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Recent Changes in Chinese and India's Agriculture and Implications on Global Trade of Agricultural Commodities

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ABSTRACT

The objective of this study is to evaluate the changes in import and export demand in China and India on the United States and global agriculture in 2020. A spatial equilibrium model is developed to optimize production and trade in China, India, and other major importing and exporting regions in the world. This research focuses on four primary crops: wheat, corn, rice and soybeans. In the model, China and India are divided into 31 and 14 regions, respectively. The model also includes five exporting countries and ten importing countries/regions.

The results indicate that India will be able to stay largely self-sufficient in 2020 and China will increase its soybean and corn imports to meet rising domestic demand. The research also gives perspectives on production and trade in the United States and other major exporting and importing countries.

INTRODUCTION

The twenty-first century has brought about a changing landscape in global agriculture. New challenges are arising in order to feed the growing world population on the same amount of arable acres. In the past fifty years, technology has made enormous strides in improving yields, which has allowed for the record harvests evident in recent years. However, technology is increasing at a decreasing rate and whether technology will be able to keep up with increasing demand remains unknown. Additionally, arable land is being taking out of production to accommodate growing populations and urbanization. These conditions have led to questions of how agriculture will have to continue to change to meet this challenge and how this will affect competitiveness in global trade.

Another changing aspect is the countries that are emerging as major players in global agricultural markets. Over the past twenty years, developing countries are playing increasingly important roles, along with developed nations that have dominated the trade in the past, such as the United States, the European Union, and Japan. Asia is one region whose developing nations are emerging in global agricultural trade.

China and India are the two largest countries in the world in terms, of population with a sound economic growth, for the last two decades. Because of their sheer size, these two countries dominate trade in this region. In land area, China is only slightly smaller than the United States and India is about a third of the size of China (The World Factbook, 2009). Currently, these two nations' populations are ranked first and second in the world, with China's population measured at 1.3 billion and India's at 1.1 billion (The World Factbook, 2009). As shown in figure 1, population growth in these two countries is 14 and 32 percent, respectively, since 1990 (Population Division Department of Economic and Social Affairs). Population growth is expected to increase at a decreasing rate for China, while India is projected to surpass China in total population by 2045 (Population Division Department of Economic and Social Affairs).

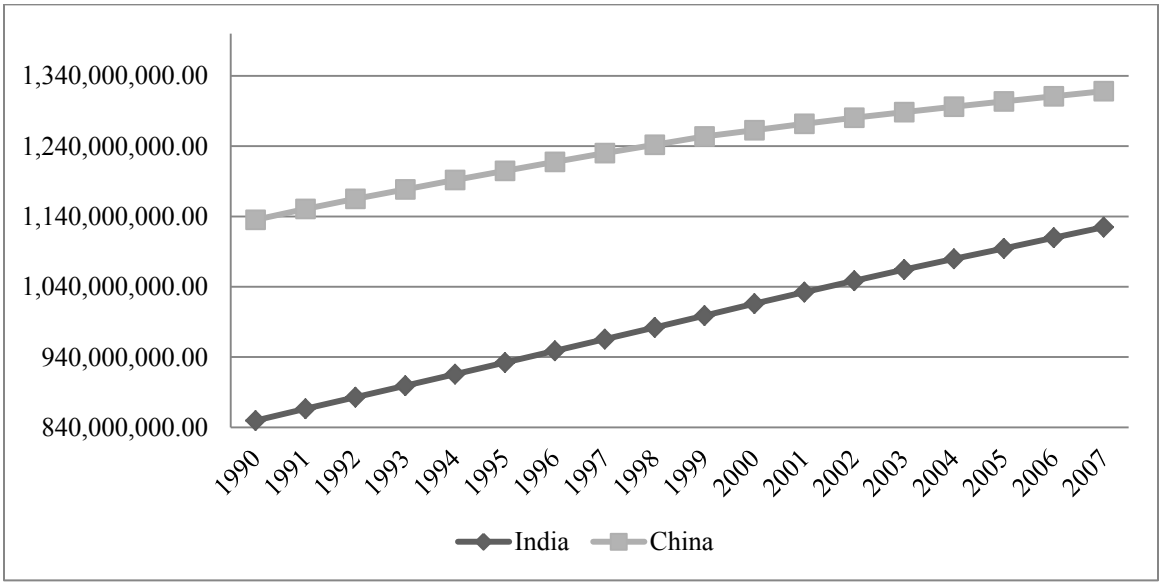

Figure 1. Total Populations of China and India 1990-2007 (The World Bank Group, 2009)

Another feature of these two nations that sets them apart is their rapid economic growth. Figure 2 depicts the historical trend of per capita Gross National Income (GNI) in China and India. Since 2000, China has seen an average growth rate of 10 percent in Gross Domestic Product (GDP), while India has been able to maintain an average of 7.1 percent (The World Bank Group, 2009). This growth has led to China and India being ranked as third and fifth in the world for GDP, respectively (World Fact Book, 2009). While the current economic crisis has affected these two economies, they have been able to retain their economic growth, just at a slower pace than previously. The United States Department of Agriculture (USDA) predicts an average growth rate of 7.6 percent for China and 7.5 percent for India, for the 2009 to 2018 time period (Economic Research Service, 2009).

