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Increases in Demand for Food in China and Implications for World Agricultural Trade

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Increases in Demand for Food in China and Implications for World Agricultural Trade

Abstract

China is experiencing rapid economic growth, resulting in increased demand for food. Estimates are made of Chinese production and consumption of rice, wheat, corn, and soybeans to the year 2005. Results indicate that China will become a large net importer especially of wheat, corn, and soybeans. China's grain shipping and handling industries will need to be expanded to handle the increased imports.

Keywords: *China, Agriculture, Trade, Food Consumption, Grain Production, Rice, Wheat, Corn, Soybeans.*

Highlights

China's economy is changing rapidly. After the economic reform of 1978, China has experienced dramatic economic growth, resulting in a rise in disposable income. Chinese consumers have demanded a more diversified higher quality diet and has substituted meat products for grain products, especially rice.

This study examines the impacts of increases in China's food consumption on China's agricultural imports and exports under alternative assumptions about agricultural production technology.

China's arable land is projected to decrease 2.8 percent during the 1995 - 2005 period and multiple cropping index to decrease 11 percent. During the same period, crop yields are projected to increase 10.4 percent for rice, 10.9 percent for wheat, 17.4 percent for corn, and 14.1 percent for soybeans.

Per capita consumption of rice in China has a decreasing trend. The total consumption of rice is projected to decrease 3.1 percent over the 1995 - 2005 period. Per capita consumption of wheat, corn, and soybeans has an increasing trend. The total consumption of these crops is projected to increase during the period; 15.7 percent for wheat, 32.8 percent for corn, and 23,3 percent for soybeans.

China is projected to export rice and corn to its neighboring countries and, at the same time, import rice, wheat, corn, and soybeans under a free trade option. However, China's imports of crops will be larger than its exports. China will be the largest wheat and soybean importing country in the world in 2005. China's net imports of crops will range between 38 million metric tons with optimistic yield increases and 56 million metric tons with pessimistic yield increases in 2005 under assuming free trade. Under the autarky assumption, China will produce more and import slightly less. Its imports, however, are still likely to be large enough to increase world grain and oilseed prices.

Unless the Chinese government restricts food demand through some type of rationing, this study indicates that even under optimistic yield increases, China will become an increasingly important market for grain and oilseeds and the United States will be the major supplier.

Increases in China's imports will also affect grain shipping and handling industries. Unless these industries increase their capacities, they will not be able to meet future demands. China's railway and ports are operating at full capacity. In addition, demand for transportation services has grown faster than increases in capacity. A significant amount of public or private investment on the transportation industry is needed to meet demand created through economic expansion.

China's food deficit beyond 2005 will likely become even larger. As China's economy continues to expand for the next several decades, demand for wheat, corn, and soybeans will increase, while arable land will likely decline. This implies that demand for these crops will likely grow faster than production, indicating that China's grain and oilseed imports will continue to increase. The question raised by Lester Brown, "Who will feed China? " will remain as an important issue.

The world can supply enough food and feed grains to China because higher prices of these crops will stimulate production in major agricultural exporting countries, mainly the United States, Canada, and Australia. Increases in prices will also affect consumption around the world and consequently affect trade flows of agricultural commodities.

Increase in Demand for Food in China and Implications for World Agricultural Trade

Won W. Koo, Jianqiang Lou, and Roger G. Johnson

1. Introduction

China is the third largest country in the world, ranked after Russia and Canada, with about 960 million hectares. However, its arable land is limited to approximately 95.7 million hectares, representing 10 percent of its total area. Arable land per capita in China is about 0.08 hectare, similar to Japan (0.05) and lower than in the United States (about 0.72 hectare) (FAO). The feeding of China is a question of concern not only to China, but also to the rest of the world (Brown).

China's population has been growing at 1.5 percent annually for the last 10 years and was estimated to be about 1.18 billion in 1993. Although the Chinese government has made tremendous effort to control population growth, China's population is expected to reach 1.3 billion by 2000. To feed its huge population, China has become one of the largest grain producers in the world. China's rice, wheat, corn, and soybean production was 178, 106, 103, and 20 million metric tons, respectively, in 1993 (Table 1). Chinese agricultural production has increased substantially the last 14 years.

Table 1. GDP, Per Capita GDP, Agricultural Output, and Total Trade Values in China

	Unit	1980	1990	1993
GDP	Bil. Yuan	447	1,768	3,138
GDP(per capita)	Yuan	570	1,555	2,665
Ag. Output	Bil. Yuan	145	495	661
Crops				
Rice	Millon MT	140	189	178
Wheat	Millon MT	55	98	106
Corn	Millon MT	63	97	103
Soybeans	Millon MT	8	11	20
Trade				
Exports	Bil. Yuan	27,120	298,580	528,530
Imports	Bil. Yuan	29,880	257,430	598,570

China's economy is changing rapidly. After the economic reform of 1978, China has experienced dramatic economic growth. The country's GDP grew from 447 billion yuan ($298 billion) in 1980 to 3,138 billion yuan ($544 billion) in 1993 (Table 1). Between 1980 and 1990, the country's gross domestic product (GDP) increased almost sevenfold with real annual growth rates averaging close to 7 percent. Recent growth rates have been even more dramatic. Between 1990 and 1993, GDP increased 77.5 percent (Table 1). During the same period, the total value of China's

agricultural output increased at an average annual rate of 8.4 percent, and its grain output increased at an annual rate of 2.7 percent.

Externally, China is becoming a major player in international markets. In 1980, the value of China's foreign trade was only about $20.6 billion. However, that figure soared to about $196 billion by 1993. Its trade with neighboring countries grew even more rapidly than its overall foreign trade. From 1983 to 1991, China's overall foreign trade grew at about 15 percent annually while trade with its neighbors grew at about 20 percent annually (Tuan).

China is a major trader of agricultural products. Export sales were $15.3 billion in 1992. Its agricultural imports, however, are relatively small in relation to total consumption (ERS/USDA). Grain is the dominant agricultural product of China's agricultural sector. Grain production represents about 57 percent of China's total agricultural production value and covers 74.2 percent of its planted area (ERS/USDA). Since the 1978 economic reforms, Chinese grain production has increased rapidly. Its grain output reached 443 million metric tons in 1992, a 45 percent increase from 1978.

The rise in disposable income has caused Chinese people, especially its urban consumers, to demand a more diversified higher quality diet. Per capita consumption of grain in urban areas fell from 134.76 kilograms in 1985 to 127.93 kilograms in 1991. Urban consumers substituted grain products with eggs, poultry, and red meat (pork and beef). In China's rural areas, the same trend also occurred. By 1991, per capita consumption of grain in rural areas fell from 257.45 kilograms in 1985 to 250.05 kilograms (Peng). These changes have altered the demand structure for food: decreases in per capita consumption of food grains, especially rice, and increases in demand for meat.

The objective of this study is to evaluate the impacts of increases in China's food consumption on world agriculture. Special attention is given to evaluating China's agricultural imports and exports under alternative assumptions about agricultural production technology.

The Chinese government has used a self-sufficiency policy for grain products at the provincial and national levels since the 1950s. This policy emphasizes minimal inter-provincial grain trade and minimal imports from other countries. Self-sufficiency policy has not optimized grain production in terms of the principle of comparative advantage. If the Chinese government would have focused attention on increasing grain productivity based on regional resource endowments and improved farming technology, China could have substantially increased total grain output. Chinese agricultural scientists agree with this assessment. The scientists have indicated that grain yields could be increased substantially if agricultural production were specialized on the basis of regional endowments and technology (Zhou and Jiang).

China's grain production, consumption, and trade balances to the year 2005 are estimated using a spatial equilibrium model based on a mathematical programming algorithm. The study focused on four grains: rice, wheat, corn, and soybeans. This study found that China will be a major agricultural importer in the next decade.

