand for livestock products. China's total demand for livestock products was made up of total rural household demand and total urban household demand. In addition, the effects of other two decisive determinants (rural-urban migration and population growth) on total demand for livestock products were also considered. The projection of China's total demand for livestock products through "demand approach" incorporated separate data for rural and urban household with respect to the average per capita consumption of livestock products, real income growth, income elasticity of demand for livestock products, with respective numbers of the urban and rural populations.

The projected total demand for livestock products was then converted into corresponding feed needs, including energy and protein requirement. It is assumed that protein requirement of animal rations is provided by protein meals. The national requirements for protein meals were estimated by incorporating of the projected national demand for livestock products, feed-meat conversion ratios, and the average use of protein meals in animal rations. China's future deficit status of protein meals is calculated through the projected protein meal requirement minus the domestic supply of protein meals.

7.2 Summary of hypotheses examined

This section summarizes the results of tested hypotheses, which are as follow: (1) It is hypothesized that the technical change has the positive effect on the soybean production in China; (2) There is a substitute relationship between soybeans and rapeseed to produce soybean meal and rapeseed meal as protein feed in China; (3) China's WTO accession has a positive impact on imports of soybeans;

Hypothesis 1: The technical change has the positive effect on the soybean production in China.

This hypothesis is affirmed.

As shown in Table 5.26 in Chapter 5, the statistically significant trend variable reflects the positive impact of technical changes on China's soybean production.

Hypothesis 2: There is a substitute relationship between soybeans and rapeseed to produce soybean meal and rapeseed meal as protein feed in China.

This hypothesis is rejected.

Table 5.25 in Chapter 5 presents the estimated results of soybean and rapeseed crush demand function. The two regression functions have the similar structure. Both of them have following variables (lagged dependent variable, China's rapeseed price, China's soybean price, and China's meat output). To identify substitute relationship between soybeans and rapeseed, the positive and significant cross-price elasticities from both soybean crush demand function and rapeseed crush demand are required.

The cross-price elasticity of demand for rapeseed with respect to change in China's soybean price receives the opposite sign (-0.52) and is statistically significant at 10% level. The cross-price elasticity of demand for soybeans with respect to change in rapeseed price displays unexpected sign (-0.17) and suffers from statistically insignificant. Two significant and positive cross-price elasticities can not be found. The hypothesis there is a substitute relationship between soybeans and rapeseed for crush use in China is rejected.

Hypothesis 3: WTO accession has a positive impact on imports of soybeans.

This hypothesis is rejected.

A dummy variable is introduced to measure the impact of China's WTO accession on soybean trade. As demonstrated by the dummy of Table 5.3 in Chapter 5, China's WTO accession did not have a significant effect on its soybean imports. China's soybean import demand with respect to increase in meat output is elastic (3.28) and statistically significant at 1% level. This implies that the rising livestock output is the main driving force boosting imports of soybeans.

7.3 Main findings and general conclusion

Supply of and demand for soybeans have become less-price responsive in China. There are positive relationships between livestock production and crush demand for protein meals as well as their joint oilseeds. The estimated results demonstrate that there are constraints on increase in soybean harvest areas in China, which is consistent with the lack of sufficient protein meals for China's livestock sector. Technical change has the positive and significant effect on China's soybean production.

China's soybean imports have become sensitive to the price development between domestic and world market. The regulations on Genetically Modified Organisms and food safety potentially have strong influence on the trade of protein meals and their associated oilseeds. Soybeans and rapeseed production in the rest of the world have turned into inelastic.

The baseline, high-bound and low-bound scenarios of supply, demand, and trade of protein meals are developed based on three alternative household income growth rates and urban-rural population ratios (small differences in population growth rates during the projection period). The results of three alternative scenarios suggest that the deficit position of protein meals will continue to exacerbate. China's increased protein sources have become dependent on the increasing soybean meal supply. Soybean meal production from domestic produced soybeans will not increase. To fill protein meal shortage, China will directly import soybeans from the international market. The basic scenario result shows that China's soybean import dependency rate will substantially increase from 40% in 2010 to 50% in 2020.

China initially liberalized soybean trade to seek WTO membership in the late of 1990s. Since then, China's domestic produced soybeans have faced tremendous pressure and challenges from cheap imported soybeans. After a decade's development, the trade, distribution, and process of soybeans have been monopolized by a few foreign-owned grain and oil trade or processing enterprises. China's farmers experience difficulty for selling their soybeans. China's high dependency on imported soybeans causes the rising soybean price and push feed cost up. Rapidly rising protein cost in animal rations has become the main constraint to further development of China's livestock industry.

7.4 Policy recommendations

Improving feeding efficiency

The share of livestock production contributed by specialized and commercial livestock farmers is expected to grow at fast rate. The transition of livestock production toward intensive production and the rising farm size can significantly improve feeding efficiency and increase productivity, which could help to reduce the dependency on imported protein sources.

China is a resource constraint country in term of its population (1.3 billion). Protein sources for feeding farm animals are extremely scarce in China. For this reason, the attention of policy makers is suggested to give to the improvement of feeding efficiency and increasing livestock productivity.

Impact of technological innovation and development of biotechnology on protein utilization

Increasing protein utilization can be realized through the development of modern bio-technology. Nutritionally improved and enhanced crops have great potential to improve protein utilization in animal rations, to decrease feed costs, and to make the protein sources for animal rations affordable (FAO, 2002). Quality protein grain is a good alternative protein source for China's animal feed. The quality and contents of protein of grain are much below the requirements for feeding farm animals. A group of scientists at the Chinese Academy of Agricultural Sciences (CAAS) have developed good quality protein maize, which corrects the protein disadvantages of normal maize (Qi et al., 2002). Increasing the use of quality protein maize and reducing the share of expensive protein sources (soybean meal and fish meal) in animal rations could significantly lower the protein cost.