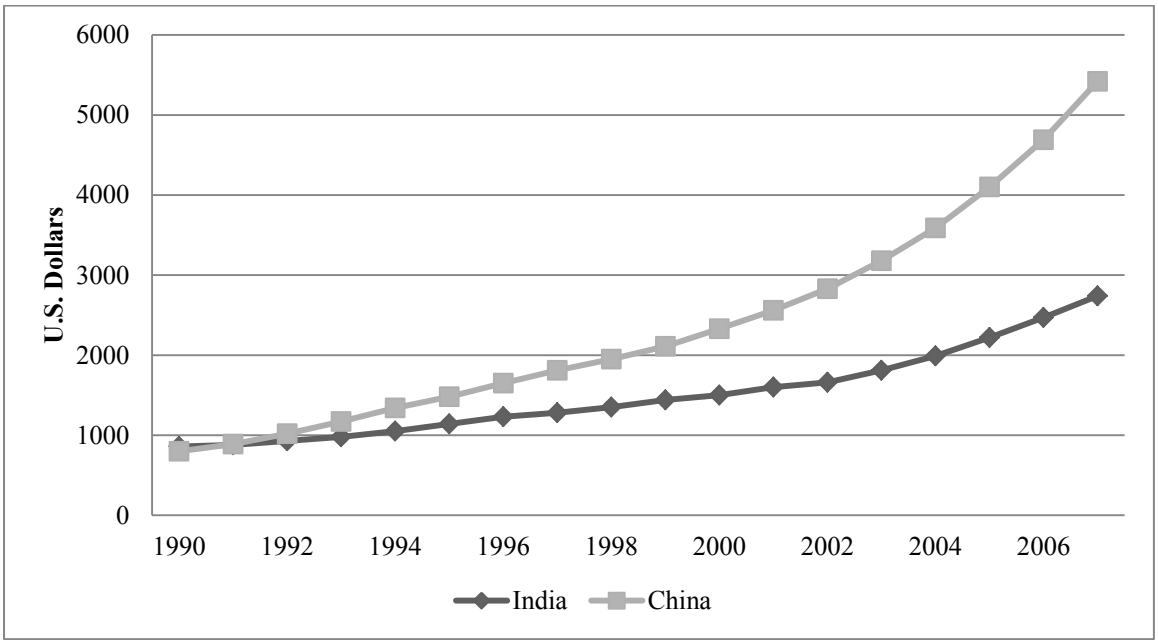

Figure 2. Gross National Income Per Capita for China and India 1990-2007 (The World Bank Group, 2009)

As consumers, the Chinese are exhibiting signs of this economic growth. Their preferences now include more expensive foodstuffs, such as; fruits, vegetables, and meats, and less food grains such as wheat and rice. These changing preferences mean the country will be demanding more of certain kinds of grains, such as those used for feedstuffs to meet the demand of the growing livestock sector. However, grain production is expected to decrease as more land and resources are used to accommodate growing urban areas.

Indian consumers also include more fruit and vegetables in their diet. However, because of cultural differences in comparison with China, India has not seen a large increase in meat consumption, though the livestock sector is still increasing to meet the growing demand for dairy products. The resulting increases in grain demand will likely result in increase in field grain consumption in India.

The purpose of this study is to examine the expected changes in import and export demand of Chinese and Indian grains and oilseed and the effects of these changes on world agriculture. More specifically, the study will look at the changes in import and export demand in these two countries and how that will impact agriculture in the United States and other major importing and exporting countries.

Specific objectives are as follows:

1. To predict Chinese and Indian crop production and trade flows and their impacts on world agriculture under different scenarios.
2. To evaluate the competiveness of the United States and other major exporting countries in exporting grains to China, India, and other major importing countries.

To conduct the study a global multi-commodity optimization model based on a mathematical programming algorithm is developed. This model will focus on the imports and exports of wheat, corn, rice, and soybeans in 2020. To determine trade flows in 2020, crop production and consumption are projected from historical data, and incorporated into the model.

Many studies have been completed to evaluate how increasing income and population growth will affect import demand for China and India. Lu and Kersten (2006) evaluated whether rising grain production would be able to keep up with growing consumption needs through the use of a regionalized multi-market model, China's Agricultural Regional Market Equilibrium Model (CARMEM), which was based on the SWOMPSIM modeling framework. However, they did not extend the research to determine import or exports. Wang and Davis (1998) used a time series econometric approach to determine supply and demand of grain and then used a grain balance sheet that accounted for wastage and stocks to determine trade. They determined that China would need to import 32 million tons by 2010 to satisfy rising domestic demand (Wang and Davis, 1998). Carter and Zhong (1991) use regression analysis to analyze grain supply and demand. They found that by the late 1990s China would have to import over 20 percent of its grain to meet domestic consumption needs. In the case of India, less research has been conducted. A study by Mohanty et al. (1998) evaluated grain demand in India using an income elasticity approach as a result of changing consumer preferences and production. The results determined that India would become an importing country of wheat and corn (Mohanty et. al., 1998). While these studies evaluated structural changes and the impact on grain demand, they did not analyze how growing import demand would affect world agriculture and global grain trade.