Section 2 presents an overview of China's agricultural policies. Sections 3 - 5 present China's agricultural production potential, expected changes in food consumption, and transportation and grain handling system. The methodology used and data development are discussed in Section 6. The results to 2005 are presented in Section 7. Implications of the research are in the final section.

2. Agricultural Policy

China's economy is a mixture of central planning and relatively open markets. Like the rest of the economy, agriculture has a free market orientation although the government continues to strongly influence agricultural production.

Agricultural Policies, 1952 - 1977

Following the establishment of the People's Republic of China in 1949, the Chinese Communist Party launched a nationwide program of land reform. Its objective was to destroy the feudalism that existed and return the land to farmers. Chinese leaders believed this was an essential condition for increasing grain production and developing China's industry (Chen). The ultimate goal was to socialize agriculture and raise agricultural productivity, especially grain production (Lin and Koo).

After land reforms were completed in 1952, the central government used various programs to develop the economy rapidly and to establish socialism. The economy was still recovering from the war. Western countries, however, were hostile to the new Chinese government and imposed a trade embargo against China. Under such difficult conditions, China turned to the Soviet Union for economic assistance and designed its economic development strategy on the basis of the socialistic system. The Chinese government adopted a rigid, highly centralized economic system and a long-term strategy emphasizing industrial development, particularly, heavy industry, rather than agriculture (Yang and Li).

The Chinese government organized farms into large collective units. The industrialization program was subsidized by capital accumulated in the agricultural sector. The government initially planned three five-year plans to move from rudimentary collectives (mutual aid teams) to advanced socialistic collective associations. The government believed that large collective farms could increase agricultural output to finance industrialization and modernize the agricultural sector. By the end of 1957, China's rural population was transformed from individual peasants into members of some 752,000 advanced cooperative farms.

Since 1954, the Chinese government has adopted a residence registration system to keep the peasants on the farm. Peasants were required to produce farm products for the government at prices less than world prices.

Agricultural growth was slow because of low investment, and farm income was too low to stimulate consumption of industrial products. The Great Leap Forward was launched to stimulate economic growth in 1958. Rural resources were mobilized to accelerate the development of the agricultural sector and to maintain balanced growth between the agricultural and industrial sectors (Lin and Koo).

Together with the introduction of rural industrialization, the Chinese government in 1958 organized the people's commune of semi-militarized organizations of 4,000 to 5,000 households. These became the basic units of social organization for agriculture, industry, commerce, education, and security. Under the commune system, the original cooperative units were reorganized into production brigades.

The communes successfully mobilized the large rural population for the rural industrialization campaign, large-scale irrigation projects, farmland reconstruction, and development of intense methods of cultivation. However, because of inefficiency and mismanagement in farming, the commune contributed little to agricultural development in the late 1950s. The lack of incentive under the commune system decreased agricultural productivity from 1959 to 1962 and resulted in a crisis. The agricultural crisis spilled over into the industrial sector. During the 1959 - 1961 period, there was a 30 percent decline in national income, a 26 percent decline in agricultural income, and a 30.3 percent decline in industrial income.

After the Great Leap Forward failed, various policy changes were introduced. The government attempted to reduce the size of agricultural production units by organizing production teams. In addition, the government emphasized agricultural development. China recovered from the fall in production of the preceding period. During the recovery period (1963 - 1965), farmers could have their private plots and rural markets flourished. The Chinese government, however, was seriously concerned with the economic movement toward capitalism. The government was unwilling to tolerate any "revisionism" in pursuit of material gains. To reverse this trend, the government launched the Cultural Revolution in 1966.

During the Cultural Revolution, only production on the commune was encouraged. Rural economic undertakings such as the peasant's private plots, the country trade fairs, and all mercantile activities, were prohibited as capitalistic ideology. The Cultural Revolution ended in 1976.

Recent Agricultural Policies

The most significant change in Chinese agricultural policy started in 1978. Key components of the new policy were the promotion of a production responsibility system and an increase in the procurement price of agricultural products. Under this system, individual farmers produced agricultural commodities on land assigned to them by a contract, which regulated taxes and a quota sales obligation to the Chinese government. The government mandated farmers to sell their grain products only to a province-owned grain bureau at a price fixed by the province.

To encourage farmers to deliver more grain to the government, it increased the fixed procurement prices substantially in 1979, and further price adjustments took place in later years.

In 1985, for example, procurement prices for grain exceeded their 1978 levels by 107 percent. In addition, the government gave bonuses for output surpassing quota deliveries. In 1979, farmers received a 50 percent price bonus for grain deliveries beyond their contract quota level (Li and Weersink). This new system significantly increased Chinese grain production. Between 1978 and 1985, grain production was increased by 25 percent. Farmers' delivery of grain to the government also was increased by 131 percent during the same period.

Starting in 1985, the government introduced a dual price system. The government purchased grain under the contract quotas at a fixed procurement price. But grain in excess of the contract quotas could be sold to the government at a negotiated price which was higher than the fixed price. The higher price was not paid until the original fixed quota requirement was completed.

Under this system, the state-owned grain bureau monopolized the purchasing and selling of grain products. The government purchased agricultural commodities from farmers and distributed them to consumers or exported them to the international market. After grain harvest, Chinese farmers sold their products to the purchasing branch of the Grain Bureau located in each village. The Grain Bureau set the procurement price according to government policy.

During this period, grain distribution was also controlled by the Chinese government. Urban consumers were divided into groups according to each person's age and employment status. Each group received a different grain ration for each month. The government allocated (using a coupon system) a fixed quantity of grain to each person living in urban areas. In practice, urban consumers used their grain coupons to buy grain products from a specified government store at a fixed low price. Under this system, types of grain consumed were also controlled by the government. Specific grain coupons were used for purchase of designated types of grain from grain stores in urban areas. But in the rural areas, most farm families were responsible for their own supply of grain. After the farm families supplied their contract quotas and allocated some for their own consumption, the remaining grain was sold to the government at a negotiated purchase price. Private marketing of grain products was not allowed.

Beginning in 1992, the government took a further step in its policy reform. The essence of the new policy was to "secure purchase of the predetermined amount of grain at the market price." Under this system, the government set its grain purchasing target at 90 million metric tons to stabilize grain prices. The government bought over 50 percent of the grain purchase target under the contract quota purchasing system, and the rest was purchased in open markets. The purchase prices of the contract grain quota were negotiated on the basis of prevailing market prices. Farmers sold their remaining grain either to an open market or to the government.

Under the marketing system, private stores were allowed to join the grain retailing system and to compete with the government-owned grain retail stores. The grain coupon system was suspended, and consumers had the right to choose grain products at their discretion.

China's foreign trade has always been controlled by the Chinese Ministry of Foreign Trade. The Ministry is responsible for decision-making concerning what, how much, and where to import or export. These decisions are executed by various government-owned foreign trade companies. China National Cereals, Oils, and Foodstuffs Import Export Corporation (CEROILS) is the primary state trading company with authority to engage in international grain trade. CEROILS controls China's grain trade. The central government also approved the formation of national grain industry firms which will have authority to participate in China's grain trade in the future. CEROILS will maintain its role in grain trade to stabilize grain prices and to accomplish self-sufficiency.

3. Production Capacity and Prediction

Major agricultural commodities produced in China are rice, wheat, corn, and soybeans. In 1993, China produced 178 million metric tons of rice, 106 million metric tons of wheat, 103 million metric tons of corn, and 15 million metric tons of soybeans. Increases in total production of these crops over 40 years between 1953 and 1993 were 149 percent for rice, 482 percent for wheat, 515 percent for corn, and 54 percent for soybean (Figure 1). Increases in wheat and corn production are primarily because of improved farming technology in producing these crops, mainly irrigation technology. Since rice has been a staple in the Chinese diet, rice production technology was emphasized during the period. Soybean production did not increase much during the period mainly because soybeans were treated as a minor crop and produced in marginal land.

