OPTIMAL GRAIN PRODUCTION AND DISTRIBUTION IN CHINA

A Thesis
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

Fengqin Huang

In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE

Major Department:
Agribusiness and Applied Economics

April 2006

Fargo, North Dakota

North Dakota State University
Graduate School

Title

Optimal Grain Production and Distribution in China

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

ABSTRACT

Huang, Fengqin; M.S.; Department of Agribusiness and Applied Economics; College of Agriculture, Food Systems, and Natural Resources; North Dakota State University; April 2006. Optimal Grain Production and Distribution in China. Major Professor: Dr. Won W. Koo.

The objective of this study is to evaluate the configuration of China's grain production pattern and the implications for agricultural trade. A spatial equilibrium model is developed to optimize grain production and distribution in China and its trade relationship with its trade partners. This study focuses on four grain crops: rice, wheat, corn, and soybeans. The model divides China into 31 producing regions and 31 consuming regions. The model also includes seven exporting countries and six Asian importing regions.

Results indicate that China can improve its grain production and social welfare through production specialization under a free-trade environment. China could become a major wheat and soybean importer, and a corn and rice exporter to Asian countries. The study also provides perspectives on U.S. exports to China and other Asian countries.

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to my major adviser, Dr. Won Koo, for his guidance and great help throughout this study. I would also thank Dr. Cheryl Wachenheim, Dr. Jang-Chul Kim, and Dr. Siew Lim for their support.

In addition, I would like to thank my friend Richard Taylor who provided much help during the study.

I dedicate this thesis to my husband, Quan Su, for his understanding and sacrifice during my graduate study.

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CHAPTER 1. INTRODUCTION

China is the world's most populous nation. The population increases by 10-15 million people per year. Even with the strict implementation of the one-child policy in past decades, China's population still grew to 1,292 million in 2003, accounting for more than one-fifth the world population (China National Bureau of Statistics, 2003). In recent years, the Chinese government has gradually changed its birth-control policies due to the possible negative effects of the overall trend of aging. In some cities, such as Shanghai, a small group of people is allowed to have two children if they meet the specific requirements of the government. Although this policy is still restricted to a few places, it implies a potential to increase the population in the future. How to feed the huge population has become a major concern in China.

Although China is the third-largest country in the world geographically, China's total arable land was 127 million hectares in 2001, which accounts for about only 10% of its total land, and China's per capita arable land is only about 0.1 hectare, which is much smaller than the United States, where it is about 0.64 hectare (World Fact Book, 2006). Further, cultivated land is highly expected to decline due to the construction of houses, roads, and factories (Novelli, 2001).

China is one of the few countries in which the economic growth is sustainable. With an average of more than an 8% annual rate since 1978, its share of the world GDP has risen from less than 1% in the 1970s to over 4% in 2003 (Shane and Gale, 2004). China is the largest producer of grain in the world, accounting for approximately 14% of world production. Specifically, it is the largest producer of wheat and rice, and the second largest producer of corn ("China: A Wildcard Player," 1999).

"Grain (mostly rice and wheat) and vegetables, by weight, make up about 70% of per capita food consumption in China, a much higher share than in the U.S and the world average level. China's per capita meat consumption exceeds the world average but is less than 50% of per capita meat consumption in the U.S. These differences in food consumption between China and the rest of the world reflect a combination of low per capita incomes in China and different tastes and preferences" (Gale, 2002, page 7). As Chinese disposable income increases, consumers' demand for high-quality diets, including consumption of meat, fish, and diary products, grows at a remarkable speed. The changing diets, as a result, boom livestock consumption that requires the country either to produce more livestock products or to import more of them. If China decides to produce more livestock to meet its domestic demand, the country will need much more feed grain than before. As shown in Figure 1.1, the per-capita consumption of food grain fell from 210.59 kg in 1985 to 166.63 kg in 2002; however, the per-capita consumption of meat, fish, fruit, etc. increased threefold from 29.07 kg in 1985 to 94.87 kg in 2002. The consumption of feed grain was climbing, peaked around 1995, and has remained almost the same since then.

China has played a major role in the international agricultural market. In the late 1980s, China's foreign trade grew about 15% annually. In 2004, China's agricultural exports totaled about $26 billion, and its agricultural imports were about $16 billion (Gale, 2005). Historically, China has been one of the largest importers of wheat and a major source of growth in world demand for soybeans since the mid-1990s (Figure 1.2). The United States has supplied a significant portion of China's

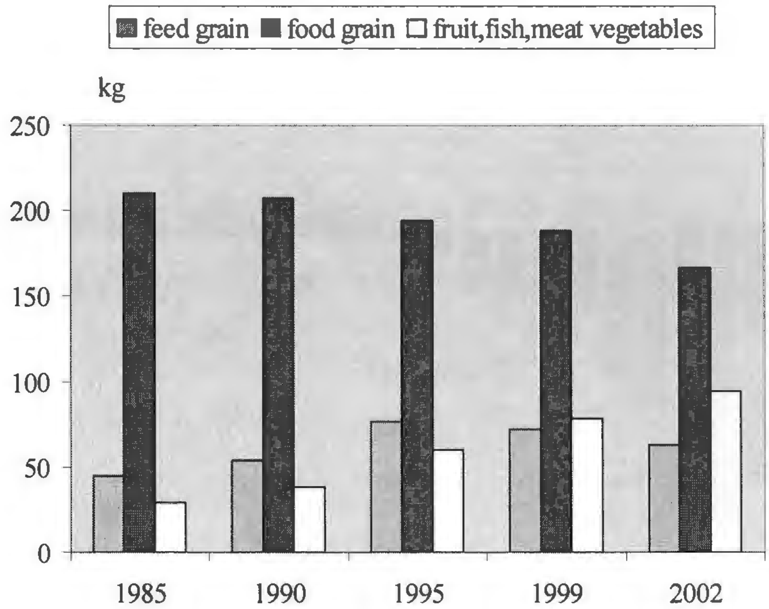

Figure 1.1. Per Capita Consumption of Food in China (1985-2002).

imports of wheat, soybeans, corn, and especially soybeans, which now account for about half of U.S agricultural exports to China (Gale, 2005). China is nearly self-sufficient in food and is a net exporter of rice. Most exports go primarily to neighboring Asian countries, including Japan and South Korea, which are also among the top markets for U.S agricultural products.

China's foreign trade has been volatile since 1990 (Figure 1.3). In 1994 and 1995, China abruptly increased its grain imports and cut off corn exports. Between 1996 and 1997, the import of wheat declined significantly. China turned from a large exporter of corn to an importer in 1995, but in the past few years, it became a net exporter of corn. Soybean imports rose from 2.3 to 6.4 million tons about 1997, roughly 10% of the average annual world trade. China temporarily became a net rice importer about 1995-1996 and rapidly changed back to a net rice exporter in the following years (Gale, 2005). Overall, the high volatility in Chinese agriculture trade would make the world market uncertain and hard to predict.

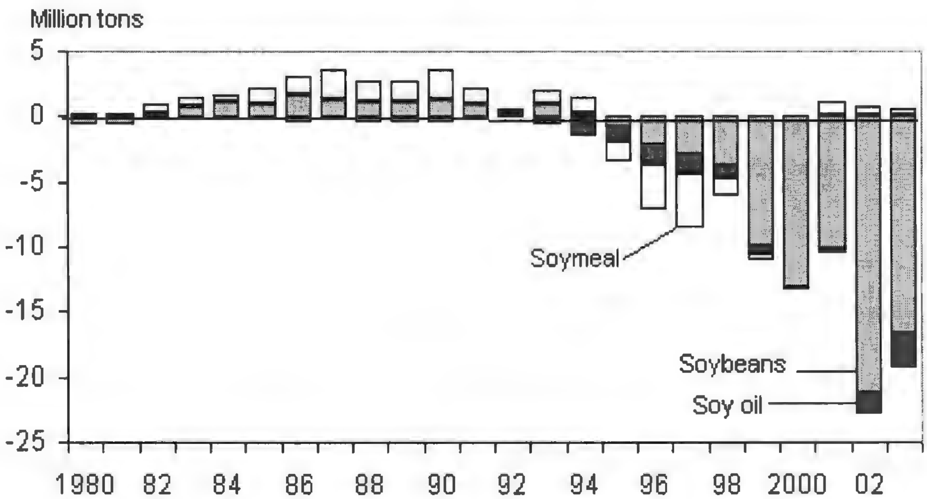

Figure 1.2. China's Net Trade in Soybeans, Oil, and Meal, 1980-2003.
Source: Gale, 2005.

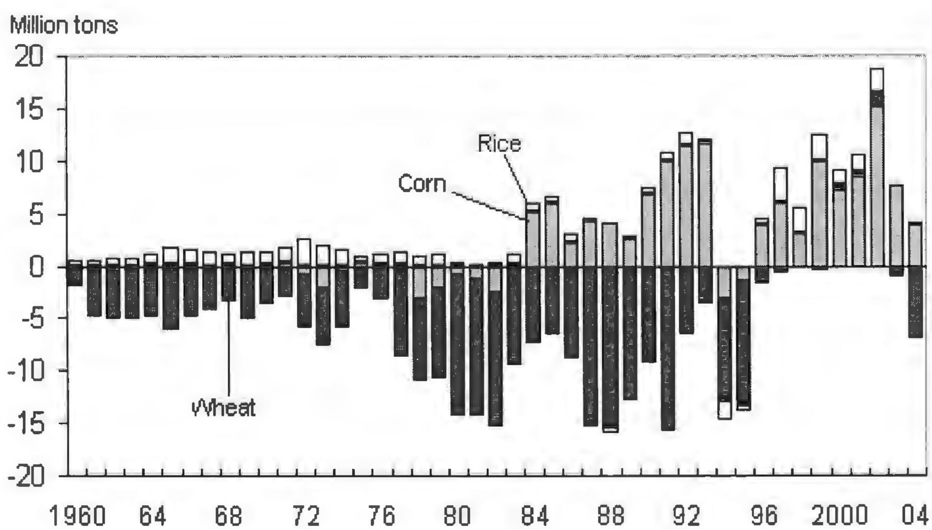

Figure 1.3. China's Net Trade in Rice, Corn, and Wheat, 1960-2004.
Source: Gale, 2005.

Despite China's status as the largest grain producer, its vast population, limited agricultural land, and rising livestock productions have made it difficult for China to achieve its self-sufficient goal of grain. The Chinese government has adopted the self-sufficiency policy for grain products since it came to power in 1949. This policy emphasizes self-sufficiency in grain production and minimizes grain imports. This self-sufficiency policy, however, may not be able to optimize grain production based on the principle of comparative advantage. If China focuses on increasing grain productivity based on regional resources endowment with improved technology and infrastructure, it could substantially increase the total grain production.

Chinese agricultural policy changed many times over the years and moved to a market-oriented grain production and distribution system. From the 1950s through the early 1990s, China taxed its agriculture sector to subsidize urban consumption and industrial development. During the 1990s, taxation of farmers receded. Most recently, China eliminated the taxation and even began to subsidize farmers directly. This is a dramatic change which has stimulated grain production. On the other hand, with China's accession to the World Trade Organization (WTO), the Chinese government must comply with the WTO's trade policy by reducing its control over trade. The government will lower tariffs on most agriculture products, eliminate export subsidies and trade barriers, weaken trading monopolies, increase the openness of import licenses and quota allocations, and require publication of trade regulations (Gale et al., 2002). Eventually, China could be one of the most open countries in terms of agricultural trade.

Objectives

The overall objective of this study is to analyze the optimal agricultural production and distribution system in China based on regional resources endowments, production conditions, and consumption in consuming regions under a globalized free-trade environment. Specific objectives are as follows:

1. To identity the optimal production and trade pattern of major agricultural commodities (rice, wheat, corn, and soybeans) on the basis of China's resources endowments.
2. To optimize domestic production in different producing regions and distribution systems of the commodities and Chinese import/export flow.
3. To predict Chinese agricultural production and trade patterns and their impacts on the world agricultural industry under different scenarios.
4. To evaluate China's and the United States' competitiveness in exporting major grains to Asian markets.

Methodology and Scope

The model developed for this study is a global spatial optimization model based on a linear programming algorithm. The objective of the model is to minimize overall costs, including production costs of grains in China, and transportation and import costs from around the world. The study focuses on four grains: rice, wheat, corn, and soybeans. Internally, China is divided into 31 producing regions and 31 consuming regions based on the political boundaries. The model includes seven exporting countries, the United States, Canada, Argentina, Australia, Brazil, Thailand,

and Vietnam; and six importing regions, Japan, Korea, Malaysia, the Philippines, Taiwan, and other Asian importing countries.