Because production costs of industrial amino acids have been largely reduced, the use of industrial amino acids in animal feed considerably increases (Toride, 2002). Expansion of the use of nutritionally improved crops and industrial amino acids can ease the scarcity of protein sources.

Moreover, due to rapid development of livestock industry and fixed-point intensive slaughter, China has become rich in slaughtered animal blood for development blood meal as protein feed. But, in China, except for a small percentage of slaughtered animal blood used directly for human consumption, the majority of slaughtered animal blood has been wasted. Blood meal, processed through high-technological spray-drying method, conquers traditional flash dehydrated or conventional cooler dehydrated nutritional weakness and has the highest nutritional value and digestible level (Tacon, 2005). Innovation and progress in blood meal processing technology makes the industrial utilization of blood meal as protein feed possible in China. A large number of blood meal processing plants have been established. Development of modern biotechnologies including nutritionally improved and enhanced crops, industrial amino acids, and blood meal processing technology can significantly reduce China's dependency on imported protein sources.

China's trade policy on Genetically Modified soybeans

Genetically modified soybeans emerged in the 1990s, but they have expanded worldwide. Most imported soybeans are genetically modified. Until 2007, 92% of U.S. soybeans, 98% of Argentina soybeans, and 64% of Brazilian soybeans were genetically modified soybeans (Genetically Modified Organisms-Compass, 2009). In the U.S. and Argentina, Genetically modified soybeans are planted as conventional soybeans without additional restrictions, whereas the Brazilian government's attitude towards genetically modified soybeans was more conservative. China is the only major country that solely plants non-genetically modified soybeans that face a massive threat from imported low-priced genetically modified soybeans.

The imported low-priced Genetically Modified soybeans have advantages in term of average yield, oil extraction rate, nutritional composition and processing conditions. According to Dalian Commodity Exchange Database (2009), the oil extraction rates of imported soybeans are from 19% to 21%, while domestic soybean oil extraction rates are about 16-17%. The higher oil extraction rates and the crush margin of imported soybeans cause the market share of domestic soybeans replaced by the imported soybeans. Domestic soybeans have to be used for producing traditional protein food like Toufu.

China's first regulation regarding imported Genetically Modified soybeans was introduced in 2002, and imports of soybeans were temporarily disrupted. Therefore, China decided to issue a permanent safety certificate for imported soybeans, which must be renewed every five years' period. Since then, imports of Genetically Modified soybeans have soared, and the soybean self-sufficient rate has sharply dropped. The potential risks of imported genetically modified soybeans toward human, animal and environment have not been fully identified and adequately addressed in China. Massive imports of Genetically Modified soybeans seriously threaten survival of domestic non-genetically modified soybeans and China's soybean farmers. China's government needs to reconsider its policy on imported Genetically Modified soybeans and formulate new regulations to protect domestic market. China's bio-safety regulation has the potential to be used as an instrument to counter foreign genetically modified soybeans.

Government support of domestic soybean production

Production situation of domestic soybean farmers has seriously worsened and China's domestic oilseed processing enterprises are facing wipeout in China's market. Under World Trade Organization agreement's "Green Box", China's government needs to improve the rural infrastructure and deliver a sustainable agricultural scientific research investment to increase yield (35% lower compared to competitors) and nutritional composition of soybeans. Moreover, China's government needs to provide soybean farmers with specialized and advanced technical assistance.

Feed safety issues

Awareness of public health and food safety issues have been heightened in China as a result of serious food safety crises since the 1990s, including the outbreak of Clenbuterol food poisoning, the Melamine scandal, food-borne bacterial infections and chemical contamination. These crises significantly erode consumers' confidence in domestically produced meat and dairy products and cause the rising concerns over the quality and safety of China's products.

In China, many farmers and livestock enterprises use illegal hazardous drugs, especially Clenbuterol, as growth promoters in their animal feed to save livestock production costs and shorten the raising period. Clenbuterol is a banned growth-promoting drug in China and fatal for human health. It not only accelerates animal growth but also makes animal weight gain in a manner that favors muscle rather than fat. Clenbuterol residues are commonly found in China's pork meat and a large number of Chinese consumers have suffered from eating meat products contaminated with Clenbuterol. In March 2009, the Guangdong Province Agriculture Department announced that 43 shipments of pigs were found, which were contaminated with

Clenbuterol (USDA-FAS, 2009). During that time, the Guangdong Province Agriculture Department collected 126,962 samples, of which 155 tests confirmed positive. This resulted in the closure of all live pig wholesale markets in Guangzhou.

The contamination of infant formula with melamine was one of the most serious public health crises in China (FAO, 2008). Melamine is an industrial chemical from coal industry that is mainly used to produce plastic and is not allowed to be used as a food or feed additive. When Melamine was added to the original milk sold to dairy companies, it could not be distinguished from normal protein by standard laboratory tests. Standard protein tests would display the false high protein content. According to FAO report (2008), the Melamine levels in the contaminated infant formula, produced by China's firm San Lu, were as high as 2,560 milligarm per kilogram. It contained 100 times the concentration of Melamine that infant can tolerate (Partos, 2008). EC food safety standards suggest that products with more than 2.5 milligarm per kilogram should be destroyed. The Melamine-contaminated infant formula caused over a thousand cases of infant kidney stones, which are generally rare in infants. The Melamine scandal highlighted concerns over the safety of the whole food chain and the effectiveness and the efficiency of China's food quality assurance and surveillance schemes. Melamine was suspected to enter the entire China's food and feed chain.

The Melamine-contaminated milk crisis have resulted in the loss of consumer confidence in domestic dairy system, market share of domestic dairy products and infant formula shrunk considerably, and exports of China's dairy products completely blocked. The public and media doubt the ability of China's government to properly regulate and enforce food safety. China's produced and exported dairy products and livestock products were commonly believed to be contaminated with Melamine, which seriously damages China's food product's reputation.