Individual crop production, to some extent, is regionally specialized on the basis of regional production conditions and resource endowments even though the Chinese government adopted a self-sufficiency policy at provincial levels to avoid long-distance shipments of agricultural commodities. Figures 2, 3, 4, and 5 show major producing areas of rice, wheat, corn, and soybeans, respectively. Rice is mainly produced in the southeastern region. Rice-producing provinces are Jiangsu, Anhui, Zhejiang, Jiangxi, Fujian, Hubei, Hunan, Guangdong, Guangxi, and Sichuan (Figure 2). Wheat is produced in most provinces except for those in the southern region. Major wheat producing provinces are Heilongjiang, Shandong, Hebei, Shangxi, Gansu, Nei Monggol, Xinjiang, Anhui, Hubei, and Sichuan (Figure 3). Corn and soybeans are produced in the northeastern region. Producing provinces for corn and soybeans are Heilongjiang, Liaoning, Jilin, Shandong, Hebei, Henan, Sichuan, and Shangxi (Figures 4 and 5).

Per capita arable land in China has been declining over the last 30 years, mainly because of increasing population and continuous uses of arable land for other purposes, such as industrial development, transportation, and recreation. Per capita arable land decreased from 0.1 hectare in 1975 to 0.08 hectare in 1994. This decreasing trend is similar to those experienced in Japan, Korea, and Taiwan.

Arable Land

Total arable land has gradually decreased for the 1978 - 1993 period (Figure 6). Total arable land is estimated to 2005 using a double-log functional form based on time series data from 1975 to 1993. Gross domestic product is used as an independent variable. The arable land and GDP data were obtained from China Statistical Yearbook (CSB). The estimated equation is

$$(1) \quad \log(AL_t) = 11.74 - 0.037\log(GDP)$$
$$(719.18) \quad (16.13)$$
$$R^2 = 0.94$$

where AL is total arable land in China and GDP is gross domestic product. Numbers in the parentheses are t-values of the corresponding variables.

Total arable land is projected to decrease 2.8 percent by 2005. Changes in arable land differ from one province to another (Table 2). Average arable land in each province for the 1980-82 period was compared with that for the 1990-92 period. Arable land decreased in most provinces, except in Heilongjiang and Guizhou. Arable land in industrial provinces has decreased faster than that in less-developed provinces.

Multiple Cropping Index

The multiple cropping index indicates the average number of crops produced in an area annually. A numerical value of 1.0 indicates one crop produced in a particular area each year, while a value of 2.0 indicates two crops per year. The average multiple cropping indices increase gradually over the period (Figure 7). To predict the multiple cropping index in 2005, the index is regressed as a cubic function of trend. The MCI data were obtained from China Statistical Yearbook (CSB). The estimated equation is

$$(2) \quad M_t = 153.57 - 3.23t + 0.42t^2 - 0.013t^3$$
$$(65.12) \quad (3.38) \quad (3.69) \quad (3.10)$$
$$R^2 = 0.72$$

where m is multiple cropping index and numbers in parentheses are t-values of the corresponding variables.

As shown in Figure 7, the multiple cropping index decreased to 1983 and then increased over the remaining period (1984 - 1992). Multiple cropping index is projected to increase gradually to 1998 and then to decrease to 1.42 in 2005. With economic expansion, the Chinese industrial sector has absorbed a large portion of population from rural areas because labor productivity in the industrial sector is larger than in the agricultural sector. Reductions in rural labor and increased wages make multiple crop farming practices less profitable. Korea and Japan have experienced decline in multiple cropping for this reason.

Table 2. China's Cultivated Area by Province

	1980-1982 Average(1)	1990-1992 Average(2)	Ratio (2)/(1)
	------1,000 hectare------		
Heilongjiang	8725	8837	1.013
Liaoning	3708	3466	0.935
Jilin	4056	3938	0.971
Shandong	7227	6852	0.948
Hebei	6633	6555	0.988
Beijing	425	413	0.972
Tianjin	462	432	0.934
Henan	7114	6933	0.974
Shanxi	3903	3694	0.946
Shaanxi	3791	3532	0.932
Gansu	3554	3478	0.979
Nei Monggol	5181	4961	0.957
Ningxia	881	796	0.903
Xinjiang	3179	3092	0.973
Qinghai	585	576	0.984
Zhejiang	1821	1723	0.946
Jiangsu	4641	4557	0.982
Shanghai	353	323	0.914
Anhui	4445	4364	0.982
Hubei	3727	3474	0.932
Hunan	3422	3314	0.968
Jiangxi	2484	2350	0.946
Guangdong/Hainan	3179	2958	0.930
Guangxi	2636	2596	0.985
Fujian	1288	1237	0.960
Sichuan	6583	6296	0.956
Guizhou	1903	1854	0.974
Yunnan	2840	2842	1.001
Xizang	227	223	0.980
Average	3413	3299	0.961

Crop Yields

Crop yields are estimated to 2004 using a double-log functional form with time series data from 1975 to 1993. The crop yield data were obtained from the China Rural Statistical Yearbook. The estimated equations for major crops are

(3) $\log(RY_t) = 1.071 + 0.196\log(RY_{t-1}) + 0.133\log(Tr)$
(3.570) (0.837) (2.999)
$R^2 = 0.94$

(4) $\log(WY_t) = 0.370 + 0.535\log(WY_{t-1}) + 0.076\log(Tr)$
(4.372) (2.745) (1.132)
$R^2 = 0.93$

(5) $\log(CY_t) = 0.632 + 0.233\log(CY_{t-1}) + 0.0.206\log(Tr)$
(2.469) (0.741) (2.300)
$R^2 = 0.87$

(6) $\log(SY_t) = -0.149 + 0.224\log(Tr)$
(-1.142) (3.699)
$R^2 = 0.55$

where RY_t = rice yield in time t

Wy_t = wheat yield in time t

CY_t = corn yield in time t

SY_t = soybean yield in time t

Tr = trend

Numbers in parentheses are t-values of the corresponding parameters. The estimated parameters associated with the trend variable and the lagged dependent variable are all positive, indicating that crop yields have been increasing over the sample period in China. Table 3 presents a comparison of average crop yields for the 1992 - 1994 period between the United States and China. China has higher wheat yield than the United States, while other crop yields in the United States are higher than in China. Wheat yields in China are higher because Chinese wheat is produced mostly under irrigation while most U.S. wheat is produced on dry land in semi-arid areas. Lower rice, corn, and soybean yields in China indicate 1) U.S. farming practices are more advanced than China and 2) the United States has more favorable weather and soil conditions than China.

Table 3. 1992-1994 Average Crop Yield in the United States and China

	U.S.	China
	--metric tons/hectare--	
Rice	4.65	4.08
Wheat	2.58	3.43
Corn	7.76	4.73
Soybean	2.51	1.55

The estimated yield equations (Equations 3 - 6) are used to predict crop yields in 2005 under an assumption that the trend representing farming technology continues as it has experienced since 1975. The projected and actual yields for rice, wheat, corn, and soybeans are shown in Figures 8, 9, 10, and 11, respectively.

Table 4 presents actual (1993) and predicted (2005) yields for rice, wheat, corn, and soybeans. Rice yield increases about 10 percent from 5.9 tons per hectare in 1993 to 6.6. tons per hectare in 2005. Wheat yield increases 11 percent during the same period. Increases in yields for corn and soybeans are higher than rice and wheat, 17.4 percent for corn and 14.1 percent for soybeans.

Table 4. The Actual and Predicted Yields for Rice, Wheat, Corn, and Soybeans

Crop	1993	2005	% increase
	----- metric tons/ha-----		
Rice	5.932	6.550	10.4
Wheat	3.408	3.781	10.9
Corn	4.692	5.509	17.4
Soybeans	1.583	1.806	14.1

Increases in total agricultural production in China could have some limitations; some of them are decreases in arable land and multiple cropping index and the other is shortage of water for agricultural uses (Brown) as the Chinese economy uses water for industrial production. Since most arable land is irrigated, the water shortage may become a major problem in expanding agricultural production.