Organization of Study

This paper is organized into six chapters. Chapter 1 is the Introduction, and an overview of China's grain production, consumption, trade, and transportation is presented in Chapter 2. Chapter 3 reviews some past literature associated with this study. Chapter 4 discusses the methodology and data development. Results of the analysis are presented in Chapter 5. The last chapter presents the Summary and Conclusions.

CHAPTER 2. OVERVIEW OF CHINA'S GRAIN AGRICULTURE

Grain Production

Grains are widely grown in China. Wheat, corn, rice, and soybeans are the most important crops produced in China. The total sown area of the 4 crops accounts for nearly 88% of the total grain sown area, and total production accounted for nearly 91.8% of total grain production in 2000 (China National Bureau of Statistics, 2003). China has 10 persons to feed per hectare of arable land, more than twice the world average of 4.4 persons per hectare, yet China has remained largely self-sufficient in grain production. The key reason for China's ability to maintain a high level of production is the use of double- and triple-cropping, and the application of large quantities of fertilizer and labor (Gale, 2002).

Rice

Rice is the most important and the largest production of grain in China, which is also the largest rice-producing country in the world, accounting for a third of global output (Hansen et al., 2002). In 2003, 26.71 million hectares of rice were planted, producing 160.66 million tons. Rice is sown on 27.65% of China's grain-growing area and represents 39.04 % of total grain production (China National Bureau of Statistics, 2003).

The major rice-producing regions are located in southern China (Figure 2.1). Traditionally, northern provinces have grown and consumed primarily the japonica rice, one of two major types of rice in China, while southern provinces preferred to grow indica rice. During the past two decades, the Japonica rice area has expanded significantly from 11% of the total rice area in 1980 to 29% by 2000 (Crook et al., 2002), mainly due to the introduction of dry-field seedling transplantation methods in the mid-1980s and rapidly rising prices (Kako and Zhang, 2000).

Even though rice yields have increased steadily at about 3.57% annually for the past two decades, because rice-sown areas have decreased substantially at the same time, total rice production has been relatively stable over the years. Since the late 1990s, the average yields of rice have been above 6.0 tons per hectare, the highest rice yield level in the world (Figure 2.2). Much of the increases in yield was due to the implementation of improved varieties. In 2000, the hybrid rice area share reached 50% of the total rice-sown areas (Zhang, 2000).

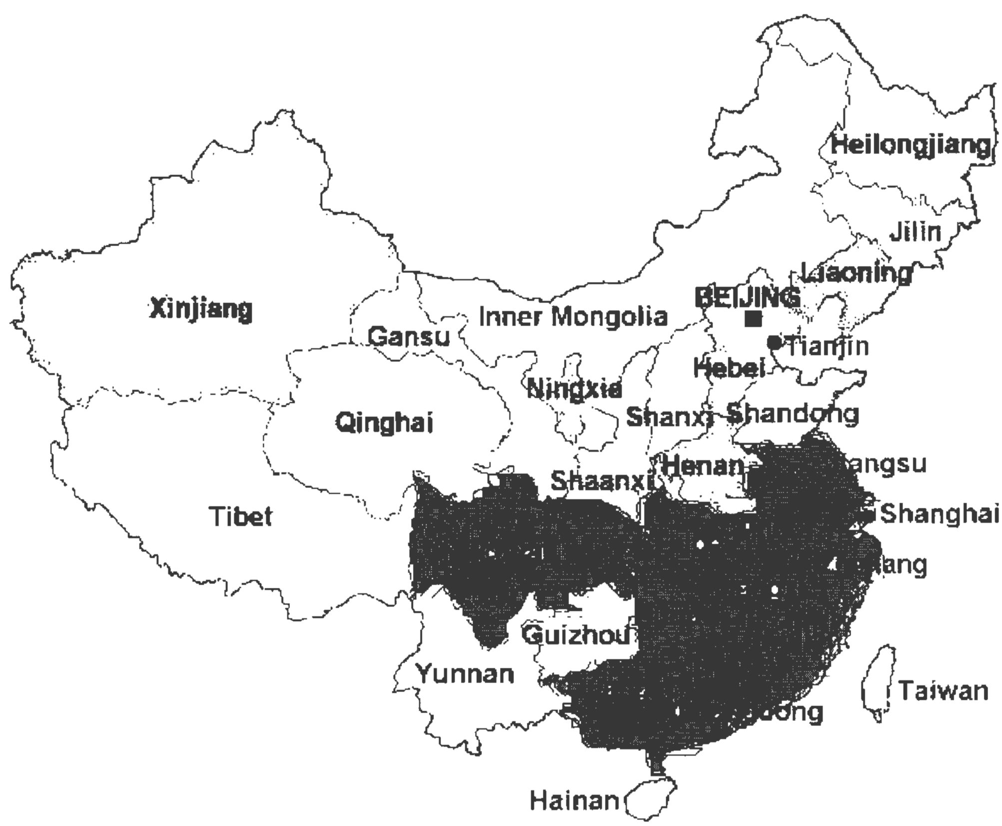

Figure 2.1. Major Rice-Producing Regions.

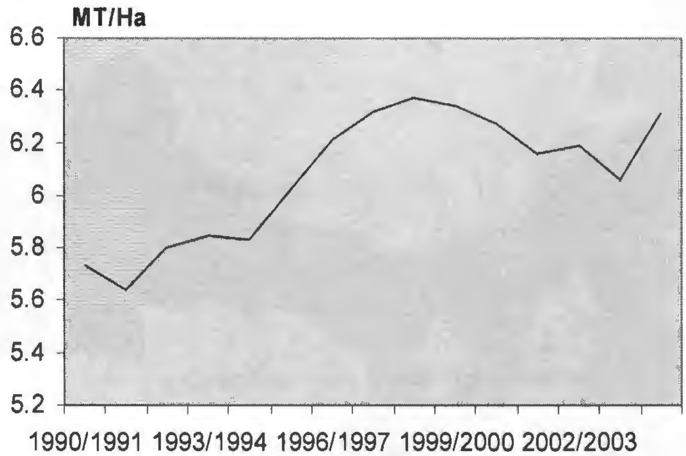

Figure 2.2. Rice Yield in China.
Source: USDA-PS&D online database (1990-2003).

Wheat

Wheat is second in total production of grain in China. In 2003, 22.26 million hectares of wheat were planted, producing 86.49 million tons. Wheat is sown on 25.5% of China's grain-growing area and accounts for 22% of total grain output (China National Bureau of Statistics, 2003). Although wheat production has fallen significantly since 1997, China is still the world's largest wheat-producing country (Lohmar, 2004).

Most of China's wheat production comes from the North China Plain (Figure 2.3). Three provinces in this area, Henan, Shandong, and Hebei, collectively account for over 50% of China's wheat output (Lohmar, 2004).

Declining wheat production since the mid-1990s is primarily due to reductions in areas sown to wheat (Lohmar, 2004). During 1997-2002, wheat production fell by 26.2% and sown area fell by 20.5% (Figure 2.4).

Figure 2.3. Major Wheat-Producing Regions.

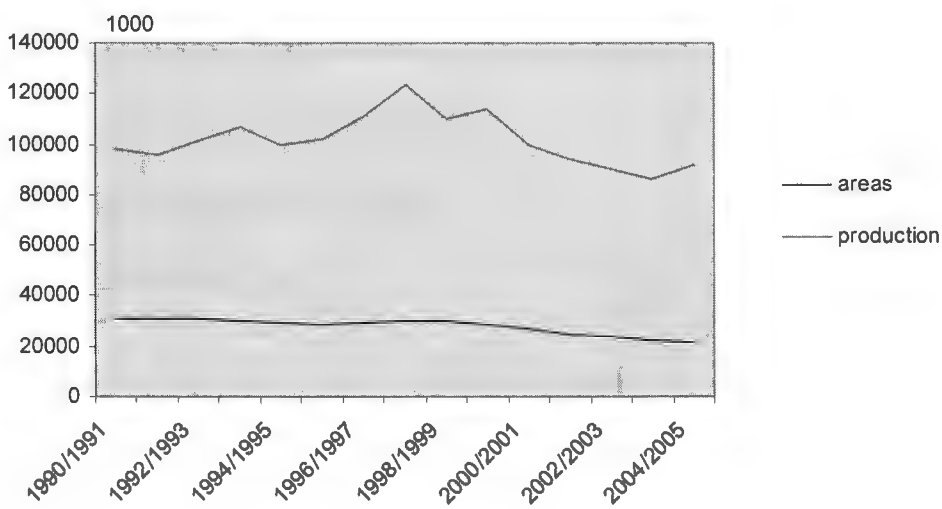

Figure 2.4. Wheat Production and Areas Harvested in China.
Source: USDA-PS&D online database (1990-2004).

Corn

Corn is another important grain in China. In 2003, 23.43 million hectares of corn were sown, producing 115.83 million tons. This represents 22.87% of the total grain growing area and 25.20% of its total grain output (China National Bureau of Statistics, 2003).

The major corn-producing regions are in the northern part of China (Figure 2.5). Four northeastern provinces, Jilin, Heilongjiang, Inner Mongolia, and Liaoning, account for about 35% of national output. The North China Plain produces roughly the same amount of corn as the northeast (Gale, 2004).

"Corn yields grew steadily through the 1980s and early 1990s as a result of improved efficiency, improvement of varieties, fertilizer use and good weather. Since 1996, the upward trend in yields has disappeared and been dominated by year to year fluctuations, mostly due to varying weather in northeastern China where summer drought, early freezes, or heavy rains at harvest frequently reduced yields" (Gale, 2004, page 10). This trend can be seen in Figure 2.6. Given that planted area is shrinking and corn must compete with other crops for land use, corn production can hardly increase significantly.

Figure 2.5. Major Corn-Producing Regions.

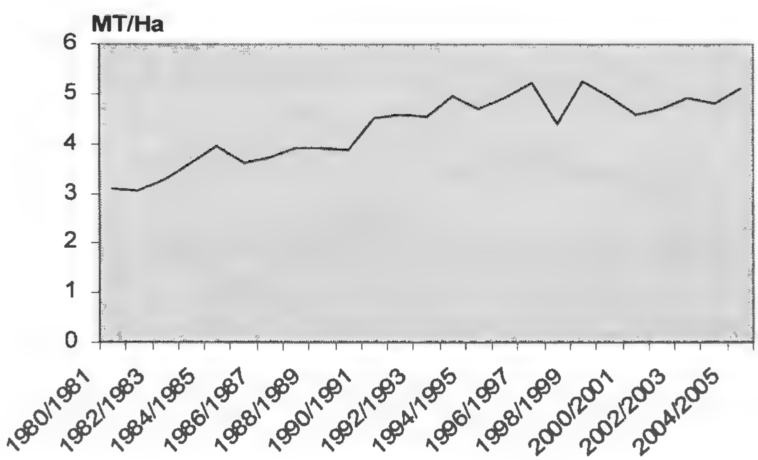

Figure 2.6. Corn Yield in China.
Source: USDA-PS&D online database (1980-2004).

Soybeans

China is the world's third-largest soybean producer, but its production of soybeans is not large enough to meet rapidly increasing domestic demand. In 2003, 9.31 million hectares of soybeans were sown, producing 15.4 million tons of soybeans. This used 8.22% of total sown area and accounted for 3.5% of total grain outputs in China, or 9% of the world's total soybean output (China National Bureau of Statistics, 2003).

The Major Soybean-Producing Regions are concentrated in the northeast (Heilongjiang and Jilin) and North China Plain (Figure 2.7). These two regions together produce about 60% of China's soybeans. If China shifts large areas of corn or spring wheat in the northeastern region into soybean production, soybean output would be expanded significantly (Tuan et al., 2004).

Soybean production in China has increased significantly over the last two decades (Figure 2.8), but given its limited arable land and slow growth of soybean yields, currently about 35% lower than U.S average yields, China faces difficulties in improving its domestic supply of soybeans (Tuan et al., 2004).

Grain Consumption

Per-capita consumption of rice and wheat has declined in past years (Figure 2.9). This is primarily due to consumers' increased diversification of their diets to include more meat, vegetables, and fruits as well as fewer staple grains. The main factors behind this change are rising incomes, urbanization, and population growth. This shift is most obvious in urban areas, where consumers have higher incomes, more

Figure 2.7. Major Soybean-Producing Regions.