To restore consumer confidence, public food safety standards have to be guaranteed through legislation, such as Good Manufacturing Practices (GMP) and Hazard Analysis and Critical Control Point (HACCP) (Mcllmoyle, 2002). China's food industry enterprises should be aware of their social responsibility, which affect the health of billion people. The priority of food industry needs to fulfill the commitment for public health. The most efficient approach to deal with the food safety crisis is to improve public awareness and media supervision. Increasing public awareness is essential for reducing the demand for immediately and potentially harmful food products. Media supervision can help consumers becoming more aware of the risks of harmful food products.

Use of processed animal proteins as animal feed in China

A large quantity of soybeans has been imported to fill in China's protein meal deficit. Compared with soybeans, imports of MBM as protein sources for feeding farmed animal in China is still negligible. There are four reasons. First, the rendering industry has been poor development in China. MBM is not a traditional protein source for China's feed industry and is unfamiliar ingredient for China's feed mills and farmers. Second, global reaction toward use of processed animal proteins affects China's government decision. Following EC feed ban and detecting BSE cases in Canada and U.S., imports of MBM from the EU and North America have been totally banned. The ban on imported MBM from EU and North America caused the supply of MBM to decline considerably in China. Third, lack of method to detect various processed animal proteins in farm animal rations and insufficient ability to monitor and enforce ruminant feed ban in China means China can not prevent transmission of TSEs. Fourth, because of outbreaks of serious food and feed safety crisis, concerns about spread of BSE have been heightened in China.

Global trade of processed animal proteins has been significantly affected by EC feed ban and detecting BSE cases in North America. Export markets for MBM from the EU and ruminant MBM from North America have absolutely disappeared. The MBM situation in the EU and North America has significantly negative impact on global trade of processed animal proteins. Global trade of processed animal proteins has been depressed. The progress of global trade of processed animal proteins is dependent on the development feed ban in the EU and MBM feeding practise in North America.

Regarding safety use of processed animal proteins in China, these policies are recommended. First, feeding processed animal proteins to ruminant animals shall be completely prohibited. Generally, the risk of the BSE in China is low since diary and ruminant sector are less developed in China and few feed has been imported from overseas. But, intensive dairy production system has appeared and rapidly developed around urban centre, livestock production system has shifted towards more intensive production and demand for low-cost high protein meals has skyrocketed. Against these backgrounds, the risk of BSE spread in China has increased. Safety measures must be taken to avoid the further spread of BSE in China. Second, the development of an efficient analysis method for distinguishing ruminant MBM from various processed animal proteins in farmed animal rations is urgently required. Safe and effective use and imports of processed animal proteins can reduce China's deficit in protein sources for feeding farmed animals. It is expected that imports of lower risk non-ruminant processed animal proteins will continue. Third, the development of China's regulation of animal by-products needs to follow the framework of 1774/2002/EC. It provides a general guideline for the management of China's animal by-products and includes categorizing animal by-products based on the risk, an obligation to collect and dispose of animal by-products, the elimination of animal by-products unfit for human consumption from the feed chain, a ban on intra-species recycling, and an obligation to handle animal by-products in a system of approved plants under official control. Fourth, the appropriate and efficient surveillance and inspection scheme shall be constructed to manage the ruminant feed ban in China.

References:

Ai, Q., Mai, K., Tan., Xu, W., Duan, Q., Ma, H., and Zhang, L. (2006): "Replacement of Fish Meal by Meat and Bone Meal in Diets for Large Yellow Croaker, Pseudosciaena Crocea" *Aquaculture*, Volume 260, Issues 1-4, Page 255-263.

Baker, R. (2007): "Lagged Dependent Variables and Reality: Did You Specify that Autocorrelation a Priori?" Paper presented at the annual meeting of the American Political Science Association, Chicago, IL. U.S.

Brookes, G. (2001): "The EU Animal Feed Sector: Protein Ingredient Use and The Implications of The ban on Use of Meat and Bone Meal." Canterbury, UK, Brookes West.

Bureau, P.D. (2006): "Rendered Products in Fish Aquaculture Feeds" Essential Rendering, Kirby Lithographic Company, Inc. Arlington, Virginia, U.S. URL:http://assets.nationalrenderers.org/essential_rendering_fish.pdf

Canadian Food Inspection Agency (2009): "What is Scrapie" URL:http://www.inspection.gc.ca/english/anima/heasan/disemala/scrtre/scrtrefse.shtml

Canadian Food Inspection Agency (2004): "CFIA's Investigation into the December 2003 BSE Case found in Washington State, U.S." URL:http://www.inspection.gc.ca/english/anima/heasan/disemala/bseesb/americ/amerinveste.shtml

Caparella, T. (2009): "European Renderers Shape Their Future" *Renderers Magazine*, August URL:http://rendermagazine.com/articles/2009_issues/2009_august/2009_08_european_renderers

Chadd, S., Davies, P., and Koivisto, J. (2002): "Practical Production of Protein for Food Animals." Discussion paper presented at the FAO Expert Consultation and Workshop on Protein Sources for the Animal Feed Industry, Bangkok, Thailand.

Chen, W., Marchant, M., and Song, B. (2009): "Impacts of China's Food Consumption on U.S Soybeans Exports" Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Atlanta, Georgia.

Cheng, G., Zhou, Y., Wang, J., and Shi, Z. (1997): "Feed Demand and Supply in China." *Problems of Agricultural Economics*, No. 5: 25-29.