4. Demand Analysis and Prediction

China's wheat and corn consumption has increased substantially over the sample period (Figures 12 and 13). This is mainly because of changes in the quantity and quality of consumer diets as personal income increases. Soybean consumption fluctuates more than consumption of other crops; consumption was lower than the overall average consumption between 1989 and 1992 and increased substantially after 1992 (Figure 14). Rice consumption peaked in 1983 and has declined gradually since then. Rice is the staple of the Chinese diet. The reduction in rice consumption is mainly because consumers desire a more varied diet as personal income increases (Figure 15). Rice has become an inferior good at the current income level in China. This also occurred in Japan, Korea, and Taiwan.

To project the demand for crops in 2005, China's domestic demand functions for rice, wheat, corn, and soybeans were estimated as a function of its GDP with annual time series data from 1981 to 1993. The per capita consumption data were obtained from the Production, Supply, and Distribution (PS&D) Database published by the Economic Research Service (ERS) and the GDP data were obtained from China Statistical Yearbook (CSB). The models are used to forecast domestic consumption of rice, wheat, corn, and soybeans in 2005. In the model, only the income variable is considered because prices of rice, wheat, corn, and soybeans in China are controlled by the government and do not reflect demand and supply conditions. The World Economic Forecast and Analysis (WEFA) group's predictions of China's GDP growth rate were used to project grain demand for 2005.

The estimated demand models of rice, wheat, corn, and soybeans are as follows:

(7) $\log(RC_t) = 1.202 + 0.781\log(RC_{t-1}) - 0.024\log(GDP_t)$
(2.146) (6.072) (1.576)
$R^2 = 0.76$

(8) $\log(WC_t) = 1.367 + 0.669\log(WC_{t-1}) + 0.018\log(GDP_t)$
(2.967) (4.181) (0.381)
$R^2 = 0.86$

(9) $\log(CC_t) = 1.179 + 0.364\log(CC_{t-1}) + 0.208\log(GDP_t) + 0.053(DY_t)$
(1.301) (1.109) (2.085) (1.109)
$R^2 = 0.81$

(10) $\log(SC_t) = 0.022 + 0.577\log(SC_{t-1}) + 0.131\log(GDP_t)$
(0.032) (1.764) (1.564)
$R^2 = 0.46$

where

RC = per capita rice consumption

WC = per capita wheat consumption

CC = per capita corn consumption

SC = per capita soybean consumption

GDP = Gross Domestic Products

DY = dummy variable representing policy changes

Numbers in parentheses are t-values of the corresponding parameters. Per capita consumption of rice has a decreasing trend, indicating that as income goes up, consumers will substitute products such as meat, milk, and eggs. Wheat, corn, and soybeans have an increasing trend, indicating that as income goes up, consumers tend to consume more of these products. Increased corn consumption is used as feed for poultry, hogs, and dairy animals. The predicted demand for rice, wheat, corn, and soybeans are shown in Table 5. Figures 12, 13, 14, and 15 show actual and predicted consumption of wheat, corn, soybeans, and rice, respectively.

Table 5. The Actual and Predicted Demand for Rice, Wheat, Corn, and Soybeans

Crop	1994	2005	% increase
	------1,000 metric tons-----		
Rice	129031	124996	-3.1
Wheat	110863	128259	15.7
Corn	98732	131122	32.8
Soybeans	12992	16021	23.3

5. Transportation and Grain Handling Capacity

The Chinese government has adopted a self-sufficiency policy for agricultural commodities to avoid long-distance commodity shipments. Under this policy, most grain produced in a province should be consumed in close proximity, usually in the same province. This policy has resulted in inefficient agricultural production. Each province produced agricultural commodities on the basis of the need rather than the province's resource endowments, such as climate and soil types. In addition, this policy did not optimize consumers utility in consuming agricultural commodities.

As economic expansion rapidly increases demand for food, the Chinese government has tried to increase its food production by optimizing regional agricultural production based on the regional resource endowment. Furthermore, consumers have tried to maximize their utility in food consumption. Optimizing production and consumption requires shipments of agricultural products from surplus regions to deficit regions, resulting in increases in demand for transportation services.

Modes of transportation available to ship agricultural commodities in China are rail, barges, and trucks. However, rail represents the principal mode of grain transport. In general, railroad transportation is used for long-haul inter-provincial shipments of agricultural commodities.

Waterway and highway transportation are used for short-haul shipments. Waterborne grain traffic represents only 2-3 percent of total waterborne freight traffic (Nyberg). Water transportation is mainly used for local grain marketing along major rivers. About 19 percent of grain marketed is moved by waterway transportation.

China has a fairly extensive network of roads linking all of the nation's counties (township). About 95 percent of its towns are connected by roads (Yuanhua). However, only 24 percent of the surfaced roads are paved with high-standard concrete, indicating that most roads are not capable of handling a large volume of freight.

Railroads are the most important mode of transportation in shipping agricultural commodities, but only 4 percent of China's rail capacity were used for agricultural shipments for the 1975 - 1994 period (Table 6). Ratios of agricultural shipments to total shipments were increased from 2.6 percent in 1975 to 4.8 percent in 1994. Demand for rail transportation has increased rapidly over the last decade with rapid economic growth. Total rail shipments increased from 2.4 million tons in 1975 to 4.3 million tons in 1994, while agricultural shipments increased 238 percent from 60 thousand tons to 203 thousand tons during the same period (Table 6).

Considering economic growth in China for the next 10 years, demand for rail transportation would be expected to grow faster than rail capacity. Railroad officials estimate that China, which has over 50,000 km of track, will need 80,000 km by 2000 to extend service to areas not now served. The rail transportation problem has been compounded with worn-out track and equipment. For example, today 61 percent of the locomotives are steam-powered, 33 percent diesel-powered, and 6 percent electric. The rail system has about 10,000 km of double or multiple track, 20 percent of the total track.

Table 6. China's Daily Shipment by Rail

Year	Total	Grain	% Grain to Total	Non-grain	% of Non-Grain to Total
1975	2351221	60371	2.57	2290850	97.43
1976	2223178	56187	2.53	2166991	97.47
1977	2516458	67718	2.69	2448740	97.31
1978	2918775	67151	2.30	2851624	97.70
1979	2976199	77203	2.59	2898996	97.41
1980	2942304	86178	2.93	2856126	97.07
1981	2848932	93350	3.28	2755582	96.72
1982	3015960	94501	3.13	2921459	96.87
1983	3151135	97001	3.08	3054134	96.92
1984	3281714	97343	2.97	3184371	97.03
1985	3468965	122686	3.54	3346279	96.46
1986	3597154	126361	3.51	3470793	96.49
1987	3724213	149933	4.03	3574280	95.97
1988	3808532	147834	3.88	3660698	96.12
1989	3995961	143922	3.60	3852039	96.40
1990	3980240	147499	3.71	3832741	96.29
1991	4024687	168363	4.18	3856324	95.82
1992	4135282	171929	4.16	3963353	95.84
1993	4280767	178600	4.17	4102167	95.83
1994	4282582	203399	4.75	4079183	95.25

Source: China Statistics Yearbook, 1992.

According to Han Zhubin, Minister of Railway, the total length of railways opened to traffic across the country is expected to reach 70,000 km by the year 2000. Total investment in railway construction is estimated at 250 billion yuan in railway construction, and another 80 billion yuan is needed to purchase engines and trains for the next five years (China's Daily Newspaper, March 7, 1996). This expansion will substantially improve inland freight movements, including agricultural commodities, in China.

Total grain traffic handled by coastal ports in China was approximately 28 million tons in 1994, which is about 4 percent of total cargos (Table 7). Dalian handled about 36 percent of total grain handled by coastal ports, followed by Shanghai (15 percent). In Dalian, about 16 percent of total cargos was grain in 1994.