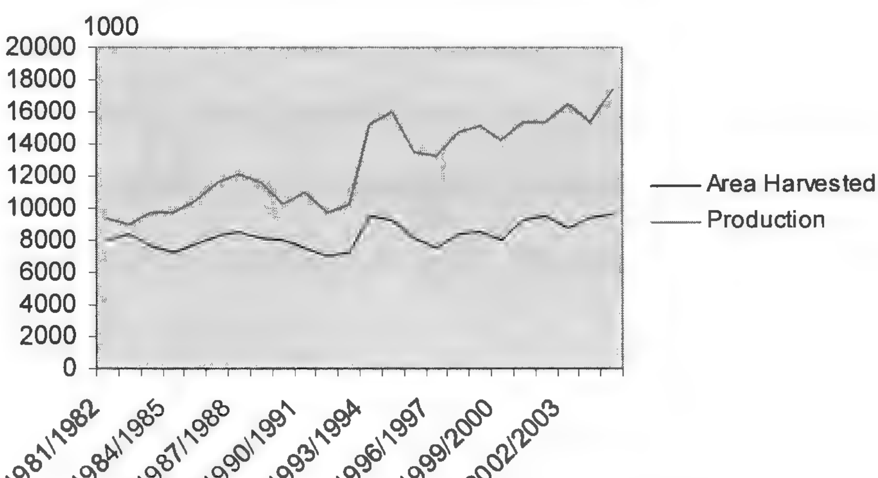

Figure 2.8. Soybean Production and Areas Harvested in China.
Source: USDA-PS&D online database (1980-2004).

food selections, and more household appliances that can be used to store and process food.

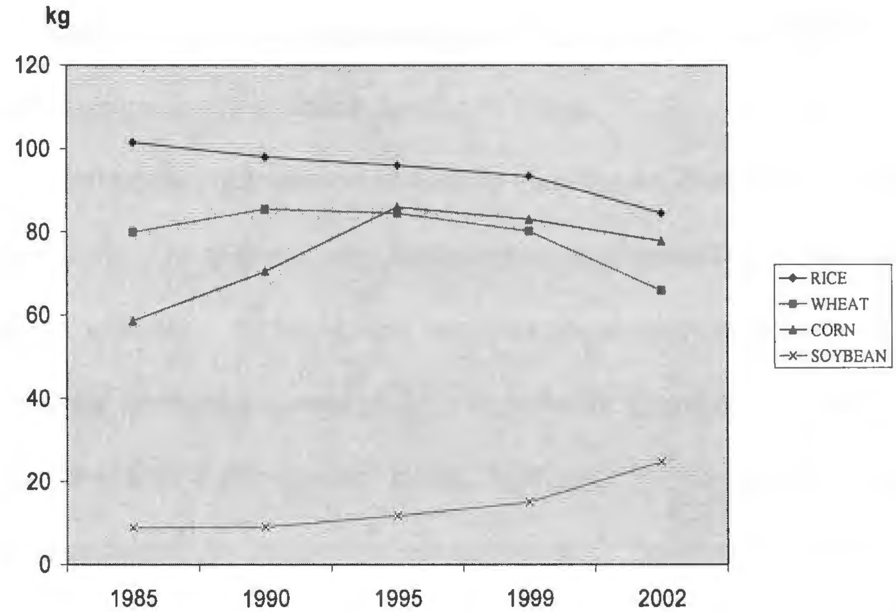

Figure 2.9. China's Per Capita Consumption of Major Grains.
Source: United Nations Food and Agriculture Organization, FAOSTAT database (1980-2004).

Rural consumers are also diversifying their diets as their income grows and the market develops (Lohmar, 2004). Rural-to-urban migrations helped to reduce the demand for grain substantially. Since China's economy has grown 8-9% annually and urban population has also increased rapidly, this generally declining trend will likely continue in the coming years.

However, there are some interesting points that need to be mentioned. Although consumption for all rice has declined, the demand for japonica rice in China has been rising at the same time. Two factors for this trend are the migration of people to northern China, where high-income consumers historically preferred japonica rice, and improved marketing channels (Hansen et al., 2002). In addition, "not only are

Chinese consumers now eating less wheat, but they are also choosing to eat wheat that has different quality characteristics than in the past" (Lohmar, 2004), and this is changing food processing industries. Combined with the campaign embarked by policymakers to increase the production of high-quality wheat, the wheat quality may play an important role in future demand in China.

Per-capita consumption of corn is showing an increasing trend over the years (Figure 2.9). In general, corn consumption is expected to grow due to a growing livestock industry. "Animal feed accounts for about three-fourths of domestic corn use and the demand for corn as feed is probably growing at a rate at least equal to China's 8-9% GDP growth rate" (Gale, 2004, page 9). Demand for livestock products is boosted further by rural-to urban migration. "Industrial use of corn is growing rapidly due to a combination of market demand and government-directed investment" (Gale, 2004, page 10).

The demand for soybeans has outstripped supply in China over the past two decades (Tuan et al., 2004). China imported a record 20.7 million tons of soybeans in 2003, which accounted for about one-third of world soybean imports, and the per-capita consumption of soybeans increased threefold from 8.89 kg in 1985 to 24.69 kg in 2002 (Figure 2.9). The reasons behind this strong demand—rising income, population growth, and urbanization—helped propel the growth in demand for animal protein products and vegetable oils. Soybean demand is ultimately driven from increased consumption of soybean oil and soybean meal (Tuan et al., 2004).

Domestic Distribution System

Before 1980, the Chinese government's central planning dominated domestic grain marketing. The government's grain bureau purchased, transported, stored, milled, and retailed all grain from the farm. Beginning in the 1980s, the market was gradually opened as the government allowed commercial growers to join the marketing systems (Crook et al., 1999). Many provinces began phasing out the old ration system that subsidized urban grain consumers with low fixed prices. This means that the government no longer subsidized urban consumers.

Chinese government and party leaders still control all aspects of China's food grain sector. Grains bureaus located at province and country levels determine grain availability and needs to purchase; and set purchase prices for wheat, rice, and corn procurement quotas. "Farmers who have been assigned quotas must deliver the specified grains to local grain bureaus. Grain bureaus are responsible for distributing major grains to military units, wholesale markets, feed mills, grain storage facilities and grain and food processors, and part of the supply for urban residents in large cities" (Crook et al., 1999, page 28). Governors from surplus and deficit provinces jointly work out the major movement of grains across provincial borders. The movement of grain within provinces is managed jointly by provincial and local government leaders, and is usually implemented prior to the circulation with other provinces. The national grain supply-and-use balance sheets enable national leaders to assess grain export or import needs (Crook et al., 1999).

Foreign Trade System

China's foreign trade of major grains (rice, wheat, and corn) is determined by the central government, and the annual plan is formulated by the State Planning and Development Commission (SPDC) with the consultation of the State Council and the Ministry of Foreign Trade and Economic Cooperation (MOFTEC) (Crook et al., 1999). China's National Cereals Oils and Foodstuffs Import and Export Corporation (COFCO) acts as an agent to implement orders from MOFTEC and receives a fee for its service. "Prior to 1989, COFCO had domestic monopoly power to import or export grain for the central government, and it had many branches in various provinces carrying out marketing functions for the central COFCO" (Crook et al., 1999, page 30). In the early 1990s, China's foreign trade market became increasingly open as the government exerted less control and entitled more companies, other than state trading enterprises (STEs), rights to trade. The market-oriented trend has formed gradually, but the role of STEs in China remains a key issue after China entered the WTO. Despite more than 15 years of economic reform, the STEs continue to manage the level and direction of the trade flows of several major agricultural commodities, including wheat, rice, and corn. From 1992 to 1997, STEs imported 8.2 million tons and exported 7.9 million tons of wheat, rice, and corn annually, on average (Crook et al., 1999).

However, the accession to WTO will have a significant impact on the role and behavior of China's STEs and will reduce the government's total control power over trade from various aspects. As required by WTO commitments, China will reduce the monopoly power of STEs; tariffs will be reduced for a wide range of agricultural products; export subsidies will be eliminated; and all trade regulations and rules will be published. Although some serious problems still exist in China's implementation of commitments in the agriculture sector, progress has been achieved. Greater integration with the global economy will inevitably open the country's domestic market to more agricultural and food imports.

It is projected by Economic Research Services (ERS) that China's net agricultural imports of most grains (corn, wheat, and soybeans) will increase with its WTO accession. According to the analysis of ERS, as the corn export subsidies are eliminated, China's exports of corn are expected to fall, and imports of corn are expected to rise. This will tend to raise world prices and increase the demand for U.S. corn exports. The growing demand for high-quality wheat, which is in short supply in China's domestic market, will make China's wheat imports rise. China's WTO accession will have little direct impact on soybean imports because it has already imported at a low tariff rate. If China eliminates the new labeling requirements for genetically modified crops, soybean imports will increase further.

Transportation

While China is working hard to comply with WTO commitments, the market could still be effectively closed to foreign suppliers if transportation is not efficient enough. It was estimated by the Chinese Academy of Social Sciences that transportation and logistics account for 20% of the retail prices of goods in China, about 5 times of that in the United States. "As transport and other marketing costs fall, the economy will become more efficient in sending price signals that will realign regional production" (Gilmour and Gale, 2002, page 24).

China's leadership has taken significant measures to improve the country's poor transportation infrastructure. Highways and airports were mass constructed, and together with highly competitive trucking firms, bus lines, and airlines, the various transportation means now provide alternatives to China's aging railways. "From 1990 to 2000, highway mileages in China increased by 36% and existing highways were greatly improved. The railways, already the longest in Asia, also increased track length by 19%. Double tracking, electrification and higher speed trains were introduced throughout the country. Even the length of China's inland waterways is increased by 9%. China will continue to expand its transportation infrastructure through a combination of public and private investment" (Gilmour and Gale, 2002, page 24-25).

"The Chinese government is trying to reform domestic distribution industries by separating policy and administrative functions from commercial operations and breaking up monopolies into multiple commercial companies that will compete with one other" (Gilmour and Gale, 2002, page 26). As a result of China's accession to the WTO, foreign companies will be allowed to enter the railway cargo service sector, which is now solely managed by the government. Competition will be intense, but will bring out a more efficient distribution environment.

CHAPTER 3. LITERATURE REVIEW

Halbrendt, Webb, and Aull-Hyde (1994) developed a multi-commodity spatial price equilibrium (SPE) model to study the changes in China's trade patterns if infrastructural improvements and trade reforms are made. It differs from past SPE studies in that it accounts for cross-commodity effects in the supply and demand specifications. The objective function is the maximization of the net social payoff function by using a concave quadratic net revenue function.

In their study, China was grouped into 14 domestic trade regions and one external import–export region. Two scenarios were examined based on the premise of an improved rail infrastructure and unrestricted trade flows among provinces. Results showed that total quantities supplied and demanded would not change dramatically, but prices would drop and volume traded would increase. The interregional trade flows would increase, suggesting that, currently, China was not internally trading optimally. Corn had the largest percentage increase in trade volume, and wheat had the second largest position. With unrestricted trade and improved infrastructure, China would have its comparative advantage by further reducing wheat production and increasing rice production, and these improved situations would facilitate more domestic specialization and efficiency significantly.

Based on the SPE model above, Webb, Halbrendt, Gana, and Tuan (1994) also used the model to analyze the impact on China's budget expenditures, interregional trade, and international trade if China was to maintain self-sufficiency with wheat, or under limited free trade.

Results indicated that the impacts on regional quantity supplied and demanded were estimated to be small, except for wheat under the self-sufficiency scenario, while the impacts on interregional trade were much stronger. Maintaining self-sufficiency and expanding transportation capacity would increase interregional trade by 23% and 57% respectively. The impacts on international trade were also quite significant as there would be a decline of 52% under a self-sufficiency scenario, and an increase of 5% under the transportation scenario. Chinese consumers would have to pay much higher prices in order to make domestic wheat production increase. The real savings for China under the free trade scenario are the government's subsidy expenditures, which are to reduce price differentials between producers and consumers.

Zhong, Xu, and Fu (2001) measured the regional comparative advantage in China's grain production and drew policy implications. In their study, Domestic Resources Costs Coefficients (DRCC) were calculated for individual crops, provinces, and regional groupings. The relative values of DRCC were taken as indicators of regional comparative advantage in grain production among provinces in China.

The analysis revealed that China has relatively strong comparative advantages in rice, sorghum, and millet production, but no advantages in wheat, soybean, and corn production. The northern region should expand production of middle indica rice, wheat, and corn, while reducing Japonica rice, millet, and soybeans. The central region should increase production of millet, soybeans, and late indica rice, and reduce other grain production. The southern region might produce fewer grain crops other than middle and early indica rice. However, the quantity of increases/decreases in the production of specific crops is still an issue. Therefore, a future study is needed.

Fang and Beghin (2003) assessed the protection and comparative advantage of China's major crops in six regions using a modified Policy Analysis Matrix (PAM) with 1997-2000 data.