Koo and Taylor (2009) used a spatial equilibrium model to study the impact of changes in the Chinese grain and oilseed industries in 2020 on world agriculture. This study focuses on corn, wheat, rice, and soybeans. Production was determined using historical production data for 2005 and forecasted to 2020 using an econometric approach. Four scenarios were analyzed incorporating 5, 10, 15, and 20 percent increases in yields in 2020. Their results concluded that under a 5 percent increase in yield, China would import corn, soybeans, and wheat. Under the second scenario of a 10 percent increase in yield, there will be significant decrease in corn imports and some in soybeans. Wheat imports

will remain steady and China would be self-sufficient in rice. In the case of a 20 percent increase in yields, China will no longer need to import rice or corn; however, China will still need to import soybeans and wheat. In addition, the research goes further to explain under each scenario what the impact will be to the other major importing/exporting countries. Their research is very similar to the focus of this study; however, this study is extended to include India, which is also expected to have a significant impact on global grain trade.

BACKGROUND INFORMATION ON CHINA AND INDIA

Global agriculture is experiencing a number of new challenges. These new challenges include the changing role of developing countries, increasing biofuel production, climate change, and increasing food security issues. In addition, technology, which has fueled production growth through increased yields, is increasing at a decreasing rate and there are increasingly less resources available to be used in agriculture production. The global community is faced with how to manage these challenges in an environment where there are escalating demands on production.

China

The evolution of Chinese agriculture began with government reforms in the late 1970s. These reforms began the process of removing the communal farm system and giving production decisions back to individual producers. Producers were now able to sell their products in a free market system, once they had fulfilled quota obligations. The government also implemented processes that helped to initiate the use of technology that was being used abroad. This allowed for vast technological gains, which greatly improved yields and thus production. Also, this began the process of the Chinese beginning its own research, which has allowed the nation to continue to expand its yield potential, Figure 3 shows the historical growth of yields since 1980 for wheat, corn, rice and soybeans. Since these reforms, agricultural production and exports in China have tripled (Food and Agriculture Organization, 2003).

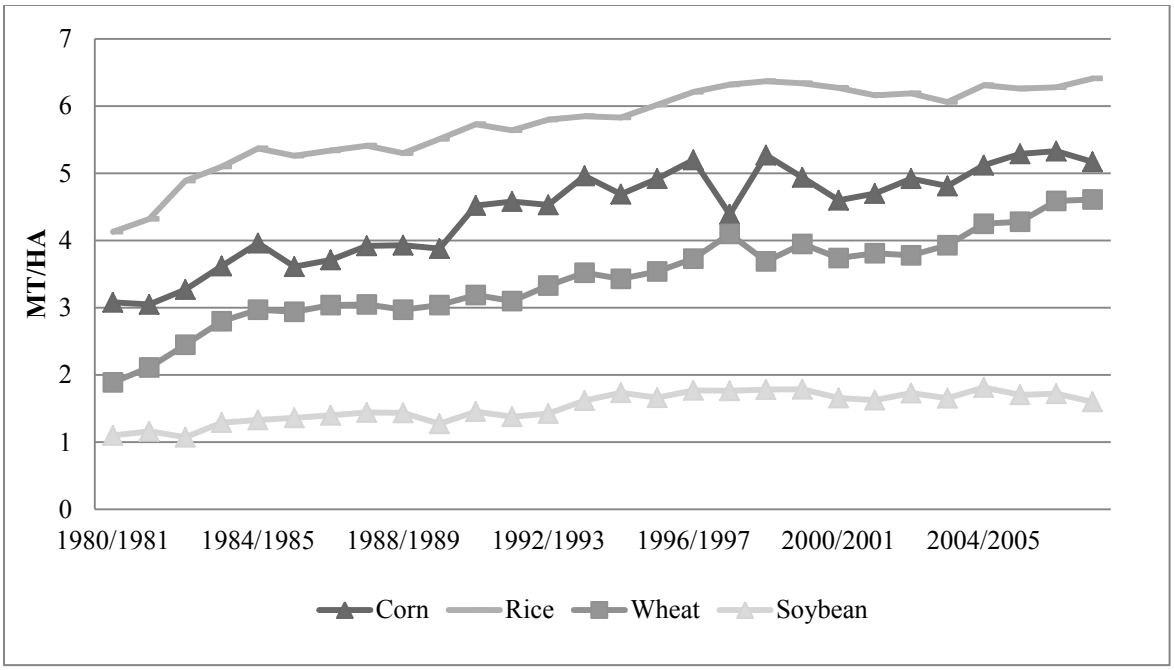

Figure 3. Historical Yield Data from China 1980/1981-2008/2009 (Foreign Agricultural Service, 2009)

These reforms also allowed individuals who were not interested in agricultural production to begin careers in non-agriculture production fields by creating township and village enterprises. The possibility of greater employment opportunities and reforms that allowed people to choose different careers led to people moving into urban areas. At the time of the reforms, only 17.9 percent of the population lived in urban areas; by 2006, that percentage had increased to 44.9 percent (China Statistical Yearbook 2008). As urban areas swell, urban populations demand a larger amount of resources. More water is used to fulfill the growing needs of urban consumers. Also, as cities expand, land is taken out of production to accommodate the growing urban housing and infrastructure needs.