The number of seaport berths increased by 87 percent from 686 in 1986 to 1282 in 1994 (Nyberg). Only 359 berths are capable of accommodating vessels larger than 10,000 tons. About a dozen berths in China currently are capable of handling vessels of 35,000 to 40,000 tons which are the most common vessel size for grain shipments. In addition, the ports do not have specialized grain-handling facilities. At most ports, grain is off-loaded by clamshell crane

buckets and moved by an assortment of makeshift facilities, including temporary mobile conveyors to storage or bagging facilities (Nyberg). Loading grain into a 35,000-ton vessel requires about 6 - 7 days (5000 tons per day). Unless China improves its grain-handling facilities at ports, the country could not handle more than the current throughput volume.

Table 7. Cargo Handled at China's Principal Ports in 1994

Port	Cargos	Grain	Ratio to Total Grain	Ratio to Cargo at Each Port
		--1,000 metric tons--		
Total	743700	28519	--	0.038
Dalian	62120	10141	0.356	0.163
Yingkou	7640			
Qinhuangd	82070	2421	0.085	0.029
Tianjing	46520	578	0.020	0.012
Yantai	12660	308	0.011	0.024
Qingdao	42130	578	0.020	0.014
Shiqiou	14290			
Liayungan	15890	1138	0.040	0.072
Shanghai	165810	4375	0.153	0.026
Ningbo	58500	985	0.035	0.017
Shantou	7080			
Guangzhou	71580			
Zhanjiang	21240	1159	0.041	0.055
Haikou	6990			
Bashuo	3550			
Shanya	790			
Others	124840	6836	0.240	0.055

Source: China Statistics Yearbook and China's Grain Marketing Infrastructure.

6. Development of An Empirical Model

A spatial equilibrium model based on a linear programming algorithm was developed for this study. A spatial equilibrium model was used because under China's centrally planned economy the government has set major agricultural commodity prices and both production and consumption have been allocated by the government. Econometric estimation of producers' and consumers' responses to prices based on a free market system, therefore, was not feasible.

The model used in this study focused on production and consumption of rice, wheat, corn, and soybeans in China and its trade relationships with other exporting and importing countries. Exporting countries included in the model are the United States, Canada, Argentina, Thailand, Vietnam, Australia, and the European Union (EU). Importing countries include Japan, Korea, Malaysia, and other importing regions grouped into two regions. In the model, China is

allowed to trade rice, wheat, corn, and soybeans with other countries. Southeast Asian countries are allowed to import rice, corn, and soybeans from exporting countries and China (Figure 16). The production and consumption of rice, wheat, corn, and soybeans within China and trade of these commodities with other countries are rationalized on the basis of resource endowments (e.g., farmland and labor), production conditions (e.g., soil type, climate, and crop yields), and demand conditions.

China is divided into 30 producing regions and 30 consumption regions based on existing government administration divisions. The model identifies five ports in China: Dalian, Qingdao, Shanghai, Guangzhou, and Haikou (Figure 17). This study uses the capital city of each province to represent the point of production and consumption.

Railroads are the mode of transportation used in moving grain from producing regions to consuming regions, and ocean vessels are used for exports and imports.

The objective function is to minimize the sum of production costs in China's producing regions, transportation costs from China's producing regions to its consuming regions, exporting costs from China to Asian importing countries, and importing costs from the major countries exporting to China and Asian importing regions. The objective function is optimized subject to a set of constraints associated with production conditions in each producing region, domestic and import demand, and physical capacity of shipping and handling facilities. Farming technology is represented by the crop yield activities in each producing region. Trade policies such as import quotas are included into the model by constraining import demand.

Mathematical Model

The objective function of the model is mathematically expressed as follows:

$$(11)\quad \text{MIN } Z = \sum_{c}\left(\sum_{i}(PC_{ci}+G_{ci})A_{ci} + \sum_{i}\sum_{p} t_{cij}Q_{cij} + \sum\sum(t_{cip}+\pi_{cip})Q_{cip} + \right.$$

$$\sum_{p}\sum_{m} t_{cpm}Q_{cpm} + \sum_{k}\sum_{p} t_{ckp}TQ_{ckp} + \sum_{k}\sum_{p} EP_{ckp}EQ_{ckp} + \sum\sum P_{ckp}Q_{ckp} +$$

$$\left.\sum_{p}\sum_{j} t_{cpj}Q_{cpj} + \sum_{k}\sum_{m} P_{ckm}Q_{ckm} + \sum\sum t_{ckm}Q_{ckm}\right)$$

where

c = index for commodities (rice, wheat, corn, and soybeans)

i = index for producing regions in China

j = index for consuming regions in China

p = index for sea ports in China

k = index for exporting countries

m = index for importing countries

π = profit margin at export port in China

A = acreage planted for crop c in producing region i in China

PC = production cost of crop c in producing region i in China

G = production cost adjustment

Q = quantities of each commodity shipped from producing regions to consuming regions and ports or from ports to importing countries

EQ = quantities of each commodity exported with subsidy

TQ = total quantities of each commodity shipped into China with and without subsidy

t = transportation costs per metric ton in shipping from producing regions to consuming regions and ports or ports to importing countries

The first term in Equation 11 represents the total production cost of the four grain crops and export or import activities of the crops. The first summation in Equation 11 represents the production cost of each crop in each producing region. The production costs are calculated by multiplying production cost per hectare by total hectares in production. The following three summations indicate the total transportation and handling costs from the producing regions to consuming regions, from producing regions to export ports, and from export ports to importing countries. The next three summations represent the total import costs of the four crops from major exporting countries. The final two summations represent the total import costs of other Asian importing countries.

The objective function (Equation 11) is optimized subject to the following constraints:

(12) $\sum_{c} A_{ci} \leq L_i$

(13) $\sum_{I} Q_{cij} + \sum_{p} Q_{cpj} \geq D_{cj}$

(14) $\sum_{j} Q_{cij} + \sum_{p} Q_{cip} = \lambda_{ci} Y_{ci} A_{ci}$

(15) $\sum_{k} Q_{ckm} + \sum_{p} Q_{cpm} \geq ED_{cm}$

(16) $\sum_{ci} \sum Q_{cip} \leq H_p$

(17) $\sum_{ip} \sum Q_{cip} = \sum_{pm} \sum Q_{cpm}$

(18) $\sum_{k} EQ_{ckp} + \sum_{k} Q_{ckp} = \sum_{j} Q_{cpj}$

(19) $\sum_{kp} \sum EQ_{ckp} + \sum_{kp} \sum Q_{ckp} = \sum_{kp} \sum TQ_{ckp}$

(20) $\sum_{p} TQ_{ckp} + \sum_{m} Q_{ckm} \leq ES_{ck}$

where

L = total arable land available for crops in producing regions in China

λ = adjustment factor for farming technology

Y = crop yields in China

D = China's domestic demand for each commodity in each consuming region

ES = upper limit export supply at each exporting country

ED = import demand for each commodity in importing countries

EP = import cost for each commodity with export subsidy at each port

P = import cost for each commodity at each port

H = handling capacity at port p

Equation 12 represents land constraints, indicating that total land used for grain production in each producing region should be less than the total land available for the crop. Equation 13 represents domestic demand constraint for consumption in each consuming region in China. The equation indicates that the total amount of grain each individual consuming region receives from the grain producing regions in China and foreign exporting countries should be greater than or equal to the amount of grain needed in the region. Equation 14 indicates that the total quantities of grain produced in each producing region in China should be greater than or equal to the quantities shipped to domestic and foreign consuming regions. Equation 15 represents the import demand constraint for Asian importing countries. The equation indicates the quantities of each crop shipped from Chinese ports and other exporting countries' ports to the individual importing region should be greater than or equal to the total import demand for the crop in each importing region. Equation 16 represents the handling capacity constraint at each port in China, indicating that the quantities of grain handled at each port should be less than its processing capacity. Equations 17, 18, and 19 represent the inventory clearing conditions of exported and imported grain at each port. Equation 20 shows the total amount of grain shipped to each importing region should be less than or equal to the export supply at the exporting countries.