Aggregate patterns of production were consistent with the Heckscher-Ohlin model, and suggested that China has a comparative advantage in labor-intensive crops, but not in many land-intensive crops. Specifically, except for high quality rice, the production of other grains and oilseeds tends to suffer from a lack of comparative advantage over other crops in China, such as fruits, vegetables, and cotton. Their study concluded that grain self-sufficiency policies reduce locative efficiency several-fold. Furthermore, the study showed that a lack of comparative advantage and protection are positively correlated in Chinese agriculture, and the regional comparative advantage has not yet been fully executed because of different policies and limited regional market integration.

Koo and Fruin (1994) examined the basic modeling techniques applied to transportation systems for agricultural products to analyze how a transportation system can improve the efficiency of agricultural production through production specialization in the Chinese agricultural sector. In this study, various deterministic mathematical models in an open economy which could optimize the Chinese agricultural sector were discussed, including quadratic programming, linear programming, and network flow models. They suggested that the transportation model with production activities can be used to optimize agricultural production based on the principle of comparative advantage, and the marketing system shipping agricultural commodities from producing regions to consuming regions.

Halbrendt and Gempesaw (1990) examined the impacts of China's historical and anticipated future reforms on its domestic wheat economy and how it affected the import demand for wheat using a stochastic coefficient regression method.

The study showed that China's agricultural sector growth has had an impressive record since market reform was initiated in 1978. The results strongly supported the hypothesis that producers and consumers in the past were responsive to a less controlled economy. Chinese authorities were also responsive to world prices, although they were constrained by foreign exchange earnings. Furthermore, imports were forecasted to be higher, indicating that China will interact more with the world wheat market, and future Chinese agricultural policy will further expand the role of market forces in the Chinese economy.

Lin and Koo (1990) examined the intersectional perspective for agricultural and industrial economies in China, including the patterns of sectors development of the past decades. Growth models for the agricultural and industrial sectors were estimated using the two-stage least squares estimator.

Mutual dependency did not occur in the Chinese economic development process, as indicated by empirical economic theories. The causality test between the agricultural and industrial sectors of the Chinese economy also showed no cause-effect relationship. Results revealed that the process of Chinese economic growth fluctuated mainly due to policy changes. Growth of the modern industrial sector was achieved at the expense of the traditional agricultural sector.

CHAPTER 4. MODEL DEVELOPMENT

Model Description

The model developed for this study is a global spatial equilibrium model based on a linear programming algorithm. The main reason for choosing a spatial optimization model is that China has had a central planning economy for the past few decades. The Chinese government controls all aspects of the distribution of major commodities. The prices are preset and cannot reflect both the producer's and the consumer's responses. Thus, econometric estimation of supply and demand based on a free market system may not be feasible. Compared with other methods, an advantage of this linear programming model over others (i.e., the quadratic programming model) is that it does not need to estimate price dependent demand and supply equations with time series data, which, in practice, is difficult to collect. Another advantage of this linear programming model is that it does not have any limitation in size and complexity, and can formulate a large-scale model with great detail.

This study focuses on four major types of crops: rice, wheat, corn, and soybeans in China. The model includes seven exporting countries and six importing regions. The exporting countries are the United States, Australia, Argentina, Brazil, Canada, European Union, Thailand, and Vietnam; the importing countries are Japan, South Korea, Malaysia, Taiwan, the Philippines, and other south Asian importing countries (OSAM). To connect China with the exporting and importing countries, the model includes five major ports (Dalian, Tianjin, Qingdao, Shanghai, and Guangzhou) along the Chinese coastal line. China is divided into 31 producing regions and 31 consumption regions based on the existing political boundary. It is assumed that both China and other exporting and importing countries are allowed to trade agricultural products freely, and the production and consumption of major commodities within China and trade of these commodities with other countries are optimized in terms of the principle of comparative advantage based on resources endowment, production conditions, and demand conditions. To simplify, this study assume that the capital city of each province represents the center of production and consumption. Further, this study also assumes that, except for China, other exporting and importing countries use only one major port to export or import grains. Railway is the major mode of transportation used in this model within China. International trade is implemented by ocean shipping.

The model has two components: one is the Chinese agricultural sector, the other is the import and export activities in the rest of the world. The objective of the model is to minimize the production costs of grains in the producing regions in China, transportation costs for shipping grains from producing regions to consuming regions in China and to importing countries through Chinese ports, and import costs from foreign exporting countries to both consuming regions in China and other Asian importing countries. The objective function is optimized subjecting to the following set of linear constraints: demand for grains in each consuming region in China, arable land and yield in each producing region in China, export costs and exportable quantities of each grain in exporting countries, and import demand in importing countries.

Figure 4.1 shows alternative shipping patterns for grains from producing regions to consuming regions and ports in China, Chinese exports from Chinese ports to importing countries, and imports from exporting countries to both consuming regions in China and other Asian importing countries. It is assumed that grains move from producing regions to consuming regions by rail or truck, and to ports by rail. International shipping is done by ocean vessel.

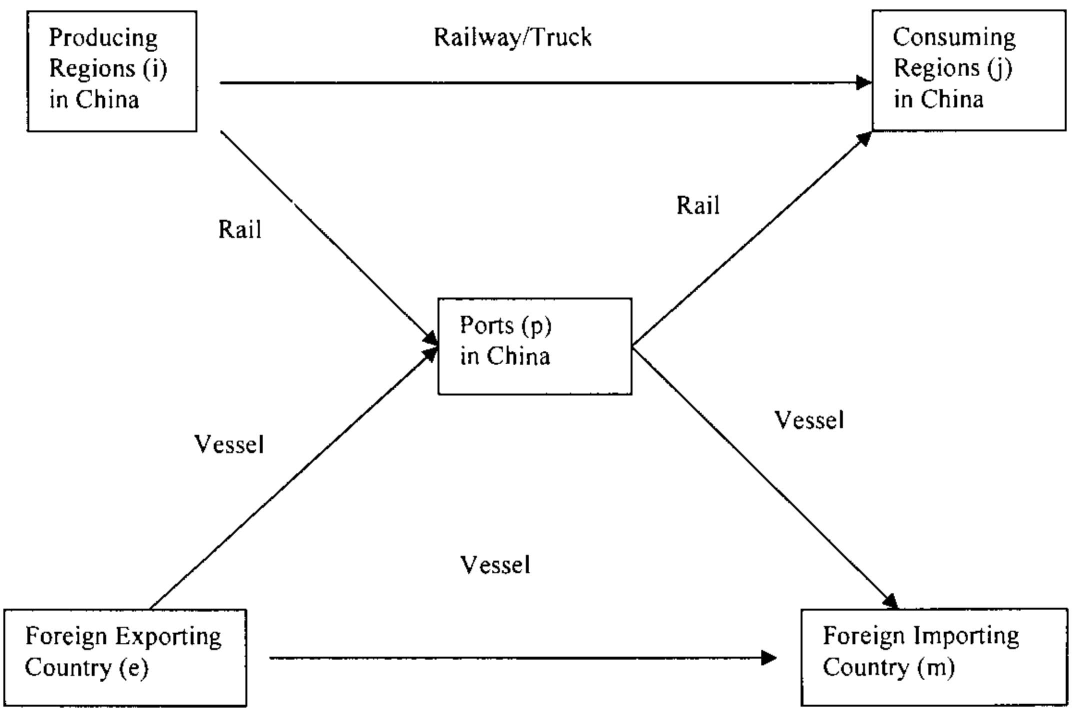

Figure 4.1. Domestic and International Flows of Grains.

Mathematical Programming Model

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

$$
\begin{aligned}
W= & \sum_c \sum_i PCciAci + \sum_c \sum_i \sum_j T\,cijQcij + \sum_c \sum_i \sum_p TcipQcip + \\
& \sum_c \sum_p \sum_m TcpmQcpm + \sum_c \sum_e EPce + \sum_c \sum_e \sum_m TcemQcem + \\
& \sum_c \sum_e \sum_p TcepQcep + \sum_c \sum_p \sum_j TcpjQcpj \quad ,
\end{aligned}
$$

where

C	=	index for crops
i	=	index for producing regions in China
j	=	index for consuming regions in China
p	=	index for ports in China
m	=	index for ports in importing countries
PC	=	production cost of each crop in each producing region in China
A	=	area used to produce each crop in each Producing region in China
T	=	transportation costs per ton between origins and destinations
Q	=	quantity of grains shipped
EP	=	export costs of grain at exporting countries

The first term of the objective function represents production costs in producing regions in China. The next two terms represent transportation costs of shipping agricultural goods from producing regions to domestic consuming regions and to ports for exports in China. The fourth term represents ocean shipping from ports in China to importing countries. The fifth term represents export costs of each grain at exporting countries. The next two terms represent transportation costs from exporting countries to importing countries and ports in China. The last term represents transportation costs from ports in China to its consuming regions.

This objective function is optimized subject to the following constraints (equations):

1. $YciAci \geq \sum_j Qcij + \sum_p Qcip$

2. $\sum_c Aci \leq TAi^{\max}$

3. $AciYci \geq Qci^{\min}$

4. $\sum_i Qcij + \sum_p Qcpj \geq Dcj$

5. $\sum_e Qcem + \sum_p Qcpm \geq Mcm$

6. $\sum_i Qcip = \sum_m Qcpm$

7. $\sum_e Qcep = \sum_j Qcpj$

8. $\sum_p Qcep + \sum_m Qcem \leq Q^s$,

where

Y	=	yield per hectare in producing regions in China
TA^{max}	=	total arable land in each producing regions in China

Q^{min} = minimum quantity of each commodity produced in producing regions in China

D = domestic demand in consuming regions in China

M = import demand in importing countries

e = index for exporting countries

Q^s = export supply in exporting countries

Equation 1 (constraint 1) indicates that total grains produced in each producing region in China should be equal to or larger than the quantities of grains shipped to domestic consuming regions and exporting ports in China. It is assumed that a country exports grains after satisfying its domestic consumption. Under this assumption, exportable surplus is the total domestic production of each grain minus domestic consumption of the individual commodity.

Equation 2 represents the physical constraint of arable land in each producing region in China. This constraint indicates that total cropland used to produce grains should not exceed the total area available for production in each producing region in China. Since total arable land is fixed in each producing region, production activities should be optimized under the physical constraint of arable land.

The next constraint (Equation 3) represents characteristics of production activities in each producing region in China. In general, producers in a region tend to produce certain crops primarily because of their experience in production practices of the crops, even though producing the crops is not economically optimal. In addition, the overall self-sufficiency goal, the less-developed grain marketing system, and transportation infrastructure would make local governments maintain the production quota to some degree. To incorporate this characteristic, the model contains the minimum production constraint which represents that each producing region should produce the minimum amount of individual crops based on crop production in the past several years.

Equation 4 indicates that the quantities of grain shipped from producing regions to each consuming region, and those from import ports to each consuming region, should be larger than the quantities demanded in the consuming region. This implies that consumption of grains in each consuming region should be met by domestic production and/or imports.

Equation 5 represents the import demand constraints, indicating that total quantities of grains shipped from Chinese ports and exporting countries to importing countries should be equal to or greater than the estimated import demand in importing countries.

Equations 6 and 7 represent inventory clearing constraints at ports in China for exports and imports respectively. It is assumed that ports in China are not allowed to carry inventories, and that ports are considered to be simply transshipment points in exporting or importing grains.

Equation 8 represents the export supply constraints, indicating that the sum of Chinese imports of grain and the imports of other Asian importing countries should be less than or equal to the total supply of exporting countries.

Base and Alternative Models

This study has one base and seven alternative models to analyze the grain production and trade patterns. The models are stated as follows:

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

Model 2 is the base model imposing a full self-sufficiency policy by stopping all imports in China.

Model 3 is the base model with a 45% increase in soybean demand estimated in the year 2015.

Model 4 is the base model with a 15% increase in corn demand estimated in the year 2015.

Model 5 is the base model with both a 45% increase in soybean demand and a 15% increase in corn demand in the year 2015.

Model 6 is the base model with a 10% increase in grain yields as a result of improved technology.

Model 7 is the base model with a 20% increase in grain yields as a result of improved technology.

Model 8 is the base model with a 20% decrease in grain production costs in China.

The base model imposes a minimum production constraint at 50% of the current production level in each producing region for each grain except for corn, for which the minimum production constraint is set at 70% of current level. Except for models 3, 4, and 5, the base model and all the other alternative models assume that the consumption of rice, wheat, corn, and soybeans is equal to the current levels. In each model, the demand and supply of grain are assumed to be perfectly price inelastic.