Since the reforms, China's economy has seen great prosperity. It has been reported that Chinese per capita GDP has increased by nine times and their value of exports by ten (Food and Agriculture Organization, 2003). As mentioned, as Chinese consumers experience this growth in income, they consume more meat, vegetables, fruits, and oils. Figure 4 shows the changes in domestic consumption of grains and meats since the time of the reforms. While increases in rice and wheat consumption remain high, they are not increasing at the same rate as corn and soybeans. Corn and soybeans show a sharp increase since the reforms. In the category of meats, there is a sharp increase in swine consumption, though beef and veal and broiler consumption is also increasing at a lesser rate.

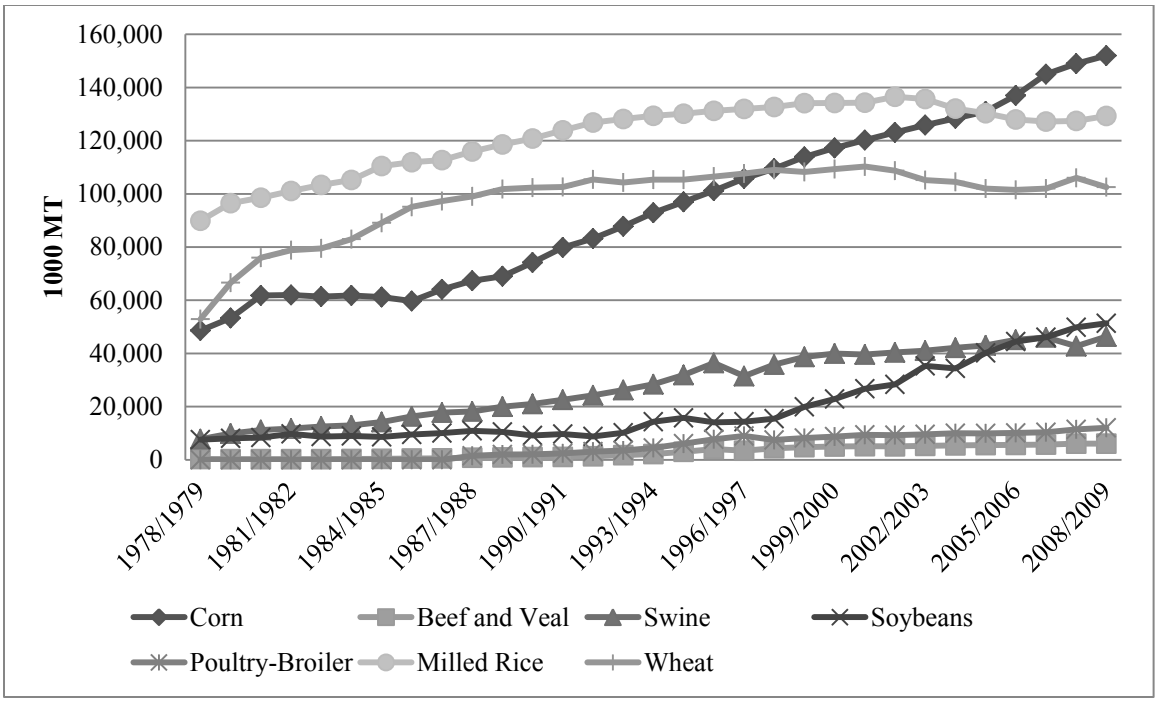

Figure 4. Domestic Consumption in China 1978/1979-2008/2009 (Foreign Agricultural Service, 2009)

To meet these changing consumer preferences, grain production has changed, as shown in Figure 5. China is producing more corn to meet the needs of the growing livestock industry. In addition, its soybean imports have grown and China is now the largest importer of soybeans in the world (Foreign Agricultural Service, 2009). Production of rice and wheat, while still important to their agriculture sector, has remained relatively flat.