Chicago Board of Trade (2010):
URL:http://www.docstoc.com/docs/17756402/%5BCBOT%5D-CBOT-Soybean-Crush-Reference-Guide

Chinese State General Administration for Quality Supervision, Inspection and Quarantine (2004): "The Administrative Measures of Inspection and Quarantine on Entry-Exit of Biotech Products" Beijing, China, effective: May 24, 2004.
URL:http:www.unescobkk.org/.../CHINA_Administrative_Measures_of_Inspection_and_Quarantine_on_Entry-Exit_GM_Products__Decree_62.doc

Colby, H., Diao, X., and Tuan, F. (2001): "China's WTO Accession: Conflicts with Domestic Agricultural Policies and Institutions." Trade and Macroeconomics Division (TMD), discussion paper No. 68, International Food Policy Research Institution.

Cruz-Suarez, L.E., Nieto-Lopez, M., Rieque-Marie, D., Guajardo-Barbosa, C., and Scholz, U. (2004): "Evaluation of the Effect of Four Levels of Replacement of Fish Meal with Poultry by-products Meal on the Survival and Yield of the White Shrimp as well as Protein, Dry matter and Energy Digestibility of the Ingredients and Diets". Proceedings of VII International Symposium on Aquatic Nutrition, Hermosillo. Mexico.

Dalian Commodity Exchange Database (2009):
URL:http://www.dce.com.cn/portal/cn/index.jsp

de Gorter, H., and Liu, J. (2002): "Managing Tariff Quota Grains in China: Possible Effects on Imports and Domestic Prices". Paper presented at Workshop on Agricultural Policy Adjustments in China after WTO Accession.

de Vos, J.C., and Heres, L. (2008): "The BSE Risk of Processing Meat and Bone Meal in Nonruminant Feed: A Quantitative Assessment for the Netherlands" *Risk Analysis* Volume 29(4): 541-557.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S., and Courbois, C. (1999): "Livestock to 2020: the Next Food Revolution: Food, Agriculture, and the Environment." Discussion paper No. 28, Co-sponsored by IFPRI, FAO and ILRI, International Food Policy Research Institute, Washington, DC.

EC (European Commission) (2007): “Commission Decision of 5 December 2007 Amending Annexes I, II, and VI to Regulation (EC) 1774/2002 of the European Parliament and of the Council as regards the Marking and Transport of Animal by-products.” 2007/1432/EC

EC (2003): Working Document “With Regard to the State of Play on the Prohibitions to Feed Animal Protein to Farmed Animals to prevent Transmissible Spongiform Encephalophthies.”

EC (2002): “Commission Decision of 3 October 2002 laying Down Health Rules Concerning Animal By-products Not intended for Human Consumption.” 2002/1774/EC

EC (2000): “Council Decision of 4 December 2000 concerning Certain Protection Measures with regard to Transmissible Spongiform Encephalopathies and the Feeding of Animal Protein.” 2000/766/EC

EC (1994): “Council Decision of 27 June 1994 concerning Certain Protection Measures with regard to Bovine Spongiform Encephalopathy and the Feeding of Mammalian Derived Protein.” 1994/381/EC.

Editing Committee of MOA (1991): “A Study of Medium- and Long-term Strategies for China’s Food Development.” Food Study Group, Beijing.

Environmental Protection Encouragement Agency (2001): “Environmental and Social Consequences of the Ban on Feeding Animal Protein” URL:http://www.stn-vvtn.de/archiv/VerfVerbot-EPEA_EN.pdf

European Fat Processors and Renderers Association Congress (2006): URL:http://www.efpra.eu/Content/Default.asp

European Union On-Line (1998): “Special Report No. 19/98 concerning the community financing of certain measures taken as a result of the BSE crisis, accompanied by the replies of the Commission” URL:http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:1998:383:0001:0033:EN:PDF

Evans, D.F., and Leibholz, J. (1979): “Meat Meal in the Diet of the Early-weaned Pig”. *Anim.Feed Sci. Technol*., 4:33-38.

Evans, G., and Honkaphja, S. (2001): "Learning and Expectations in Macroeconomics" Princeton, NJ: Princeton University Press.

Fang, C., and Fuller, F. (1998): "Feed-Grain Consumption by Traditional Pork-Producing Households in China." CARD Working Paper: 98-WP 203.

FAO (2009): Animal Feed Resources Information System URL: http://www.fao.org/ag/aga/agap/frg/AFRIS/default.htm

FAO (2008): "WHO Expert Meeting to Review Toxicological Aspects of Melamine and Cyanuric Acid" Held in collaboration with FAO and supported by Health Canada URL: http://www.fao.org/ag/agn/agns/chemicals_melamine_en.asp

FAO (2002): "Protein Sources for the Animal Feed Industry." Executive Summary presented at the FAO Expert Consultation and Workshop on 29 April, Siam City Hotel, Bangkok, Thailand

FAO (2001): "BSE - More than 30 countries have taken action on BSE, but more needs to be done."
URL:http://www.fao.org/WAICENT/OIS/PRESS_NE/PRESSENG/2001/pren0141.htm

FAOSTATA database (various years): URL: http://faostat.fao.org/

FAPRI database (various years): URL: http://www.fapri.iastate.edu/tools/

Fischer, G., Huang, J., Keyzer, M.A., Qiu, H., Sun, L. and van Veen, W.C.M. (2007): "China's Agricultural Prospects and Challenges: Report on Scenario Simulations until 2030 with the Chinagro Welfare Model Covering National, Regional and County level." SOW-VU, Amsterdam.
URL:http://www.sow.vu.nl/pdf/china_prospects_challenges.pdf

Fishmeal Information Network (2009): URL: http://www.gafta.com/fin/index.php

Food and Drug Administration (2005): "Commonly Asked Questions about BSE in Products Regulation" FDA's Center for Food Safety and Applied Nutrition.

Food Study Group (1991): "A Study of Medium- and Long-term Strategies for China's Food Development." Food Study Group, Beijing.

Fox, J., and Peterson, H. (2004): "Risks and Implications of Bovine Spongiform Encephalopathy for the Untied States: Insights from Other Countries" Food Policy, Volume 29, Issue 1, page 45-60.