Base and Alternative Models

This study uses one base and four alternative models to analyze grain production and trade patterns under two trade policy options (free trade and autarky). Scenarios used in this study, therefore, are

1. No import or export restrictions under a free trade option
2. Restricted export under an autarky option.

The models in each scenario are stated as follows:

Model 1 is the base model incorporating existing (1993) production, transportation, importing, and exporting conditions under current agricultural and trade policies in China and other exporting and importing countries.

Model 2 uses the projected demand for rice, wheat, corn, and soybeans in 2005 and 4 - 6 percent increase in crop yield as a result of an advance in farming technology in China (50 percent of the statistically derived yield estimates).

Model 3 uses the projected demand for rice, wheat, corn, and soybeans in 2005 and 8 - 12 percent increases in crop yields as a result of an advance in farming technology in China (the statistically derived yield estimates).

Model 4 uses the predicted demand for rice, wheat, corn, and soybeans in 2005 and 12-16 percent increases in crop yields as a result of an advance in farming technology in China (150 percent of the statistically derived yield estimates).

Each model imposes a minimum production constraint at 50 percent of the current production level for each crop and a maximum constraint at 120 percent of the current production level in each producing region. In each model, demand for and the supply of grain are assumed to be perfectly price inelastic. Multiple crop index is projected to decrease from 1.57 in 1992 to 1.42 in 2005 (see section 3). The index, however, is assumed to be constant at the 1992 level, mainly because of difficulties in incorporating the index in the model. Total arable land was predicted for 2005 with time series data (Figure 6). Demand for and yields of the crops are also predicted for 2005 with time series data (Tables 4 and 5). Because of uncertainty in yield prediction, three different yields are considered: predicted yields (Model 3), 50 percent lower than the predicted yields (Model 2), and 50 percent higher than the predicted yields (Model 4).

Source and Use of Data

Data requirements for the model include production costs for crops, domestic transportation rates, ocean shipping rates, crop yields in each producing region, constraints on arable land, domestic demand quantities, import demand quantities and import cost, and export supply quantities.

Crop Production Cost

The production costs for rice, wheat, corn, and soybeans are variable costs of producing the crops on one hectare of land ($/hectare). The cost of land is not included because the opportunity cost of farm land is near zero and land for nonagricultural uses have been deducted from land available for crop production. Production costs were obtained from Economic Research Service publication Agricultural Statistics of the People's Republic of China and from China Rural Economy Statistics Yearbook published by the China Statistics Bureau (CSB). The production costs of rice, wheat, corn, and soybeans are reported annually by the China Statistics Bureau at the provincial level up to 1990. The 1992 production costs of rice, wheat, corn, and soybeans have not been published. In this study, therefore, 1990 production costs data are adjusted to 1992 production costs by using the agricultural inputs price index.

Domestic Production and Consumption

China is divided into 30 consuming regions for rice, wheat, corn and soybeans because the consumer's diet has been largely established by availability of crops in a region. However, the differences in diet across regions may narrowed as the country improves its transportation system for agricultural commodities.

Per capita consumption of the crops in each consuming region for 2005 are estimated on the basis of predicted national average per capita consumption obtained from the previous section and the weighted average of urban and rural per capita consumption within each consuming region. The per capita consumption in 2005 in each consuming region is calculated as:

(21) $C_{it} = PC_{it}(c) + AC_{i,1993}(1-c)(PC_{it}/PC_{1993})$.

where C_{it} is per capita consumption of the ith crop in time t in each consuming region,
c is a weighting factor for national average per capita consumption. It is assumed that c is equal to 0.25,
Pc_{it} is predicted national average per capita consumption of the ith crop in time t, and
$Ac_{i,\ 1993}$ is actual per capita consumption of the 1th crop in 1994 in each consuming region (weighted average of urban and rural consumption).

Per capita rice and wheat consumption data were collected from China Agricultural and Trade Report: China Situation and Outlook Series (ERS) and China Urban Family Expenditure Survey Data (CSB). The former reports the rural per capita consumption data, and the latter reports the urban per capita consumption data. Per capita consumption in each province was calculated by using the weighted average of the two data sets based on urban and rural population. There are no sources of per capita consumption for corn and soybeans for every province. Only a few provinces' data are available. Average per capita consumption of corn and soybeans were calculated by dividing the total consumption by population. Provincial per capita data were obtained by adjusting the average consumption based on regional production, considering the production and consumption ratio provided by sample provincial data.

Total available land for the production of rice, wheat, corn, and soybeans in each producing region was determined on the basis of the total 1992 planted hectares published by the China Statistics Bureau. Total arable land was predicted for 2005 as explained in Section 3.

Yield data of rice, wheat, corn, and soybeans at each producing region were obtained from China Rural Statistical Year Book (CSB). A three-year average of crop yields in each producing region, 1990-1992, was used in the base model to represent yields of each producing region to avoid possible bias in measuring crop yields which could have resulted from extreme weather conditions. Yields for the crops are predicted for 2005 as shown in Section 3.

Transportation Cost

Transportation costs were divided into two parts: 1) China inland transportation costs from producing regions to domestic consuming regions and 2) ocean transportation costs from exporting country's ports to importing country's ports by ocean vessels.

Most inland grain movements between provinces are by rail. In China, the railway system is state owned with rail rates regulated by the central government. The policy is to discourage long distance shipping by rail because of the system's limited capacity. There are no data on rail rates for long distance shipments in China. Therefore, a rail freight rate was developed using average rates from 12 railway administrations under the Ministry of Railways reported by Cook, Martland, and Feng.

Specific ocean freight rates between China's ports and its trading partners are not available. An ocean freight rate function was developed using average shipping rates reported in World Grain Statistics (IWC 1992). These freight rates were regressed against ocean mileage using the double-log function. The estimated freight rate function is as follows:

(22) $\log(OR) = -0.5334 - 0.548og(DIS)$

$\qquad\qquad (1.992) \quad (10.72)$

$\qquad R^2 = 0.952$

where OR = ocean freight rates for grain shipments between original ports and destination ports

DIS = actual ocean mileage between origin ports and destinations

The t-value (number in the parentheses) indicates that the coefficient differs significantly from zero at the 5 percent significance level.

The shortest distance between exporting and importing ports was collected from the Distance Between Ports (U.S. Defense Mapping Agency). The ocean freight rates were calculated with the ocean mileage in Equation 20.

Trade Data

FOB prices of rice, wheat, corn, and soybeans at selected ports in exporting countries were obtained from World Grain Statistics (IWC) and Commodity Statistics Bulletin (ABARE). The prices used in the model are average prices from 1990 to 1992. Wheat price includes the export subsidies used by the United States and the EU. Handling costs at export ports and import ports are assumed to be 5 percent of FOB price.

Major importing countries are China, D.P.R. Korea, the Republic of Korea, Japan, Malaysia, Hongkong, Singapore, Thailand, Sri Lanka, Indonesia, and Russia, and several parts of the former Soviet Union. Some of these importing countries are aggregated into several regions according to their geographic location.

Importing countries' demand quantities were calculated using a three-year average of imports, except for Japan's and Korea's rice import data. The import data were collected from ERS Asia and Pacific Rim Situation and Outlook Series which reports the potential demand for grain under the Uruguay Round GATT Agreement.

7. Results

Results obtained from the base model are compared with those obtained from alternative models. Results are presented for each of the four models under free trade and autarky options.

Production, Consumption, and Trade Under a Free Trade Option

Rice

Rice production is 131.0 million metric tons and the total planted area is 32.6 million hectares in the base model (Table 8). Rice production is concentrated in the southern provinces (see Figure 2 in Section 3). The production pattern in the base model is similar to actual rice production in China.