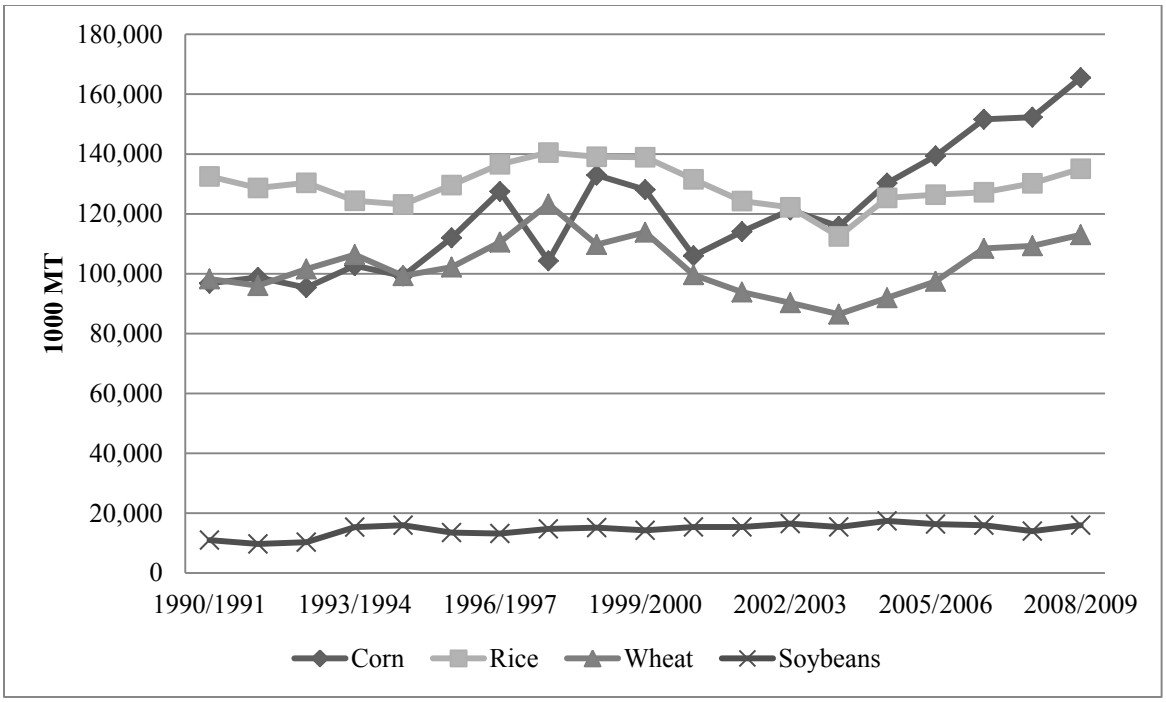

Figure 5. Grain Production in China 1990/1991-2008/2009(Foreign Agricultural Service, 2009)

In the area of grain trade, imports have been variable, shown in Figure 6, with wheat imports decreasing and an insignificant amount of corn or rice imports. The main trend to observe is in soybeans. This is a trend that is expected to continue and is a direct result of growth in the livestock sector. The soybeans are needed for protein in animal feed and China is not able to produce enough to meet this growing need; as a result, there is a sharp increase in imports. Exports are even more variable, shown in Figure 7, with the government keeping stocks in some years to help alleviate the need for imports in subsequent years.

It is important to note the trend in corn. China plays a pivotal role in the global corn market. It is the second largest producer of corn; producing 22 percent of the global crop in 2008 (Foreign Agricultural Service, 2009). However, its exports are controlled by the government through export subsidies and tax rebates. Therefore, its exports are largely unpredictable and can have a substantial impact on global corn prices.

India

India, while behind China in economic growth and population, is quickly making strides to have just as large of a global presence as China. As far as trade, India did not have much of a presence until its reforms in the early 1990s, during which trade liberalization measures were discussed. Since then, India has moved towards a more market-based economy and has experienced more economic growth. While the trade reforms have not had the same effect as with China, India has a different government structure; though it also is beginning to play a larger role in global agriculture.

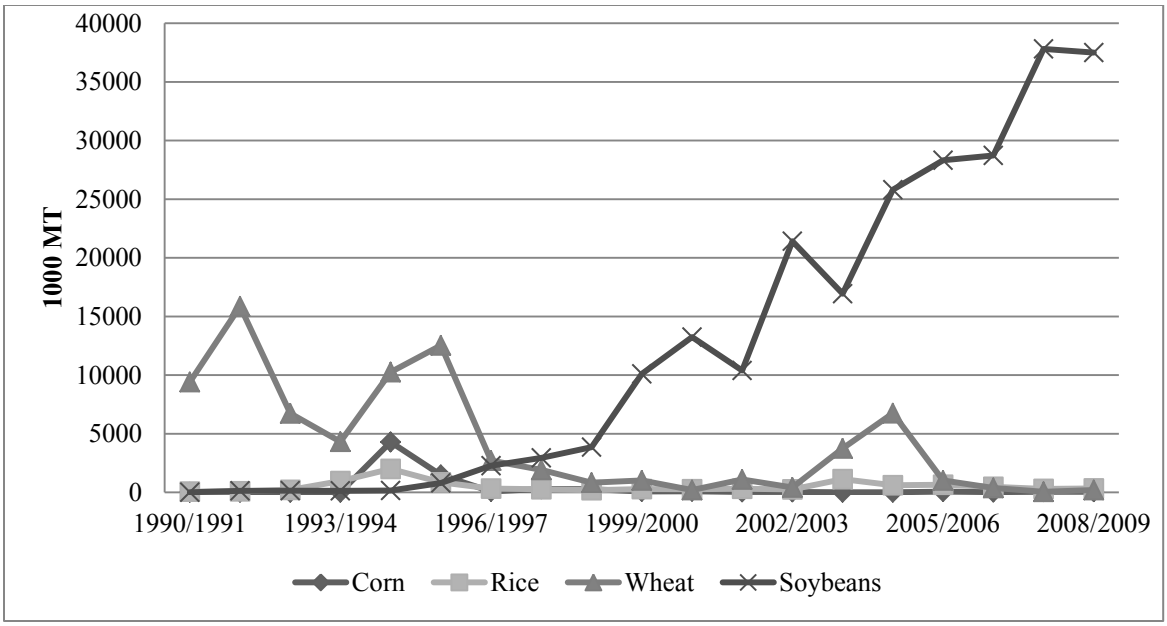

Figure 6. China Grain Imports 1990/1991-2008/2009 (Foreign Agricultural Service, 2009)