Fuller, F., Beghin, J., De Cara, Stephane., Fabiosa, J., Fang, C., and Matthey, H. (2001): "China's Accession to the WTO: What Is at Stake for Agricultural Markets?" Center for Agricultural and Rural Development, Iowa State University, Working Paper 01-WP 276.

Fuller, F., and Fang, C. (1999): "The Impact of Structural Change in Chinese Livestock Production on World Feed Grain Trade." Paper presented at AAEA Annual Meeting, Nashville, Tennessee, U.S.

Fuller, F., Tuan, F., and Wailes, E. (2002): "Rising Demand for Meat: Who Will Feed China's Hogs." Economic Research Service/USDA, China's Food and Agriculture: Issues for the 21st Century / AIB-775.

Fumiere, O., Veys, P., Boix, A., von Holst, Christoph., Baeten, V., and Berben, G. (2009): "Methods of Detection, Species Identification and Quantification of Processed Animal Proteins in Feedingstuffs". *Biotechnol. Agron. Soc. Environ.* 13(S), 59-70.

Gao, R. (1990): "Symposium of China's Fishery Economy." Beijing, China: China Agricultural Press.

Gilbert, R. (2002): "The World Animal Feed Industry." discussion paper presented at the FAO Expert Consultation and Workshop on Protein Sources for the Animal Feed Industry, Bangkok, Thailand.

GMO-Compass (2009): URL: http://www.gmo-compass.org/eng/home/

Greene, W. (2001): "Econometric Analysis" Fourth Edition, Beijing, China; Tsinghua University Press.

Guo, Q., Liu, X., Teng, H., and Wang, L. (2001): "Household Animal Raising Behavior in China's Feedgrain Surplus Regions: the Case of Jilin", AARC Working Paper No. 17, the University of Sydney.

Hamilton, C.R. (2002): "Real and Perceived Issues Involving Animal Proteins." Discussion paper presented at the FAO Expert Consultation and Workshop on Protein Sources for the Animal Feed Industry, Bangkok, Thailand.

Haniotis, T. (2000): "Regulating Agri-Food Production in the U.S and the EU" *Ag Bio Forum* – Volume 3, Numnber 2&3, Page 84-86.
URL:http://www.agbioforum.org/v3n23/v3n23a03-haniotis.pdf

Hard, D. (2002): “Innovative Developments in the Production and Delivery of Alternative Protein Source” Discussion paper presented at the FAO Expert Consultation and Workshop on Protein Sources for the Animal Feed Industry, Bangkok, Thailand.

Hasha, G. (2002): “Livestock Feeding and Feed Imports in the European Union-A Decade of Change”. USDA-ERS
URL: http://www.ers.usda.gov/publications/fds/july02/fds0602-01/fds060201.pdf

Hayes, D. (1998): “China’s Role in World Livestock and Feed-Grain Markets.” CARD Briefing Paper-BP 18.

Hishamunda, N., Bidler, B.N., Bueno, P., and Yap, G.W. (2008): “Commercial Aquaculture in Southeast Asia: Some Policy Lessons” *Food Policy,* Number 34: 102-107.

Horn, G., Bobrow, M., Bruce,M., Goerdert, M., McLean, A., and Webster, J. (2001): “Review of the origin of BSE” Report for the Department for Environment, Food & Rural Affairs and the Department of Health, Page 1-66.

Houck, J.P., Ryan, M.E., and Subotnik, A. (1972): “Soybeans and Their Products: Markets, Model and Policy.” Minneapolis, MN: University of Minnesota Press.

Huang, J., Hu, R., Van Meijl, H., and Van Tongeren, F. (2003): “Economic Impacts of Genetically Modified Crops in China.” The 25th International Conference of Agricultural Economists (IAAE). Durban, South Africa.

Huang, J., and Rozelle, S. (2002): “China's Accession to WTO and Shifts in the Agriculture Policy.” Department of Agricultural & Resource Economics, UCD. ARE Working Papers. Paper 02-002.

Huang, J., Rozelle, S., and Rosegrant, M.W. (1999): “China’s Food Economy to the 21st Century: Supply, Demand and Trade.” *Economic Development and Cultural Chang*, 47: 737-766, (Orig. pub. 1997).

Huang, J., Rozelle, S., and Rosegrant, M.W. (1997): “China’s Food Economy to the 21st Century: Supply, Demand and Trade.” International Food Policy Research Institute. 2020 Vision for Food, Agriculture, and the Environment, Discussion Paper No. 19.

Huang, Y. (1998): “Agricultural Reform in China: Getting Institutions Right” Cambridge, UK: Cambridge University Press.

Islam, N. (2003): "Demand Projections for Poultry Products and Poultry Feeds in Bangladesh." MSSD discussion papers from IFPRI, No 54.

James, C. (2002): "Global Status of Commercialized Transgenic Crops." International Service for the Acquisition of Agri-Biothech Application.
URL: http://www.ask-force.org/web/UNIDO/ISAAA_Briefs_No._27.pdf

Jiang, J. (2001): "The Impact of China's Expanding Market on the U.S Soybean Industry." PhD dissertation, Department of Economics, North Carolina State University.

Jim, H., Tuan, F, Somwaru, A., and Seeley, R. (2009): "Impact of China's Agriculture Policies on Domestic and World Commodity Markets" Contributed Paper for presentation at the International Association of Agricultural Economics Conference, Beijing, China.

Ke, B. (2001): "Perspectives and Strategies for the Asian Livestock Sector in the Next Three Decades: Sub-regional Report, China." Agricultural and National Resource Economics Discussion Paper 02/2001, School of National and Rural Systems Management, University of Queensland, Australia.

Keyzer, M., and Merbis, M. (2002): "Can We Feed the Animals? Origins and Implications of Rising Meat Demand." Paper Presented at the Xth EAAE Congress, Zaragoza, Spain.