Data Collection

Data requirements for the model include production costs of each crop, domestic transportation costs (railway and truck freight rate), and ocean shipping rates of every country. The model also needs data of crop yield in each producing region in China, the total available land in each producing region in China, Chinese domestic demand for each crop in each consuming region, the total demand of each crop in other importing countries, and export costs and available supply of each crop in each exporting country.

Crop Production Costs, Yield, and Available Land

The production costs for rice, wheat, corn, and soybeans in China are in hectares (Table 4.1). Land cost is not included. The production costs were from the College of Economics and Trade, Nanjing Agriculture University (NAU) in China, data year 2003. The arable land, yield, and the actual sown area of each crop in each producing region were obtained from the Chinese rural economy investigation official website (2001).

The production costs of rice, wheat, corn, and soybeans in each exporting country were obtained from The Center for Agricultural Policy and Trade Studies (CAPTS), NDSU, in hectares (dollars/hectare). The yield of each crop was also provided by CAPTS. The production costs were then transformed to metric tons (dollars/ton) by dividing the production costs with yield. The export prices of rice, wheat, corn, and soybeans were calculated by adding product costs and inland transportation costs from producing regions to ports together (Table 4.2).

Table 4.1. Production Costs of Crops in China (Unit: $/hectare)

	Rice	Wheat	Corn	Soybean
Beijing	902.45	606.12	376.16	289.12
Tianjin	901.45	502.39	336.14	267.12
Hebei	806.62	536.5	411.32	261.36
Shanxi	638.79	439.05	481.33	258.58
Neimong	702.06	601.16	477.95	219.81
Liaoning	631.94	348.2	416.04	274.45
Jilin	556.47	352.30	443.54	303.89
Heilongjiang	467.54	239.67	303.12	224.82
Shanghai	700.95	347.20	320.14	335.24
Jiangsu	616.54	438.18	434.07	321.39
Zhejiang	615.15	406.62	512.33	312.50
Anhui	484.83	394.16	364.45	213.01
Fujian	630.62	528.96	546.32	202.5
Jiangxi	510.07	515.96	556.52	198.30
Shandong	745.33	578.15	485.92	306.30
Henan	546.37	422.27	433.47	225.22
Hubei	480.99	412.70	524.71	322.81
Hunan	618.31	452.70	587.35	324.20
Guangdong	669.85	487.67	612.23	216.25
Guangxi	590.54	572.32	549.06	309.2
Hainan	548.77	-	587.21	238.96
Chongqing	639.10	496.73	587.02	301.91
Sichuan	685.02	544.943	636.01	226.35
Guizhou	787.97	381.83	620.08	353.63
Yunnan	755.72	408.70	637.97	227.20
Xizhang	1032.00	510.02	466.36	359.45
Shaanxi	599.96	427.30	825.44	223.40
Gansu	789.49	565.12	605.96	239.35
Qinghai	-	521.95	476.93	-
Ningxia	777.49	578.97	545.07	335.89
Xinjiang	792.96	515.77	651.68	287.25

Source: Nanjing Agricultural University of China (2003).

Table 4.2. Export Costs at Exporting Countries (Unit: $/ Metric Ton)

	Rice	Wheat	Corn	Soybean
Argentina	257.58	74.32	80.25	80.56
Brazil	392.34	167.92	108.19	109.80
Australia	131.15	82.42	188.68	476.19
EU	309.52	79.64	54.14	127.79
Canada	-	86.56	80.80	140.60
Thailand	136.90	-	-	225.43
US	129.78	62.33	55.84	105.54
VN	39.66	-	26.32	157.60

Source: The Center for Agricultural Policy and Trade Studies (2001).

Transportation Costs

Transportation costs were divided into the following two parts:

1. China and other exporting countries' inland transportation costs from producing regions to consuming regions and to ports by railway.
2. Ocean shipping costs from exporting ports to importing countries ports.

For bulk agricultural commodities, railway is the main mode of transportation in most inland areas. Government monopoly manages the rail system in China. All prices are set and do not reflect the responses from demand and supply. The distance between all major producing regions and consuming regions, as well as the distance between producing regions to ports and consuming regions to ports, were also provided by NAU in China. The railway freight rate was obtained from the Chinese Transportation Department. So the railway transportation costs are calculated based on the freight rate and the distance. The ocean freight rates between all exporting and importing countries were provided by CAPTS. To simplify the transportation costs, all models assume no handling fee at ports.

Demand

China is divided into 31 consuming regions for rice, wheat, corn, and soybeans. Per-capita consumption of each crop in each consuming region, Table 4.3, was provided by NAU (2003).

The demand in each importing country, and the production costs and the available export supply of rice, wheat, corn, and soybeans in each exporting country, were obtained from CAPTS. Those were 2002 data.

Production and Export Supply

The current production level for each crop in each producing region was obtained from China Rural Economy Investigation Online Reports (2001).

The export supply of each exporting countries was obtained from the USDA Production, Supply, and Distribution (PS&D) online database by taking an average of the years 2002, 2003, and 2004.

Table 4.3. Consumption by Province in China (Unit: Metric Ton)

	Rice	Wheat	Corn	Soybean
Beijingc	585622.95	2046753.3	782037.52	448205.2
Tianjinc	488661.8	1407062.8	673456.99	430480
Shijiazh	1863062.8	8717932.5	10758196	1909083
Taiyuan	1266157.4	4333646.1	4674517.1	948997
Hohoot	1232473.2	2693215.9	2997779.1	693846.9
Shengyang	5159470.2	4393027.9	4368858.8	1282667
Changchun	3439317.1	2763660.9	3058210.6	806928.2
Harbin	5153084.1	3749885.5	3997670.2	1094884
Shanghaic	2587138.4	605072.66	386779.33	874040.5
Nanjing	11165614	5786269.6	5084126.2	2111829
Hangzhou	6614963.4	1576517.1	2999739.4	1380925
Hefei	8656662.1	4658130.4	5133291.7	1439964
Fuzhou	5938922.8	461923.49	2481973.1	1011536
Nanchang	7062509.3	536806.6	3555778.7	1175518
Jinan	3060324.6	13719788	12314977	2647055
Zhengzhou	3967804.5	13506035	15301009	2605814
Wuhan	9991370	3600939.6	4394651.2	1752325
Changsha	10404529	3772398.3	5393243.6	1835762
Guangzhou	12984354	1187167.9	4984045.4	2599702
Nanning	6372605.5	582576.99	3833735	1275747
Haikou	1181784.4	104451.88	574650.7	228732.4
Chongqingc	3648341.3	1821533	2480341.1	886412.6
Chengdu	9468507.2	4889077.8	7245490.2	2274253
Guiyang	4100849.5	2041903.3	3166756.8	993651.4
Kunming	5167837.3	2481483.2	3874641.1	1207564
Lasha	92401.824	334076.7	248770.32	73157.28
Xian	1125263	4526382.5	5303149.7	1032503
Lanzhou	887783.08	3384097.4	4199883	741061.5
Xining	195051.99	680678.9	735986.36	149057.4
Yinchuan	464132.65	797773.63	824812.73	161013.1
Urumqi	640100.18	2739731	2771441.6	552954.7

Source: Nanjing Agricultural University of China (2003).

CHAPTER 5. EMIPIRICAL RESULTS

Chapter 5 discusses the results of the analysis to optimize China's grain production and trade patterns. It also evaluates China's grain production and trade patterns on the basis of improvement of technology, changes in production costs, and changes in demand. This chapter is divided into two parts: (1) the base model which gives the optimal solution under current grain production and demand conditions, and (2) alternative model solutions based on the improvement of technology, changes in production costs, and changes in demand.

Base Model Solution

This section evaluates China's production of rice, wheat, corn, and soybeans under given production conditions and farm policies, and analyzes import and export patterns of the commodities.

General Production and Trade

In the model, the total amount of rice, wheat, corn, and soybeans produced are 133.65, 95, 118.89 and 11.50 million metric tons, respectively (Table 5.1). The total amounts of land used for rice, wheat, corn, and soybeans production are 20.40, 24.73, 25.22, and 7.15 million hectares, respectively. In the base model, China imports 1.31 million metric tons of rice, 8.89 million metric tons of wheat, 19.58 million metric tons of corn, and 25.13 million metric tons of soybeans. Rice is the leading grain crop at 37% of total grain production. Wheat, corn, and soybeans comprise 26%, 33%, and 3% of total grain production, respectively.

In the base model solution, China only needs to import a small amount of rice in order to fill in its total demand for rice. Because the production of wheat is not large enough to meet the total demand, China has to import about 9% of its total wheat supply. Corn production satisfies 92% of domestic demand with the remaining 8% to be imported, but at the same time, China is exporting 9.88 million metric tons of corn to other Asian importing countries. Soybean production accounts only for 31% of its total demand, so China imports a lot of soybeans to satisfy its domestic consumption, which could have a big effect on world soybean trade.

Table 5.1. Production, Consumption, and Trade in the Base Model
(Unit: Million Metric Tons)

Grain	Production	Consumption	Prod./Cons.	Export	Import
Rice	133.65	134.97	0.99	0.00	1.31
	(0.37)	(0.33)			(0.02)
Wheat	95.00	103.90	0.91	0.00	8.89
	(0.26)	(0.26)			(0.16)
Corn	118.89	128.60	0.92	9.88	19.58
	(0.33)	(0.32)			(0.36)
Soybean	11.50	36.63	0.31	0.00	25.13
	(0.03)	(0.09)			(0.46)
Total	359.04	404.10		9.88	54.91

Note: Numbers in parentheses are percentage of total for each column.

Optimal Land Utilization

When the optimal use in the base model is compared with current land utilization, the ratio of optimal to actual land utilization reveals the region's production advantages. When the ratio is greater than 1, it suggests that this region has a comparative advantage and should increase that particular crop's production, and vice versa.

Rice

Table 5.2 shows both the optimal land use and the actual land utilization for rice production in each producing region. Among the 15 producing regions in northern China, the ratios indicate that Heilongjiang and Xinjiang provinces should increase their land use to produce more rice than they do now while the rest of the producing regions in the northern part should reduce the land use for rice production. According to the optimal model, the southern provinces have an overall comparative advantage in producing rice since their average ratio is higher than northern regions; and the optimal land use for rice production in the southern regions accounts for 84% of China's total rice sown area. Of 16 southern provinces, the base model suggests that Hubei province should utilize a lot more land for rice production than its actual land utilization level while the remaining provinces should use less land.

Wheat

Table 5.3 shows both the optimal land use and the actual land utilization for wheat production in each producing region. The ratios indicate that five of 15 northern provinces should utilize more land to produce wheat than they actually use while the remaining 10 northern provinces should use less land for wheat production than they actually use. According to the base model, northern provinces have an overall comparative advantage in wheat production when compared with southern producing regions. The amount of land used for wheat production in northern regions accounts for 75% of the total wheat production area. Of the 16 southern provinces, the model implies that three provinces should increase their actual land utilization levels for wheat production while the remaining 13 provinces should use less land.

Table 5.2. Land Utilization for Rice in the Base Model (Unit: 1000 hectares)

Region	Province	Base	Actual	Ratio (1)/(2)
Northern	Heilongjiang	1728	1605.9	1.08
	Hebei	86.87	143.9	0.60
	Henan	234.9	459.6	0.51
	Tianjin	33.41	35.4	0.94
	Shandong	96.53	176.8	0.55
	Shaanxi	69.11	144.8	0.48
	Xinjiang	82.78	78.1	1.06
	Beijing	8.37	14.1	0.59
	Gansu	3.44	7.2	0.48
	Neimong	57.81	118.4	0.49
	Qinghai	-	-	-
	Ningxia	39.36	76.7	0.51
	Liaoning	257	489.7	0.52
	Shanxi	2.28	4.5	0.51
	Jilin	304.5	584.8	0.52
Subtotal		3004.36		
Southern	Hubei	4023.54	1995.3	2.02
	Anhui	1154.5	2236.7	0.52
	Jiangxi	1476.46	2832	0.52
	Hunan	1935	3896.1	0.50
	Chongqing	387.9	776.6	0.50
	Sichuan	1242	2123.8	0.58
	Jiangsu	1991.75	2203.5	0.90
	Shanghai	93.54	176.1	0.53
	Zhejiang	856.4	1598	0.54
	Fujian	649.54	1222.3	0.53
	Guangdong	1316.96	2467.4	0.53
	Hainan	195.21	367.5	0.53
	Guangxi	1178.1	2301.6	0.51
	Xizhang	0.55	1	0.55
	Yunnan	529	1073.6	0.49
	Guizhou	367.51	750.5	0.49
Subtotal		17397.96		
Total		20402.32		
Northern(%)		0.15		
Southern(%)		0.85		

Note: (1) refers to the data in the base model.
(2) refers to the data in the actual model.