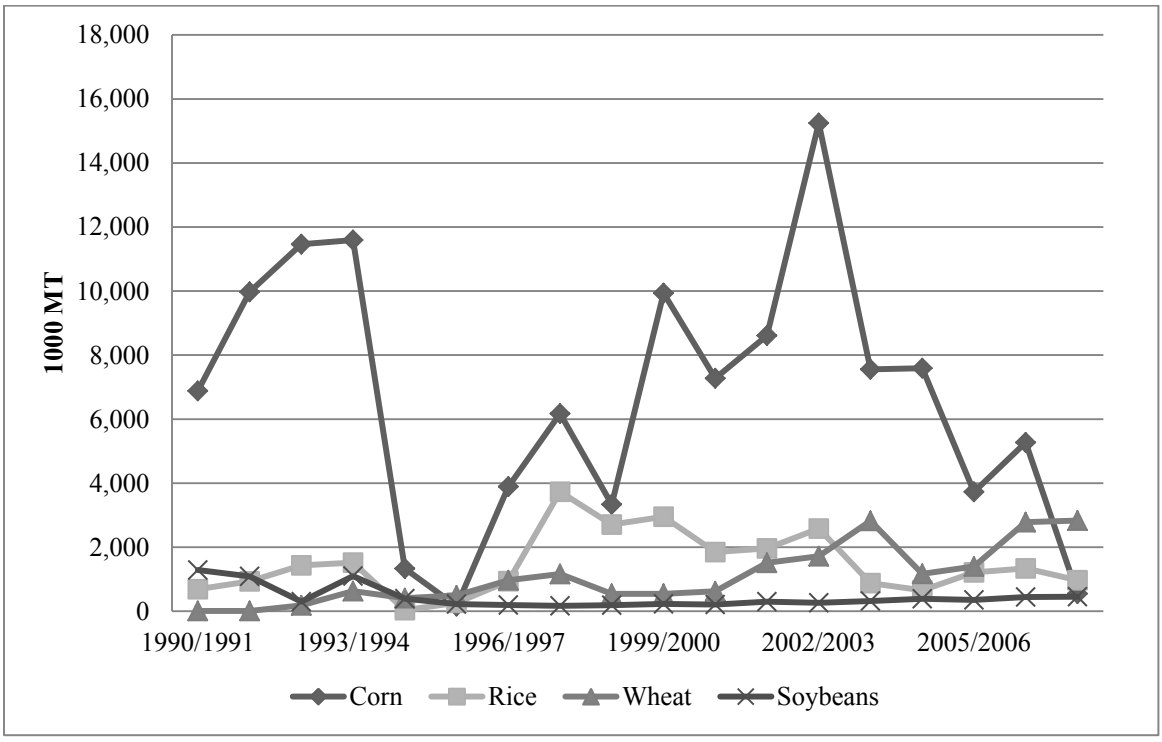

Figure 7 China Grain Exports 1990/1991 – 2008/2009 (Foreign Agricultural Service, 2009)

Indian agriculture experienced large growth in the mid-1960s with improvements in farming technology providing for higher yielding varieties of rice and wheat. This led to the creation of the Agricultural Price Commission and the Food Corporation of India in

1965. These two government entities strived to set the minimum support prices for rice and wheat, to prevent prices from falling below a specified level. Throughout the 1960s and 1970s, Indian agriculture prospered due to an increase in public investment in agriculture. However by the 1980s and 1990s, this public investment declined, and input and output subsidies increased.

In 1991, the economy in India had reached difficult times with fiscal and balance of payment problems. This led to the 1991 reforms that provided short-term stabilization measures to reduce the fiscal deficit and the value of the currency, and removed barriers for foreign capital. Looking further into the future, the government also implemented fiscal, trade, industrial, and exchange rate policies. It also reformed the nation's financial sector and capital markets. Collectively, these reforms allowed for the liberalization of agricultural trade.

Similar to China, India's consumers are changing their food preferences as a result of economic growth. In the past ten years, consumers are demanding more dairy products, poultry, meat, and vegetable oils. Also while consumer still demand the staple grains of wheat and rice, this demand is shifting. One factor contributing to this shift is the increasing price of cereal grains, as a result of agricultural reforms, in addition to changes in consumer tastes (Food and Agricultural Organization, 2006). This has led to the decreasing trend in per capita consumption of cereal grains since 1991 (Food and Agricultural Organization, 2006). In the future, the demand for oilseeds is expected to increase drastically. Figure 8 shows the trend of consumption of wheat, corn, rice, and soybeans in India.