Rice consumption is 129.0 million metric tons in the base model, indicating that domestic rice production is larger than domestic consumption. In the base model, China exports 1.97 million metric tons of rice to neighboring countries.

When rice yields are assumed to increase by 4 percent (50 percent of the statistically derived yield estimates), 8 percent (the statistically derived yield estimates), and 12 percent (150 percent of the statistically derived yield estimates) in Models 2, 3, and 4, respectively, with the predicted rice consumption, rice production and planted acres decline compared to the base model. As a result, China imports 3.94 million, 3.71 million, and 3.48 million metric tons of rice in Models 2, 3, and 4, respectively, and also exports 1.97 million metric tons to neighboring countries. This implies that China would be a net rice importer under the predicted demand and production conditions in 2005. Since transportation costs of shipping rice from southern provinces to deficit regions in China are inefficient and also high, it is more economical for major rice-producing provinces in the southern region to export rice, while deficit provinces in the northern region import rice. China's net rice import in Model 2 is approximately 11 percent of the 1994 total rice trade in the world, 10 percent in Model 3, and 8 percent in model 4.

Wheat

China's wheat production is 100.24 million metric tons and planted area is 30.52 million hectares in the base model (Table 8). Twelve provinces produce almost 90 percent of China's wheat in the base model (see Figure 3 in Section 3). Nine wheat-producing provinces are located in northern China. China produces only soft wheat.

Domestic demand is 110.86 million metric tons, which is much larger than domestic production in the base model. China imports 10.62 million metric tons of wheat from major exporting countries, including the United States and Canada. China has been one of the largest wheat-importing countries for the last decade.

When wheat yields increase by 5 percent (50 percent of the statistically derived yield estimates), 10 percent (the statistically derived yield estimates), and 15 percent (150 percent of the statistically derived yield estimates) in Models 3, 4, and 5, respectively, with the predicted demand, wheat production and planted area decline in the models. As a result, China's wheat imports increase substantially in the models compared to the base model. Its wheat import in Model 2 is approximately 27 percent of the 1994 total wheat traded in the world, 21 percent in Model 3, and 15 percent in Model 4. Most imports come from the United States, Canada, and Australia.

Corn

China is one of the largest corn-producing countries in the world. China's corn production is 99.10 million metric tons and planted area is 21.66 million hectares in the base model. Corn is mainly produced in seven northern provinces and two southern provinces, which produce about 84 percent of corn produced in the country (see Figure 4 in Section 3).

Domestic demand for corn is 98.73 million metric tons in the base model, indicating that China is a corn exporter. China exports 8.71 million metric tons of corn to its neighboring countries, including Korea and Japan, and also imports 8.34 million metric tons. Because of high transportation costs in shipping corn from surplus regions in northern China to deficit regions in southern China, the northern provinces export their surplus corn to neighboring countries, while the southern provinces import corn from exporting countries, including the United States.

When corn yields are increased by 5.5 percent (50 percent of the statistically derived yield estimates), 11 percent (the statistically derived yield estimates), and 16.5 percent (150 percent of the statistically derived yield estimates) in Models 3, 4, and 5, respectively, with the predicted demand, corn production and planted acres increase compared to the base model. Corn is only crop for which China increases its acres in Models 2, 3, and 4 compared to the base model. In 11.56 million metric tons, while its export is 7.39 million metric tons. China imports all corn from the United States. Its corn import in Model 2 is approximately 20 percent of the 1994 total corn traded in the world and 6 percent in Model 3. However, China becomes a net corn exporter

Table 8. Production, Consumption, Exports, and Imports of Each Crop Under the Base and Alternative Models

	Area Planted	Production	Consumption	Export	Import	% of Net Import to World Trade	% of Net Import to U.S. Export
			1,000 metric tons				
Rice							
Model 1	32,619	131,005	129,031	1,974	0	--	--
Model 2	29,060	123,035	124,996	1,974	3,935	11.11	69.81
Model 3	27,782	123,265	124,996	1,974	3,705	9.81	61.62
Model 4	26,489	123,495	124,996	1,974	3,475	8.50	53.44
Wheat							
Model 1	30,520	100,245	110,863	0	10,618	9.66	32.51
Model 2	28,678	98,086	128,258	0	30,173	27.45	92.39
Model 3	29,271	104,966	128,258	0	23,293	21.19	71.32
Model 4	29,932	111,809	128,258	0	16,450	14.96	50.37
Corn							
Model 1	21,659	99,104	98,732	8,713	8,342	--	--
Model 2	23,818	117,435	131,122	873	14,559	20.02	25.66
Model 3	23,876	126,948	131,122	7,388	11,562	6.11	7.82
Model 4	23,913	136,423	131,122	16,800	11,498	--	--
Soybeans							
Model 1	5,787	8,384	12,992	0	4,607	14.15	20.64
Model 2	5,337	8,148	16,021	0	7,872	24.18	35.27
Model 3	5,504	8,841	16,021	0	7,179	22.05	32.17
Model 4	5,525	9,426	16,021	0	6,595	20.26	29.55
All Crops							
Model 1	90,585	338,738	351,618	10,687	23,567	10.31	21.21
Model 2	86,893	346,704	400,397	2,847	56,539	24.74	50.88
Model 3	86,433	364,020	400,397	9,362	45,739	20.02	41.16
Model 4	85,859	381,153	400,397	18,774	38,018	16.64	34.21

in Model 4; its corn import is 11.50 million metric tons, while its export is 16.80 million metric tons. China would export corn to its neighboring countries, including Korea and Japan.

Soybeans

China is the third largest soybean producer in the world. China's soybean production is 8.38 million metric tons and planted area is 5.79 million hectares in the base model. Soybeans are mainly produced in six northern provinces. Heilongjiang province accounts for about 30 percent of soybeans produced in China (see Figure 5 in Section 3).

Domestic soybean demand is 12.99 million in the base model, indicating that China is a net importer of soybeans. China imports 4.61 million metric tons of soybeans in the model, and most of the imports come from the United States.

As soybean yields increase 5 percent (50 percent of the statistically derived yield estimates), 10 percent (the statistically derived yield estimates), and 15 percent (150 percent of the statistically derived yield estimates) in Models 3, 4, and 5, respectively, with the predicted demand (16,021 thousand metric tons), domestic production is smaller in Model 2 and larger in Models 3 and 4, compared to the base model. In the models, China is a net soybean importer. Its soybeans import in Model 2 is approximately 24 percent of the total soybeans traded in the world market in 1994, 22 percent in Model 3, and 20 percent in model 4.

All Crops

China is one of the largest agricultural producing countries in the world. The country produces 338 million metric tons of major crops (rice, wheat, corn, and soybeans), and the total planted area is about 90 million hectares. China exports 10.69 million metric tons of grains, mainly rice and corn, in the base model and also imports 23.57 million metric tons. This means that China is a net grain importer and its import is 10 percent of the total grain traded in 1994.

When the predicted demand for the crops on the basis of expected economic growth to 2005 and the predicted yields are incorporated in Models 2, 3, and 4, China's imports increase substantially. China's total imports range from 38 million metric tons in Model 4 to 56 million metric tons in Model 2. China's imports are 24 percent of the total grain traded in 1994 in Model 2, 20 percent in Model 3, and 17 percent in Model 4.

Trade Flows of Agricultural Products

As shown in Table 9, China imports rice from Viet Vietnam and Thailand in Models 2 through 5 mainly because transportation costs between China and these countries are lower than those between the United States and China. On the other hand, China imports corn and soybeans from the United States, mainly because of lower shipping costs from the United States to China than from Argentina to China. China imports about 30 percent of its import of wheat from the United States, 42 percent from Canada, 15 percent from the EU, 8 percent from Australia, and 1.4 percent from Argentina. This is mainly because China imports hard wheat which is produced in the United States and Canada. This implies that increases in China's agricultural consumption will increase U.S. agricultural exports more than other countries' exports.