Keyzer, M., Merbis, M., Pavel, I., and van Wesenbeeck, C. (2005): "Diet Shifts towards Meat and the Effects on Cereal Use: Can We Feed the Animals in 2030?" *Ecological Economics*, 55(2): 187-202.

Kruse, J.R. (2003): "A Structural Model of the International Oilseed Sector: An Econometric Investigation." PhD Dissertation, University of Missouri-Columbia.

Lattimore, R. (2000): "Is Livestock a Sunset Industry" Commerce Division, Discussion Paper No. 85. Lincoln University, Canterbury, New Zealand.

Leitgeb, R. Oberrauch, P., Baumann, F., and Wetscherek, W. (1998): "Use of Meat and Bone Meal in Broiler Diets" *Die Bodenkulur* 49: 193-199.

Li, P. (2009) : National Renderers Association (NRA).
URL:http://rendermagazine.com/articles/2009_issues/2009_february/2009_02_people

Li, X. (2004): "The Livestock Revolution and Feed Demand in China." Research Paper at the International Livestock Research Institute (ILRI). ILRI-Beijing Office. URL:http://www.eseap.cipotato.org/MF-ESEAP/Publications/PH-China-2004/03-Chapter-3.pdf

Lin, D. (2010): "China's Feed's Dynamic but Rocky Road to 2020" *Feed Business Asia*, Issue 30.

Liu, K. (1985): "A Grain, Oilseeds and Livestock Model of Japan." Washington. DC: U.S Department of Agriculture, Economic Research Service, International Economic Division.

Liu, X. (2004): "China's Grain Consumption Demand and its Implications for Canada-China Grain Trade". PhD Dissertation. Department of Rural Economy, University of Alberta.

Lu, W., and Kersten, L. (2006): "Prospects of Chinese Grain Supply and Demand in 2010: A Regionalized Multimarket Model Simulation and Policy Implication". Poster paper prepared for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia. URL:http://ageconsearch.umn.edu/bitstream/25662/1/pp060099.pdf

Ma, H., Huang, J., and Rozelle, S. (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.

Ma, H,. Huang, J., Rozelle, S., and Rae, A. (2003): "Livestock Product Consumption Patterns in Urban and Rural China." China Agriculture Working Paper 1/03, Centre for Applied Economics and Policy Studies, Massey University.

Ma, H., and Rae, A. (2004): "Hog Production in China: Technological Bias and Factor Demand." China Agriculture Working Paper 2/04. Centre for Applied Economics and Policy Studies, Massey University, New Zealand

Martin, W. (2001): "Implications of Reform and WTO Accession for China's Agricultural - Policies." *Economics of Transition*, 9:717-742.

Martin, W. (1999): "WTO Accession and China's Agricultural Trade Policies." Working Paper at Development Research Group, World Bank. URL:http://www.agecon.ucdavis.edu/people/faculty/facultydocs/Sumner/iatrc/martin.pdf

Masuda, T., and Goldsmith, P. (2009): "World Soybean Demand: An Elasticity Analysis and Long-Term Projections" Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2009 AAEA & ACCI Joint Annual Meeting, Milwaukee, WI, July 26-28.

Mathews, H.K. (2008): "Economic Impacts of Feed-Related Regulatory Responses to Bovine Spongiform Encephalopathy" ERS-United States Department of Agriculture

Mattson, J,. Sun, C., and Koo, W. (2004): "Analysis of the World Oil Crops Market." Agribusiness & Applied Economics Report No. 529. Center for Agricultural Policy and Trade Studies, North Dakota State University, Fargo.

Mcllmoyle, W.A. (2002): "Codes of Good Management Practice (GMP) for the Animal Feed Industry, with Particular Reference to Proteins and Protein by-products" Paper presented at the FAO Expert Consultation and Workshop, Siam City Hotel, Bangkok, Thailand

Meeker, L.D., and Hamilton, C.R. (2006): "An Overview of the Rendering Industry". Essential Rendering, Kirby Lithographic Company, Inc. Arlington, Virginia, U.S.

Meyers, W., Devadoss, S., and Helmar, M. (1991): "The World Soybean Trade Model: Specification, Estimation, and Validation." Working paper 91-TR 23, Center for Agricultural and Rural Development, Iowa State University.

Miller, E. (2002): "Protein Nutrition Requirements of Farmed Livestock and Dietary Supply." Discussion paper presented at the FAO Expert Consultation and Workshop on Protein Sources for the Animal Feed Industry, Bangkok, Thailand

MOA (2007): China's Rural Development Report.
URL: http://www.agri.gov.cn/sjzl/baipsh/2007.htm

MOA (2002): "Temporary Administration Procedure of Import of Agricultural Transgenic Products."

MOA (2001): "Bio-safety Administration Regulations on Agricultural Biotech Products."
URL:http://www.biosafety.gov.cn/swaq/73192290037792768/20040109/1044833.shtml

Morgan, N. (2001): "Repercussions of BSE on International Meat Trade: Global Market Analysis." Commodities and Trade Division, Food and Agriculture Organization,
URL: http://www.fao.org/ag/AGA/AGAP/frg/Feedsafety/pub/morgan%20bse.doc

National Pork Board (2008): “Alternative Feed Ingredients in Swine Diets II: Use, Advantages and Disadvantages of Common Alternative Feedstuffs.” URL: http://www.pork.org/documents/PorkScience/Alt_Feed_2.pdf

National Population and Family Planning Commission (2009): China’s Population Estimation, URL:http://www.chinapop.gov.cn/

Nin, A., Hertel, T.W., Foster, K. and Rae, A.N. (2004): “Productivity growth, catching-up and uncertainty in China’s meat trade.” *Agricultural Economics* 31(1): 1-16.