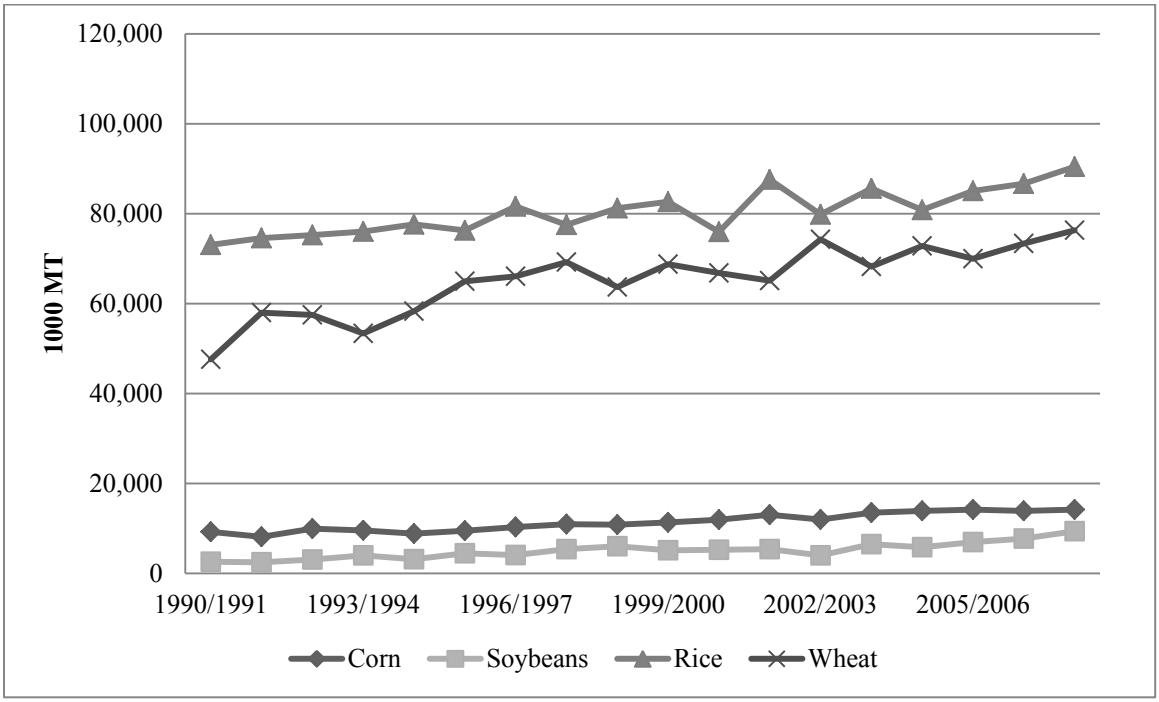

Figure 8. India Grain Consumption 1990/1991 – 2008/2009 (Foreign Agricultural Service, 2009)

Agriculture production in India experienced large increases during the Green Revolution. However, recent increases in crop yields has been in the 1-2% per year compared to 3-4% per year during the 1960s and 1970s . Two-thirds of India's production land is limited to one growing season each year primarily due to moisture stress, though this is changing as measures to provide irrigation are expanding (Food and Agricultural Organization, 2006).

The largest crop in India is paddy rice, accounting for more than 20 percent of the value for all crops produced (Food and Agricultural Organization, 2006). The second largest crop produced is wheat, which accounts for approximately 10 percent of total crop value (Food and Agricultural Organization, 2006). Wheat production has increased due to technology gains in the Green Revolution in the 1960s; however, gains have been at a much slower rate since 1970/1971 (Food and Agricultural Organization, 2006). India's third largest individual crop is sugar cane, followed by cotton. Oilseed production has been increasing as a result of government policy to make India self-sufficient in oilseeds. As a result, oilseeds accounted for 9 percent of total crop output in 1980/1981 and grew to 13 percent in 1990/1991 (Food and Agricultural Organization, 2006). This policy, however, has since been removed and as a result, oilseeds accounted for only 7 percent of total crop output in 2000/2001 (Food and Agricultural Organization, 2006). It should be noted that India does not have much soybean production, as the main oilseed produced is groundnut.