Table 5.3. Land Utilization for Wheat in the Base Model (Unit: 1000 hectares)

Region	Province	Base(1)	Actual(2)	Ratio (1)/(2)
Northern	Heilongjiang	585.26	590.2	0.99
	Hebei	2450	2678.8	0.91
	Henan	5765.78	4922.3	1.17
	Tianjin	500	121.7	4.11
	Shandong	2764.69	3748.2	0.74
	Shaanxi	756.58	1537.2	0.49
	Xinjiang	1140.65	838.8	1.36
	Beijing	193.12	121.7	1.59
	Gansu	656.81	1192.2	0.55
	Neimong	386.03	617.1	0.63
	Qinghai	97.42	165.6	0.59
	Ningxia	149.94	292.6	0.51
	Liaoning	2194.39	117.6	18.66
	Shanxi	499.96	893.2	0.56
	Jilin	38.41	77.3	0.50
Subtotal		18179.04		
Southern	Hubei	486.76	845.1	0.58
	Anhui	1172.53	2126.4	0.55
	Jiangxi	28.46	51.4	0.55
	Hunan	57.77	118.6	0.49
	Chongqing	238.28	466.2	0.51
	Sichuan	810.69	1605	0.51
	Jiangsu	2076.3	1954.6	1.06
	Shanghai	208.96	57.1	3.66
	Zhejiang	102.61	177.6	0.58
	Fujian	22.34	38.7	0.58
	Guangdong	7.29	13.7	0.53
	Hainan	_	_	_
	Guangxi	9.57	19.5	0.49
	Xizhang	356.6	51.9	6.87
	Yunnan	329.15	645.6	0.51
	Guizhou	289.32	567.4	0.51
Subtotal		6196.63		
Total		24375.67		
Northern		0.75		
Southern		0.25		

Note: (1) refers to the data in the base model.
(2) refers to the data in the actual model.

Corn

Table 5.4 shows both the optimal land use and the actual land utilization for corn production in each producing region. The base model suggests that seven of the 15 northern provinces should utilize more land to produce corn than those actually used, while the remaining eight northern provinces should utilize less land for corn production. The northern regions constitute 77% of the total corn sown area, thus northern regions have a comparative advantage in corn production. Of the 16 southern provinces, the base model indicates that four provinces should utilize more land for corn production than their actual land utilization levels while the remaining 12 producing regions should only use about 70% of their actual utilization levels.

Soybeans

Table 5.5 shows both the optimal land use and the actual land utilization for soybean production in each producing region. The base model suggests that three provinces should utilize more land to produce soybeans than what is actually used, while the remaining 12 northern provinces should utilize less land for soybeans production. According to the base model, northern provinces have an overall comparative advantage in soybean production since northern regions use 73% of total soybean sown areas. Of the 16 southern provinces, the base model indicates that eight provinces should utilize more land for soybean production than their actual land utilization levels while the remaining eight producing regions should only use about 50% of their actual utilization levels.

Table 5.4. Land Utilization for Corn in the Base Model (Unit: 1000 hectares)

Region	Province	Base(1)	Actual(2)	Ratio (1)/(2)
Northern	Heilongjiang	3679.47	1801.3	2.04
	Hebei	2076.12	2478.6	0.84
	Henan	1827.94	2201.3	0.83
	Tianjin	124.7	131.2	0.95
	Shandong	3972.76	2413.9	1.65
	Shaanxi	872.89	1057	0.83
	Xinjiang	394.73	382.4	1.03
	Beijing	134.56	135.8	0.99
	Gansu	410.99	464.4	0.88
	Neimong	1155.92	1298.2	0.89
	Qinghai	4.76	2.1	2.27
	Ningxia	242.5	131.1	1.85
	Liaoning	1586.39	1422.5	1.12
	Shanxi	653.47	793.7	0.82
	Jilin	2376.76	2197.3	1.08
Subtotal		19513.96		
Southern	Hubei	329.4	424.1	0.78
	Anhui	767.27	485.9	1.58
	Jiangxi	19.05	25.3	0.75
	Hunan	224.31	278.5	0.81
	Chongqing	394.09	500.06	0.79
	Sichuan	1071.98	1235.5	0.87
	Jiangsu	717.21	423.2	1.69
	Shanghai	9.67	5.2	1.86
	Zhejiang	38.16	52.2	0.73
	Fujian	29.17	36.8	0.79
	Guangdong	147.86	189.3	0.78
	Hainan	13.92	18	0.77
	Guangxi	471.85	610.7	0.77
	Xizhang	5	3.2	1.56
	Yunnan	890.59	1129.7	0.79
	Guizhou	575.55	727.3	0.79
Subtotal		5705.08		
Total		25219.04		
Northern		0.77		
Southern		0.23		

Note: (1) refers to the data in the base model.
(2) refers to the data in the actual model.

Table 5.5. Land Utilization for Soybeans in the Base Model (Unit: 1000 hectares)

Region	Province	Base(1)	Actual(2)	Ratio (1)/(2)
Northern	Heilongjiang	1428.6	2868.3	0.50
	Hebei	201.3	423.7	0.48
	Henan	281.68	564.7	0.50
	Tianjin	14.5	34.6	0.42
	Shandong	529.82	458.2	1.16
	Shaanxi	1431.99	246.9	5.80
	Xinjiang	61.75	62.8	0.98
	Beijing	7.84	22.1	0.35
	Gansu	102.61	88.2	1.16
	Neimong	389.33	793.9	0.49
	Qinghai	_	_	_
	Ningxia	26.69	43.6	0.61
	Liaoning	137	301.9	0.45
	Shanxi	119.2	272.5	0.44
	Jilin	494.38	539	0.92
Subtotal		5226.69		
Southern	Hubei	109.8	224.8	0.49
	Anhui	357.89	682.2	0.52
	Jiangxi	175.22	152.5	1.15
	Hunan	101.82	205.8	0.49
	Chongqing	35.54	80.2	0.44
	Sichuan	181.24	169.6	1.07
	Jiangsu	276.43	249.2	1.11
	Shanghai	2.94	6.2	0.47
	Zhejiang	141.23	129.1	1.09
	Fujian	128	105.4	1.21
	Guangdong	113.8	96.9	1.17
	Hainan	10.37	9.5	1.09
	Guangxi	138.19	281.4	0.49
	Xizhang	0.44	0.5	0.88
	Yunnan	87.52	52	1.68
	Guizhou	70.5	141	0.50
Subtotal		1930.93		
Total		7157.62		
Northern		0.73		
Southern		0.27		

Note: (1) refers to the data in the base model.
(2) refers to the data in the actual model.

Optimal Flows of Grain

This section outlines the optimized flow pattern of rice, wheat, corn, and soybeans in the base model. In the base model, grains move from China's surplus regions to consuming regions and to ports. China also imports grain and oilseed from exporting countries through ports.

Rice

The optimal flows of rice are presented in Figure 5.1. In this model, most rice surplus regions are located in the southern and central regions of China. Central regions produce nearly 50% of total rice grown in China and ship their surplus to other deficit-consuming regions. Hubei is the largest producing region, and Jiangsu is in the second position. Both regions ship their surplus to nearby consuming regions. Liaoning and Heilongiang ship their surplus rice to nearby rice-deficit regions, mainly Neimong and northern capital areas where there is a large population. Shaanxi ships its surplus rice to the northwestern deficit-consuming regions of Neimong and Qinhai, and Sichuan ships its surplus rice to Tibet. The importing ports for rice in the base model are Guangzhou, which is located in the very southern part of China, and Tianjin, which is in the northern part of China. The imported rice is consumed mainly within the deficit regions around the ports. Generally, the imported amount is relatively small because China is still the largest rice-producing country, and it can almost realize self-sufficiency.

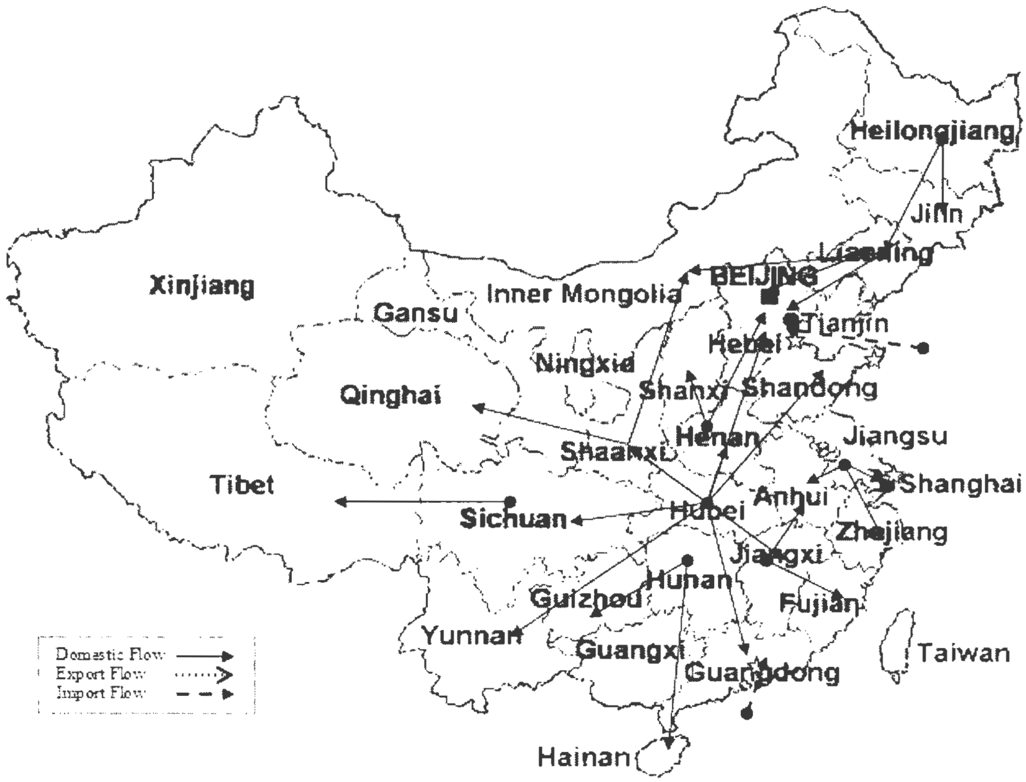

Figure 5.1. Optimal Flow of Rice in the Base Model.

Wheat

Henan is the largest wheat-producing region in China in the base model. It ships its surplus wheat to the western and central wheat-deficit regions, such as Shanxi, Ningxia, Shaanxi, Qinghai, etc., which are geographically closer to it than the southern regions (Figure 5.2). Shandong is the second-largest producing region, followed by Hebei. Xinjiang ships its surplus wheat to the western wheat-deficit regions of Gansu, Qinghai, etc. Because the total wheat production level is still lower than consumption, China has to import quite a bit of wheat from foreign countries, including the United States and Argentina, to meet its import demand, which accounts for almost 8% of China's total wheat consumption. The most frequently importing regions are coastal provinces. Guangzhou is one of the largest importing ports in southern China, and

Dalian and Tianjin are the major wheat-importing ports in the northern regions. As a result of this flow, most imported wheat via ports Dalian and Tianjin goes to supplement northern-consuming regions, and the wheat imported via Guangzhou flows to the southern-consuming regions of Guangxi, Hainan, and Yunnan due to lower transportation costs.