NORHS. (1998): “A Comparative Study of Production Efficiency and Profitability of Various Animal Raising Practices.” *Reference Materials for Rural Economic Research*. No.8: 20-25.

NRA (2009): Animal Nutrition. URL : http://nationalrenderers.org/

NRA (2009): Economic Impact. URL: http://nationalrenderers.org/

NRA (2008): Annual Convention Global Update URL:http://convention.nationalrenderers.org/assets/Swisher.pdf

NRA (2008): Essential Rendering Global Market URL: http://nationalrenderers.org/assets/essential_rendering_global_market.pdf

National Research Council (1993): Nutrient Requirements of Fish. Washington, DC: National Academy Press.

Pan, C. (2003): “China’s Meat Industry Overview” Food & Agribusiness Research, Rabobank International. URL: http;/www.rabobank.com/far

Partos, L. (2008): “Cadbury Recalls all Chocolate Products made at Beijing Plant” URL:http://www.foodanddrinkeurope.com/Product-Categories/Company-news/Cadbury-recalls-all-chocolate-products-made-at-Beijing-plant

Pearl, G. (2002): “The Future of Animal Protein in Poultry Diets.” Fats and Proteins Research Foundation, Inc. Multi-State Poultry Meeting, May 14-16.

Perera, J. (1996): “An Econometric Study of Fats and Oils Commodities: With Special Emphasis on World Trade” PhD. Dissertation, Texas A&M University.

Persaud, S., and Chern, W. (2002): “Meat Trade Liberalization and Soybean-Rapeseed Consumption in the Japanese Market.” *Journal of Agribusiness,* 20, 1: 67-83.

Petry, M., and B, Wu (2009): "China–Peoples Republic of Agricultural Biotechnology Annual" USDA/FAS URL:http://gain.fas.usda.gov/Recent%20GAIN%20Publications/AGRICULTURAL%20 BIOTECHNOLOGY%20ANNUAL_Beijing_China%20-%20Peoples%20Republic%20of_8-3-2009.pdf

Pothidee, A. (1999): "Impact of Corn and Soybean Meal Price Change on the demand and Supply of U.S Broilers." Paper Presented at the meeting of the American Agricultural Economics Association (AAEA), Nashville, Tennessee.

Qi, G., Diao, Q., Tu, Y., Wu, S., and Thang, S. (2002): "Nutritional Evaluation and Utilization of Quality Protein Maize (QMP) in Animal Feed." Discussion paper presented at the FAO Expert Consultation and Workshop on Protein Sources for the Animal Feed Industry, Bangkok, Thailand.

Rae, A.N., and Hertel, T. (2000): "Future Development in Global Livestock and Grains Markets: the impact of livestock productivity convergence in Asia-Pacific." *Australian Journal of Agricultural and Resource Economics* 44: 393-422.

Rae A.N., Ma, H., Huang, H., and Rozelle, S. (2006): "Livestock in China: Commodity-specific Total Factor Productivity Decomposition Using New Panel Data." *American Journal of Agricultural Economics,* Vol. 88-3:680-695

RGCFDS (1993): "China's Medium and Long-term Food Development Strategies." Beijing, China: China Agricultural Press.

Rutherford, A.S. (1999): "Meat and Milk Self-sufficiency in Asia: Forecasts, Trends and Implications." *Agricultural Economics*, 21:21-39.

Simpson, J. R., and Li, Q. (2001): "Long-Term Projections of China's Supply and Demand of Animal Feedstuffs." International Agricultural Trade Research Consortium, Auckland, New Zealand.
URL: http://ageconsearch.umn.edu/bitstream/14547/1/cp01si01.pdf

Song, B., and Marchant, M. (2006): "China's Biotech Policies and Their Impacts on U.S. Agricultural Exports to China" Poster paper prepared for presentation at the International Association of Agricultural Economist (IAAE) conference, Gold Coast, Australia.

Song, B., Merchant, M., Reed, M., and Xu, S. (2007): "Market Power and Competitive Analysis of China's Soybean Import Market." Paper presented at International Agricultural Trade Research Consortium (IATRC) Beijing, China.

Song, B., Merchant, M., and Xu, S. (2006): "Competitive Analysis of Chinese Soybean Import Suppliers – U.S., Brazil, and Argentina" Selected Paper prepared for Presentation at the American Agricultural Economics Association Annual Meetings, Long Beach, CA.

Speedy, A. (2002): "Overview of World Feed Protein Needs and Supply." Discussion paper presented at the FAO Expert Consultation and Workshop on Protein Sources for the Animal Feed Industry, Bangkok, Thailand.

Spongiform Encephalopathy Advisory Committee (2008): "Statement on Options Relating to Modification of the Total Feed Ban"
URL:http://www.seac.gov.uk/statements/feedban-oct08.pdf

SSB (Chinese State Statistics Bureau), China's Statistical Yearbook, (various years):
URL: http://www.stats.gov.cn/tjsj/ndsj/

State Science and Technology Commission (1993): "Safety Administration Regulation on Genetic Engineering"
URL: http://faolex.fao.org/docs/texts/chn19138.doc

Steinfeld, H., and Jaeki-Hokkonen, J. (1997): "A Classification of Livestock Production Systems" *World Animal Review* 88-1.
URL: http://www.fao.org/docrep/v8180t/v8180t0y.htm

Sun, W., Knerr, B. and Kuhn, M. (2009): "The Increase in Protein Demand for China's Livestock Sector and its Implications for the International Agricultural Trade" *Outlook on Agriculture*. Volume 38 (1):55-62.