Table 9. China's Agricultural Imports by Sources With Projected Demand Structure in 2005

	U.S.	Canada	Australia	Argentina	EU	Others
	1,000 metric tons					
Rice						
Model 1	0	0	0	0	0	0
Model 2	0	0	0	0	0	3,935
Model 3	0	0	0	0	0	3,705
Model 4	0	0	0	0	0	3,475
Wheat						
Model 1	5,066	3,918	226	41	1,366	0
Model 2	14,396	8,992	2,785	118	3,883	0
Model 3	11,113	6,941	2,150	91	2,998	0
Model 4	7,848	4,902	1,518	64	2,117	0
Corn						
Model 1	8,342	0	0	0	0	0
Model 2	14,559	0	0	0	0	0
Model 3	11,562	0	0	0	0	0
Model 4	11,498	0	0	0	0	0
Soybeans						
Model 1	4,607	0	0	0	0	0
Model 2	7,872	0	0	0	0	0
Model 3	7,179	0	0	0	0	0
Model 4	6,595	0	0	0	0	0

One concern is China's handling facilities at ports and transportation capacity in shipping agricultural commodities from ports to consuming regions. Most ports in China are mainly used for shipments of industrial goods and do not have facilities specialized for grains. The existing port facilities are not large enough to handle the predicted amount of grains. In addition, inland transportation, mainly railroad, is operating at its full capacity. Only 3-4 percent of China's rail capacity has been used for grain shipments. China may not be able to ship required grains from ports to consuming regions unless it increases its capacity substantially.

Production, Consumption, and Trade Under an Autarky Option

In the autarky option, China does not export any crops and tries to produce agricultural commodities as much as possible by maximizing the utilization of all arable land. China uses more arable land under this option than under the free trade option, resulting in more crop production. Under this option, China's rice imports remain the same as those under the free trade option (Table 10). China's imports of other crops decrease compared to those in the free trade option. Rice production decreases in this option, while production of other crops increases compared to the free trade option. China's total imports range from 21 million metric tons in Model 4 to 51 million metric tons in Model 2 under this autarky option.

Table 10. Production, Consumption, Exports, and Imports of Each Crop Under the Base and Alternative Models (Autarky)

	Area Planted	Production	Consumption	Export	Import	% of Net Import to World Trade	% of Net Import to U.S. Export
			1,000 metric tons				
Rice							
Model 1	32,229	129,031	129,031	0	0	--	--
Model 2	28,852	121,061	124,996	0	3,935	22.29	140.09
Model 3	27,950	122,583	124,996	0	2,413	13.67	85.90
Model 4	27,876	122,789	124,996	0	2,207	12.50	78.57
Wheat							
Model 1	31,091	102,528	110,863	0	8,335	7.58	25.52
Model 2	30,712	103,343	128,259	0	24,916	22.66	76.29
Model 3	31,468	111,206	128,259	0	17,053	15.51	52.22
Model 4	32,413	120,519	128,259	0	7,739	7.04	23.70
Corn							
Model 1	20,711	94,145	98,732	0	4,587	6.71	8.60
Model 2	23,724	116,675	131,122	0	14,447	36.45	46.71
Model 3	23,473	124,069	131,122	0	7,053	10.32	13.22
Model 4	21,944	124,638	131,122	0	6,483	9.48	12.15
Soybeans							
Model 1	6,818	9,929	12,992	0	3,063	9.41	13.72
Model 2	5,473	8,248	16,021	0	7,773	44.38	64.74
Model 3	5,870	9,590	16,021	0	6,430	19.75	28.81
Model 4	6,529	11,417	16,021	0	4,604	14.14	20.63
All Crops							
Model 1	90,849	335,633	351,618	0	15,985	7.00	14.38
Model 2	88,761	349,327	400,398	0	51,071	22.35	45.96
Model 3	88,761	367,448	400,398	0	32,949	14.42	29.65
Model 4	88,762	379,363	400,398	0	21,033	9.21	18.93

This autarky option costs China about 270 million yuan ($46.9 million) per year in the base model and 1,289 million yuan ($223.5 million) per year in Model 4 (Table 11), indicating that China would be better off through trading agricultural commodities with major exporting countries and its neighbors.

Trade flows of the crops from exporting countries to China are similar to those shown in the free trade scenarios; China imports all corn and soybeans from the United States, while China imports wheat from all of the major exporting countries (Table 12). China imports rice from its neighboring countries, such as Thailand and Viet Vietnam. The United States is the largest exporter of wheat, followed by Canada and Australia.

Table 11. Objective Values of the Base and Alternative Models Under Free Trade and Autarky Options

	Free Trade	Autarky	Differences
	million yuans		
Model 1	43,722	43,993	271
Model 2	50,133	50,600	467
Model 3	47,121	47,850	729
Model 4	44,195	45,484	1,289

Table 12. China's Agricultural Imports by Sources With Project Demand Structure in 2005 (Autarky)

	U.S.	Canada	Australia	Argentina	EU	Others
	1,000 metric tons					
Rice						
Model 1	0	0	0	0	0	0
Model 2	0	0	0	0	0	3,935
Model 3	0	0	0	0	0	2,413
Model 4	0	0	0	0	0	2,207
Wheat						
Model 1	3,977	3,076	178	33	1,073	0
Model 2	11,887	7,425	2,300	97	3,207	0
Model 3	8,136	5,082	1,574	67	2,195	0
Model 4	3,692	2,306	714	30	996	0
Corn						
Model 1	4,587	0	0	0	0	0
Model 2	14,447	0	0	0	0	0
Model 3	7,053	0	0	0	0	0
Model 4	6,483	0	0	0	0	0
Soybeans						
Model 1	3,063	0	0	0	0	0
Model 2	7,773	0	0	0	0	0
Model 3	6,430	0	0	0	0	0
Model 4	4,604	0	0	0	0	0

This scenario requires more interprovincial movements of agricultural commodities than the free trade scenario. Surplus grains in producing regions are shipped to consuming regions to reduce imports. As a result, more grains are moved in this scenario.

8. Implications

China's food consumption will increase as a result of expected rapid economic growth. Even though China increases its agricultural productivities through improving farming practices, its domestic production is not likely to be large enough to meet domestic demand in 2005.

China likely will export rice and corn to its neighboring countries and, at the same time, import rice, wheat, corn, and soybeans under a free trade option. However, China's imports of the crops will be larger than its exports. China will be the largest wheat and soybean importing country in the world in 2005. China will import rice from neighboring southeast Asian countries, corn and soybeans from the United States, and wheat mainly from the United States, Canada, European Union, and Australia. China's grain imports will affect the world agricultural economy. Under the autarky option, China will produce more and import slightly less. Its imports, however, are still likely to be large enough to increase world grain and oilseed prices.

Unless the Chinese government restricts food demand through some type of rationing, this study indicates that even under optimistic yield increases, China will become an increasingly important market for grain and oilseeds and the United States will be the major supplier. China's market will have a positive impact on grain and oilseed prices.

Increases in China's imports will also affect grain shipping and handling industries. Unless these industries increase their capacities, they will not be able to meet future demands. China's railway and ports are operating at full capacity. In addition, demand for transportation services has grown faster than increases in capacity. A significant amount of public or private investment on the transportation industry is needed to meet demand created through economic expansion.

China's food deficit beyond 2005 will likely become even larger. As China's economy continues to expand for the next several decades, demand for wheat, corn, and soybeans will increase, while arable land will likely decline. This implies that demand for these crops will likely grow faster than production, indicating that China's grain and oilseed imports will continue to increase. A question raised by Lester Brown, "Who Will Feed China?" will remain as an important issue.

The world can supply enough food and feed grains to China if the prices of these crops are high enough to stimulate production in major agricultural exporting countries, mainly the United States, Canada, and Australia. Increases in prices will affect production and consumption around the world and consequently affect trade flows of agricultural commodities.

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