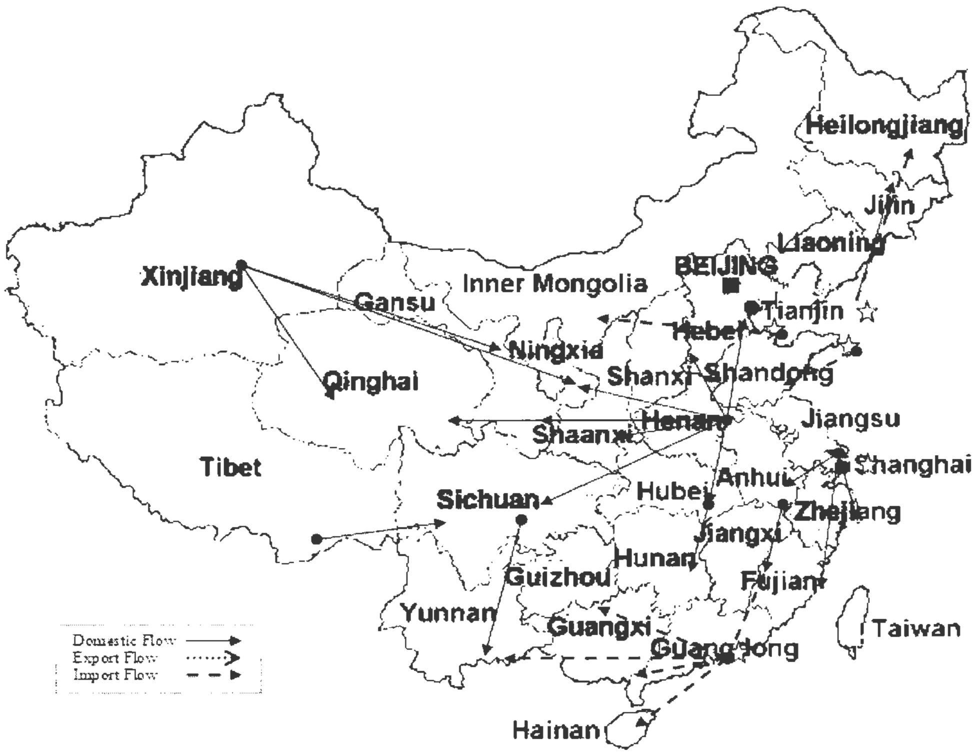

Figure 5.2. Optimal Flow of Wheat in the Base Model.

Corn

Corn flows overland, mainly from the northeastern corn-producing regions to central corn-deficit provinces of Hubei, Hebei, and Sichuan (Figure 5.3). The major corn-producing provinces are Shandong, Heilongjiang, and Jilin. Corn produced in Shandong supplements the need of the eastern corn deficit regions of Henan and Anhui while Jilin province supplements its neighboring provinces, Liaoning and Tianjin. In the south, Guangdong province ships almost all its corn to Guizhou, and from there, some corn is allowed to be transferred further to Yunnan and Sichuan to meet corn demand in the southwestern part of China. China exports some corn to Japan in the base model through the Dalian port. China imports a lot of corn from the United States. Shanghai and Guangzhou are two major importing ports. The majority of corn imported via these ports is shipped to nearby eastern and southern coastal deficit regions of Zhejiang, Jiangsu, Guangxi, Jiangxi, Fujian, and Hunan.

Figure 5.3. Optimal Flow of Corn in the Base Model.

Soybeans

The major soybean-producing regions are located in the northern plain. Heilongjiang and Shaanxi are the largest producing regions. Heilongjiang ships its soybean surplus to neighboring northern-consuming regions of Jilin and Liaoning while Shaanxi ships its soybeans to inland deficit regions of Qinhai and Sichuan (Figure 5.4). Neimong and Henan also produce a lot of soybeans, and they ship their surplus to western inland areas of Xinjiang, Qinhai, Tibet, and Sichuan. Soybeans are in great demand in China now, so a large amount of soybeans are imported from the United States and move to inland consuming regions in northern China, mainly through the ports of Tianjin and Qingdao, while Guangzhou and Shanghai are major import ports for the consuming regions in southern China. The Tianjin port ships the imported soybeans to northern and central deficit regions while Guangzhou ships the imported soybeans to southern regions, and Shanghai covers mainly eastern-coastal deficit areas.

Export and Import Pattern

In this model, China produces 133.65 million metric tons of rice (Table 5.6). The base model shows that China has a comparative advantage in rice production and can nearly realize its self-sufficiency. In the base model solution, China is a rice importer because demand is huge and changing diets require more high-quality rice. Rice is imported primarily through the Guangzhou port since, geographically, it is closer to the major southern Asian rice exporters than other ports included in this model.

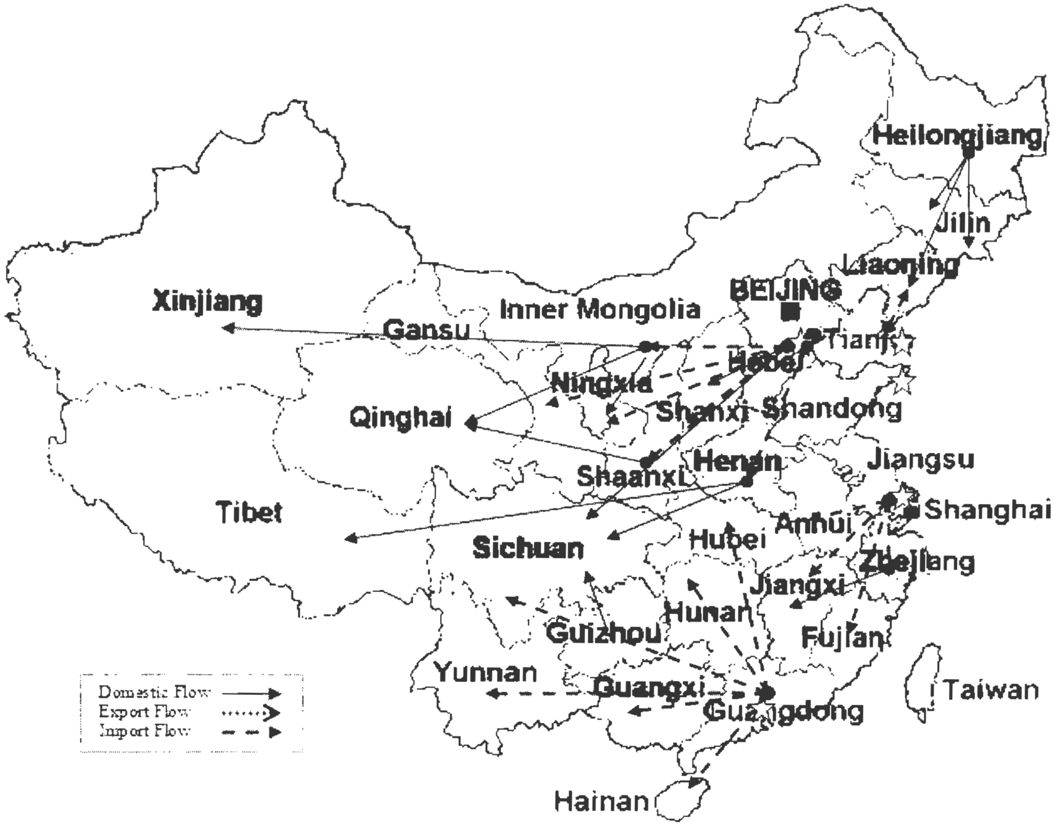

Figure 5.4. Optimal Flow of Soybeans in the Base Model.

Table 5.6. China's Exports and Imports by Ports in the Base Model (Unit: Million Metric Tons)

		Rice	Wheat	Corn	Soybean
Dalian	Export	0	0	9.88	0
	Import	1.31	3.2	0	0
Qingdao	Export	0	0	0	0
	Import	0	0	0	1.44
Shanghai	Export	0	0	0	0
	Import	0	0	7.27	6.65
Guangzhou	Export	0	0	0	0
	Import	0.96	3.28	12.32	8.79
Tianjin	Export	0	0	0	0
	Import	0.35	2.42	0	7.38

The base model shows China has a comparative disadvantage in wheat production and has to import 8.89 million metric tons of wheat. The majority of wheat imports enter China through ports at Dalian, Guangzhou, and Tianjin. Northern ports import more wheat than southern ports as a result of lower transportation costs and greater demand for wheat in those regions.

According to the base model, China exports 9.88 million metric tons of corn from northern corn-producing regions, while at the same time, imports 19.58 million metric tons of corn for its southern provinces. The reason for this dual export/import is that the cost of China's inland transportation for moving corn from its northern producing provinces to its southern corn-deficit regions is higher than the costs of importing. All corn exports move through port Dalian. The majority of imported corn moves through ports at Shanghai and Guangzhou which are located in southern China.

China imports 25.13 million metric tons of soybeans in the base model. Most of the soybeans imported enter into China through Shanghai, Guangzhou, and Tianjin ports which are located in the eastern-coastal, southern, and northern of China, respectively. Therefore, when the three ports ship the imported soybeans to nearby consuming- regions, the domestic China soybeans demand can be met.

In the base model solution, Vietnam is the sole rice exporter for China (Table 5.7). Although Argentina and Thailand are close competitors, it seems that they are not able to overtake Vietnam since both production and transportation costs are much lower in Vietnam.

In the base model solution, the United States has the largest export proportion of wheat to China, followed by Argentina. Other countries do not export wheat to China due to their higher costs. The United States ranks first among seven countries exporting wheat to China, but Argentina is very competitive. In the base model, we assume a fair free-trade environment, which means no agricultural subsidies are considered in the model. This also means the United States is going to be more competitive in exporting wheat if there is government support.

In the base model solution, the United States is the sole exporter of corn to China. Regarding the soybean market in China in the base model, the United States enjoys the biggest share, too. China imported its 55% of soybeans from the United States, and imports have tended to increase in recent years. The only competitor in the model is Argentina, which has a share close to the level of the United States.

Table 5.7. Chinese Grain Imports from Exporting Countries
(Unit: Million Metric Tons)

Exporting Countries	Rice	Wheat	Corn	Soybeans
United States	0	5.61	19.58	17.61
Argentina	0	3.28	0	14.18
Australia	0	0	0	0
Brazil	0	0	0	0
Canada	0	0	0	0
EU	0	0	0	0
VN	1.31	0	0	0
Thailand	0	0	0	0

According to the base model, only Vietnam exports rice to other Asian importing countries, including China (Table 5.8). Other rice exporting countries do not export rice to Asian regions since the export cost of rice in Vietnam is much lower. But if China specializes in rice production according to its comparative advantage, it might have the potential to be an exporter to Asia's rice market due to China's geographic advantage.

Table 5.8. Rice Export to Asia's Importing Regions (Unit: Million Metric Tons)

Regions	Japan	South Korea	Philippine	Taiwan	Malaysia	OSAM
China	0	0	0	0	0	0
U.S	0	0	0	0	0	0
Canada	0	0	0	0	0	0
Australia	0	0	0	0	0	0
Argentina	0	0	0	0	0	0
Brazil	0	0	0	0	0	0
Thailand	0	0	0	0	0	0
VN	0.82	0.089	0.68	0	0.65	0.84
EU	0	0	0	0	0	0

Note: OSAM refers to other south Asian importing countries that are not listed in the base model.

The United States is the largest wheat exporter to other Asian importing countries in the base model (Table 5.9). Australia is the second largest wheat exporter in the model. The United States enjoys 69% of total market share in Asia, showing that it has an overall advantage in exporting wheat to Asian markets.

Table 5.9. Wheat Export to Asia's Importing Regions (Unit: 1000 Metric Tons)

Regions	Japan	South Korea	Philippine	Taiwan	Malaysia	OSAM
U.S	4.06	3.66	0	1.08	0	3.81
Canada	0	0	0	0	0	0
Australia	1.4	0	3.2	0	1.17	0
Argentina	0	0	0	0	0	0
Brazil	0	0	0	0	0	0
Thailand	0	0	0	0	0	0
VN	0	0	0	0	0	0
EU	0	0	0	0	0	0

Only the United States, Vietnam, and EU are corn exporters in the base model, and the United States is the largest supplier to Asian importing countries other than China, with 96% total market share (Table 5.10). The United States exports corn to every Asian country included in this study, indicating that it has a paramount edge in corn exports to Asia. The EU exports about 1 million metric tons of corn, and the amount that Vietnam exports is far below that of the EU, thus even the combination of the exports from both the EU and Vietnam is too small to have any effect on the United States.

Table 5.10. Corn Exports to Asia's Importing Regions (Units: 1000 Metric Tons)

Regions	Japan	South Korea	Philippine	Taiwan	Malaysia	OSAM
U.S	6.47	8.12	0.48	4.93	2.29	1.84
Canada	0	0	0	0	0	0
Australia	0	0	0	0	0	0
Argentina	0	0	0	0	0	0
Brazil	0	0	0	0	0	0
Thailand	0	0	0	0	0	0
VN	0	0	0	0	0.028	0
EU	0	0	0	0	0	0.88

The United States is also the sole soybean exporter to Asia in the base model (Table 5.11). Although Brazil is another big exporter, it cannot export more than the United States because both the production and transportation costs in Brazil are much higher than those in the United States.

Generally, the base model solution indicates that the United States has a comparative advantage in exporting wheat, corn, and soybeans to Asian markets, and the United States should specialize in producing them to minimize total costs.