Syal, R. (2007): "Supermarkets Say They Will Not Sell Chicken Fed on Pork if Ban Is Lifted." The Times.
URL: http://www.timesonline.co.uk/tol/news/uk/health/article1873259.ece

U.S. Bureau of Labor Statistics, Consumer Price Index (1980-2006):
URL: http://www.bls.gov/cpi/

U.S. Census Bureau, International Data (1980-2006):
URL: http://www.census.gov/ipc/www/idb/worldpop.php

U.S. Department of Agriculture, Economic Research Service (USDA-ERS) (1999): "The Long-Term Boom in China's Feed Manufacturing Industry." *Agricultural Outlook*. URL: http://www.ers.usda.gov/publications/agoutlook/dec1999/ao267f.pdf

U.S. Department of Agriculture, Foreign Agriculture Service (USDA-FAS) (2009): "China, Peoples Republic of Agricultural Situation Weekly Hongbao" URL:http://www.stat-usa.gov/agworld.nsf/e8f3f9479ecf620085256d8200534251/7fbdf8dc5c5cee15852575a70060d6a6/$FILE/CH9023.PDF

U.S. Department of Agriculture, Foreign Agriculture Service (USDA-FAS) (2002): "Meat-and-Bone Meal Down For the Count in the European Union?" URL: http:// www.fas.usda.gov/dlp/IATRs/2002/eu%20mbm%200205.pdf

U.S. Department of Agriculture, Production, Supply and Distribution Database (USDA-PS&D) (1980/1981-2006/2007): URL: http://www.fas.usda.gov/psdonline/

Tacon, A.G. (2005): "The Current and Potential Use of Blood Products and Blood meal in Aquafeeds" Working Paper, University of Hawai, Honolulu, U.S. URL: www.hawaii.edu/HIMB/Faculty/tacon.html

Taylor, D.M., and Woodgate, S.L. (2003): "Rendering Practices and Inactivation of Transmissible Spongiform Encephalopathy Agents" *Rev. sci. tech. Off. Int. Epiz.* 22(1): 297-310.

Tian, G. (2006): "The Outlook for China's Oilseeds and Edible Oil Industry." (in Chinese) URL: http://www.dce.com.cn/portal/servlet/look

Tongeren, F Van and Huang, J. (2004): "China's Food Economy in the Early 21st Century." Report # 6.04.04, Agricultural Economics research Institute (LEI), The Hague.

Toride, Y. (2002): "Lysine and Other Amino Acide for Feed: Production and Contribution to Protein Utilization in Animal Feeding." Presented at the FAO Expert Consultation and Workshop on 29 April, Siam City Hotel, Bangkok, Thailand.

Traylor, S.L., Cromwell, G.L., and Lindemann, M.D. (2005): "Bioavailability of Phosphorus in Meat and Bone Meal for Swine." *Journal of Animal Science*, 83:1054-1061.

Tsai, R. (1994): "Taiwanese Livestock and Feedgrain Markets: Economic Structure, Policy Intervention and Trade Liberalization." The Ph.d dissertation, Texas A&M University.

Tuan, B.P. and Yu, Y. (2003): "Replacement of Fish Meal with Meat and Bone Meal and Methionine on Growth Performance of White Shrimp" NRA Research Report No. 25. National Renderers Association, Inc., Hong Kong, China.

Tuan, F. and Dyck, J. (2001): "Structural Changes in China's Hog and Feed Production." URL:http://www.ipsard.gov.vn/news/mispa/Nhom%20Nganh%20hang/Tap%20huan%20USDA/Structural_Changes_in_China_s_Hog_and_Feed_Industries_2_060215.pdf

Tuan, F., Fang, C. and Cao, Z. (2004): "China's Soybean Imports Expected to Grow despite Short-Term Disruptions." Outlook Report from Economic Research Service/USDA

Wanapat, M. (2002): "Current Livestock Production and Protein Sources as Animal Feeds in Thailand." Discussion paper presented at the FAO Expert Consultation and Workshop on Protein Sources for the Animal Feed Industry, Bangkok, Thailand.

Wang, H., and Huo, Q. (1996): "China's Grain and Animal Product Production" *China Feed*, No. 10: 6-8.

Wang, W. (2004): "Econometrics" Xi'an, China: Xi'an Jiaotong University Press (Chinese)

Woodgate, S., van den Hoven, S., Vaessen, J., and Margry, B. (2009): "Control Tools to detect Processed Animal Proteins in Feed and in Animal by-products: Specificity and Challenges" Biotechnol, *Agron. Soc. Environ,* 13(S):9-13.

World Bank World Development Indicators Data Source. (Various years): URL: http://web.worldbank.org

World Health Organization (2009): "Bovine Spongiform Encephalopathy" URL: http://www.who.int/mediacentre/factsheets/fs113/en/

Yang, Y., Xie, S., Cui, Y., Lei, W., Zhu, X. and Yu, Y. (2004): "Effect of Replacement of Dietary Fish Meal by Meat and Bone Meal and Poultry by-products Meal on Growth and Feed Utilization of Gibel, Carp Carassius Auratus Gibelio". *Aquaculture Nutrition,* Volume 10-5: 289-294.

Yu, J. (1991): "Study on Rationalization of China's Food Structure." Research Institute of Aerospace Ministry, Beijing.

Yu, Y. (2006): "Rendered projects in shrimp aquaculture feeds." In: Meeker, D.C. (ed.), Essential rendering. National Renderers Association, pp. 195-211.

Zhang, J. (2005): "The Goal of China's Self-sufficient Rate 95." *Chinese Agricultural Science Bulletin.* Volume 21-10.

Zhou, A. (2002): "Feedstuffs Handbook." Beijing, China: China Agriculture Press, (in Chinese).

Zhou, L. (1993): "Continual Increased in China's Livestock Production: the Reasons Explained." *Chinese Rural Economy*, No. 5: 27-29.

Zhou, Z., Tian, W., and Malcolm, B. (2006): "Why Projections of China's Feedgrain Demand and Supply Differ: A Review" Paper presented at the 18th ACESA International Conference: "Emerging China: Internal Challenges and Global Implications", held at Victoria University, Melbourne, Australia.