Alternative Model Solutions

In this section, the optimal solution in the base model is changed to reflect variations in constraints and exogenous variables. Variables examined are production costs, yield increase resulting from improved farm technologies, the Chinese policy of self-sufficiency, and changes in demand. Optimal solutions for seven alternative models are compared to the base model solutions. Model 2 examines policy impacts of China's self-sufficiency on the production and trade of agricultural commodities by stopping all imports. Models 3 and 4 examine the effects of different demand levels of corn and soybeans on the production and trade of agricultural commodities. Model 5 combines the demand change both in corn and soybean to examine the total effects of them on production and trade. Model 6 and Model 7 examine the effects of different increased yield levels on production and trade. Model 8 examines the impact of decreasing production costs on grain production and trade patterns.

Table 5.11. Soybean Export to Asia's Importing Regions (Unit: Million Metric Tons)

Regions	Japan	South Korea	Philippine	Taiwan	Malaysia	OSAM
U.S	4.69	1.37	0.26	2.28	0.56	0
Canada	0	0	0	0	0	0
Australia	0	0	0	0	0	0
Argentina	0	0	0	0	0	0
Brazil	0	0	0	0	0	0
Thailand	0	0	0	0	0	0
VN	0	0	0	0	0	0
EU	0	0	0	0	0	0

Self-Sufficiency Policy

Model 2 evaluates China's self-sufficiency policy. The optimal solution suggests that it is possible that China can fulfill its goal of self-sufficiency through reorganizing its resources allocation. However, China's total production and transportation costs will increase by $334 million. China's self-sufficiency policy also affects its neighboring countries. The importing costs of Asian importing countries decrease from $6,932 to $6,593 million (Table 5.12). The results indicate that China may achieve its self-sufficiency by experiencing higher production and transportation costs, and at the same time, other Asian importing countries may benefit from China's self-sufficiency since a lot more grains will be available in the global market, and they can choose the cheapest one for them. Thus, it is highly likely that China would not pursue the full self-sufficiency policy.

Table 5.12. Base Model and Self-Sufficiency Model 2 (Unit: Million U.S Dollars)

	Base model	Self-sufficiency
Total cost	50,704	51,038
China's production cost	35,555	42,633
China's shipping cost	1,366	1,812
China's importing cost	6,851	0
Other importing countries' cost	6,932	6,593

Demand Change

Models 3, 4, and 5 evaluate the impact of changes in demand on China's grain production and international trade patterns. All these three models suggest that China's production, export, and import of rice and wheat will remain the same as those in the base model since the demand for rice and wheat is assumed to be the same (Table 5.13). For corn and soybeans, the production and trade patterns change a lot. In Model 3, demand for soybeans is allowed to increase by 45%, ceteris paribus. As a result of the change in demand, soybean production increases by 11.7 million metric tons, and soybean imports increase by 4.78 million metric tons. In Model 4, corn demand is assumed to increase by 15%. According to the projected result, a ceteris paribus 15% increase in corn demand would induce the production to increase by 18.11 million metric tons, and corn imports to increase by 3.78 million metric tons.

At the same time, China is able to increase corn exports by 2.59 million tons. Model 5 measures the effects of the increased demand for both soybeans and corn.

This model shows that the effect on corn exhibits the same pattern as in Model 4 while soybean production increases only by 4.95 million tons, much less than the level of Model 3. As a result, soybeans imports increase by 11.54 million, more than the level in Model 3. This happens due to the fact that the total arable land is limited. Since China has a comparative disadvantage in producing soybeans, preference is given to produce corn.

Models 3, 4, and 5 suggest that, with an increase in the demand only for soybeans or corn, China tends to produce more of them instead of importing more.

When both soybean and corn demands increase at the same time, China will reallocate its resources to produce more corn while import more soybeans. Overall, China is a potentially large net importer of soybeans in the global market.

Table 5.13. Optimal Production and Trade in the Base Model and Alternative Models 3, 4, and 5 (Unit: Million Metric Tons)

		Base Model	Model 3 (45% increases in soybean demand)	Model 4 (15% increases in corn demand)	Model 5 (Increases in both soybeans and corn demand)
Production	Rice	133.65	133.65	133.65	133.65
	Wheat	95	95	95	95
	Corn	118.89	118.89	137	137
	Soybeans	11.49	23.19	11.49	16.44
Export	Rice	0	0	0	0
	Wheat	0	0	0	0
	Corn	9.88	9.88	12.47	12.47
	Soybeans	0	0	0	0
Import	Rice	1.31	1.31	1.31	1.31
	Wheat	8.89	8.89	8.89	8.89
	Corn	19.58	19.58	23.36	23.36
	Soybeans	25.13	29.91	25.13	36.67

Yield Increasing

Models 6 and 7 evaluate the impact of yield changes on production and trade patterns in China. As yield increases by 10% in Model 6 and by 20% in Model 7, the rice pattern is not affected (Table 5.14). Wheat production increases by 8% in Model 6 and 9.5% in Model 7. The increases in wheat production lead to decreases in wheat imports in both models. China is turning from a net wheat importer to a small exporter in the models. Corn production increases significantly in Models 6 and 7, about 13 and 27 million metric tons more than the base model. A large part of the increases in corn production flows to the export market, making the export doubled in both models. China's corn imports drop by 1.7 million in Model 6, and drop by 12.25 million in Model 7. Soybean production increases by about 43% in both models. Correspondingly, soybean imports decrease by about 20%.

Models 6 and 7 indicate that, with increased yield as a result of improvements in farming technologies, production and trade patterns for wheat, corn, and soybeans will be affected significantly, but rice industry will remain unchanged. China will produce more agricultural commodities and supply them to its consumers, at the same time, reduce its imports, making China much less dependent on other countries.

Decreasing Production Costs

Model 8 evaluates the impact of a 20% decrease in production costs on grain production and trade pattern in China. Table 5.15 shows the optimal production and trade pattern of the base model compared to alternative Model 8.

Table 5.14. Optimal Production and Trade in the Base Model and Alternative Models 6 And 7 (Unit: Million Metric Tons)

		Base model	Model 6 (10% yield increase)	Model 7 (20% yield increase)
Production	Rice	133.65	133.65	133.65
	Wheat	95	102.89	104.06
	Corn	118.89	131.85	145.73
	Soybeans	11.49	16.41	17.17
Export	Rice	0	0	0
	Wheat	0	1.08	1.43
	Corn	9.88	21.13	24.46
	Soybeans	0	0	0
Import	Rice	1.31	1.31	1.31
	Wheat	8.89	2.09	1.26
	Corn	19.58	17.88	7.33
	Soybeans	25.13	20.22	19.44

Table 5.15. Optical Production and Trade in the Base Model and Alternative Model 8 (Unit: Million MT)

		Base model	Model 8 (20% production costs decreased)
Production	Rice	133.65	133.65
	Wheat	95	104.06
	Corn	118.89	146.46
	Soybeans	11.49	16.42
Export	Rice	0	0
	Wheat	0	3.62
	Corn	9.88	29.39
	Soybeans	0	0
Import	Rice	1.31	1.31
	Wheat	8.89	3.45
	Corn	19.58	11.53
	Soybeans	25.13	20.20

As production costs decrease, China's rice output remains constant, but the other three grains' production and exports increase while imports decrease. Corn is the biggest player in the changing scenarios again, followed by wheat and soybeans.

Corn production increases by 23%, and 71% of the increased corn flow to exporting markets, making exports increase nearly threefold. This would have a big impact on the global market.

CHAPTER 6. SUMMARY AND CONCLUSIONS

China is a wheat and soybean importer, and a corn exporter to Asian countries in recent years. Historically, China has tried to maximize its grain and oilseed production given its resources endowment. China has emphasized self-sufficiency in grain production and minimized dependence on imports from others. This policy, nevertheless, has been expensive for Chinese consumers, and caused inefficient use of resources in China. If the Chinese government optimizes its agricultural production based on the country's resources endowment and farming technology, China could substantially increase its grain production and lower production costs. China could be a major exporter of grain (corn and rice) to Asian markets. For the United States, Asia is a large and fast growing market for agricultural commodities. This implies that China and the United States may be potential competitors in the Asian market.

The objective of this study is to identify the optimal production and international trade patterns for rice, wheat, corn, and soybeans in China. The followings are specific objectives of this study:

1. To identity the optimal production and trade pattern of major agricultural commodities (rice, wheat, corn, and soybeans) on the basis of China's resources endowment.
2. To optimize domestic production in different producing regions and distribution systems of the commodities and import/export flow.
3. To predict Chinese agricultural production and trade patterns and their impacts on the world agricultural industry under different scenarios.

4. To evaluate China's and the United States' competitiveness in exporting major grains to Asian markets.

Research is conducted by developing a spatial equilibrium model based on linear programming. The model optimizes grain production within China and its international trade relationships with Asian importing regions and other potential export competitors.

Summary

In the optimal model, China produces 133.65, 95, 118.9, and 11.50 million metric tons of rice, wheat, corn, and soybeans, respectively. China's rice production in the base model is close to the actual production level, but the production levels of wheat, corn, and soybeans are less than the current level. This is especially true for wheat and soybeans, indicating that China has a comparative disadvantage in producing both wheat and soybeans.

This study shows that the northern regions of China have a comparative advantage in producing wheat, corn, and soybeans, and that they distribute their surplus mainly to the northern and central regions. The southern regions have a comparative advantage in producing rice, and they satisfy most of the nation's needs. In regard to regional competitiveness in producing grains, Hubei, Heilongjiang, and Xinjiang have a comparative advantage in producing rice; Liaoning, Tianjin, Henan, Xinjiang, and Jiangsu have a comparative advantage in producing wheat; Heilongjiang, Qinhai, Shandong, Anhui, Ningxia, Jiangsu, Jilin, and Xinjiang have a comparative advantage in producing corn; Shaanxi, Shandong, Gansu, Sichuan, Jiangxi, Zhejiang, Fujian, and Guangdong have a comparative advantage in producing soybeans.

In the base model, the United States enjoys the largest share in China's agricultural product imports. U.S. exports of agricultural commodities to China account for at least half of China's total major grain imports except for rice. Vietnam has a comparative advantage in exporting rice to China, and it phrases out all other competitors in the Asian rice market according to the model. But Argentina has an advantage in exporting wheat and soybeans to China, and it could become a major competitor to the United States in the Asian markets. The United States should focus on producing and exporting corn, followed by wheat and soybeans to the Asian countries. The major China's wheat importing regions are the northern provinces, and the major soybean importing regions are the southern provinces in the base model.

In regard to grain trade in other Asian importing countries in the base model, the United States has overwhelming competitiveness except in the rice market.

China does not export much according to the optimal solution. It is able to export some corn to Asian neighboring regions, but it also imports a lot to meet domestic demand, mainly because inland transportation costs are higher than import costs.

The study indicates that China can reach self-sufficiency through reallocating its resources for rice, wheat, corn, and soybean production. However, the production and transportation costs are much higher than those in the base case. This implies China can be better off with international trade.

If China's demands for corn and soybeans increase individually, both the production and imports of them would increase, but production will increase more than imports. If the demands for both crops increase simultaneously, corn production would continue to have a fast growth rate while soybeans imports would increase at a much faster rate than before.

If yield increases by 10% or 20%, the production of wheat, corn and soybeans would increase significantly except for rice. As a result, the imports of grain would decrease a lot. If production costs decrease by 20%, rice production and trade pattern would remain the same, but the production and exports of wheat, corn and soybeans would increase greatly with decreasing imports.

Conclusions

The following conclusions are drawn based on the discussions above:

1. Given its resources endowments and demand conditions, China could achieve its self-sufficiency objective without participating in international trade. However, it would be expensive for consumers and cause inefficient use of resources. So China should participate in free trade of agricultural commodities.
2. Under a free–trade environment, China could become a large importer of wheat and soybeans while it may be able to export some amount of corn to Asian markets.
3. The United States has advantages in exporting its wheat, corn, and soybeans to China, but it may have to compete with other countries, such as Argentina, in exporting wheat and soybeans. In addition, the United States may face competition from China in exporting rice and corn to other Asian importing countries. Overall, the United States is the largest exporter of agricultural commodities to Asian markets.

Need for Further Study

Because the Chinese government has controlled grain prices for a long time, price information may not reflect the true relationship between quantity supplied and quantity demanded. No time series price data are available to estimate this relationship. In this study, the demand for grain in consuming regions and importing regions and the supply of grain in producing provinces and exporting countries were assumed to be exogenous rather than price dependent. If China liberates its grain markets, it can be expected that price information will begin to reflect the real demand and supply, making quadratic modeling feasible. Further studies using quadratic programming models, which assume that the demand and supply are endogenous, may better identify changes in optimal grain production and trade pattern under alternative scenarios.

In addition, the minimum production level for each grain in each producing region is set almost at the same level. But this may not reflect the actual production situation. Also, crop rotation needs are not considered in this analysis. Further studies could use different limit levels for individual producing region rather than one same level.

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