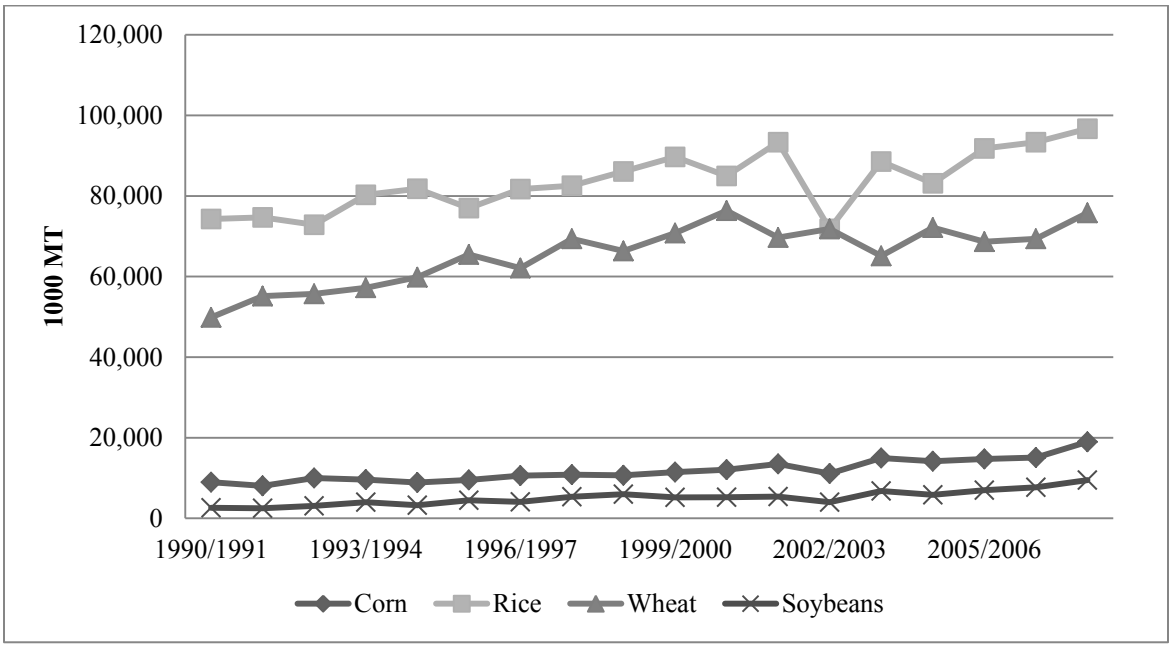

Figure 9 India Grain Production 1990/1991 – 2008/2009 (Foreign Agricultural Service, 2009)

As mentioned, Indian consumption of dairy products and meats, such as poultry, is increasing. The livestock sector is growing to meet the rising demand. Livestock contributed to 17.5 percent of total agricultural output in 1980/1981, and grew to 28 percent in 2000/2001 (Food and Agricultural Organization, 2006). Although meat consumption is growing, the largest area of growth is for dairy products. Fluid milk consumption was increased from 54 million mt in 1990 to over 100 million mt in 2005

Indian grain imports are expected to expand to meet the rising needs of the growing population. On the other hand, India exported rice and corn for the 1990-2006 period. This trend may continue in the near future. Except wheat, there have not been any significant imports of grain since the trade liberalization reforms of the early 1990s.

MODEL DEVELOPMENT

Conceptual Framework of the Model

This study addresses the impact of changes in demand for four principle crops, wheat, corn, rice, and soybeans, using a spatial equilibrium model based on a mathematical programming algorithm. Spatial equilibrium models are commonly used to address trade flows as a result of changes in supply or demand. The spatial equilibrium model optimizes trade flows of commodities on the principle of comparative advantage in terms of production and distribution costs of commodities from producing regions to consuming regions in domestic and foreign countries.

To evaluate the impact of structural changes of demand in China and India on other major importing and exporting countries, the world was divided into 17 countries and regions. The exporting countries are Argentina, Australia, Brazil, Canada, and the United States. The importing countries/regions are Japan, Mexico, the European Union-27, South Africa, the Former Soviet Union-Middle East, Latin America, North Africa, South Korea, South Asia, and Southeast Asia. China and India are treated as both importing and exporting countries. Also, it is important to note that since China and India are evaluated independently they are excluded from the Southeast Asia and South Asia regions, respectively. Further explanations of the countries included in producing/consuming regions are included in Table 1.

The modes of transportation used for this study are rail, truck, and barge for domestic transportation and ocean vessels for inter-country shipments.

Table 1. Exporting and Importing Countries and Regions

Region	Symbol	Countries/Regions Included
Argentina	ARG	Argentina
Australia	AUS	Australia
Brazil	BRZ	Brazil
Canada	CAN	Canada
China	CHN	China
EU-27	EUR	Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Faroe Islands, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom
Former Soviet Union-Middle East	FSU-ME	Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, Bahrain, Gaza Strip, Iran Iraq, Israel, Jordan, Yemen, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, Turkey, United Arab Emirates, West Bank
India	IND	India
Japan	JAP	Japan
Latin America	LAT	Bolivia, Chile, Colombia, Ecuador, Falkland Islands, French Guiana, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela,
Mexico	MEX	Mexico
North Africa	NAF	Algeria, Egypt, Libya, Morocco, Tunisia
South Africa	SAF	Angola, Benin, Botswana, Burkina, Burundi, Cameroon, Canary Islands, Cape Verde, Central Africa Republic, Chad, Comoros, Congo, Cote d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Fr. Ter. Africa, Gabon, Gambia, Terr. Ghana, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Madeira islands, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Somalia, South Africa, St. Helena, Sudan, Swaziland, Tanzania, Togo, Uganda, Western Sahara, Zambia, Zimbabwe
South Asia	SA	Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan, Sri Lanka
Southeast Asia	SEA	Brunei, Cambodia, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand, Vietnam
United States	US	United States

In the case of some of these importing/exporting countries, there are significant differences in production conditions among regions within a country. As a result, Canada, the United States, Brazil, China and India are divided into several producing and consuming regions. Canada is divided into 6 regions (Quebec (CQB), Ontario (CON), Manitoba (CMB), Saskatchewan (CSK), Alberta (CAL), and British Columbia (CBC)), the United States into 17 regions Brazil into two regions (North and South), China into 31

regions and India into 14 regions. The model includes 83 producing and consuming regions. Regions in China and India are shown in Figures 10 and 11, respectively. The U.S. regions are similar to those in Koo an Taylor (2009).

Figure 10. Producing and Consuming Regions in China

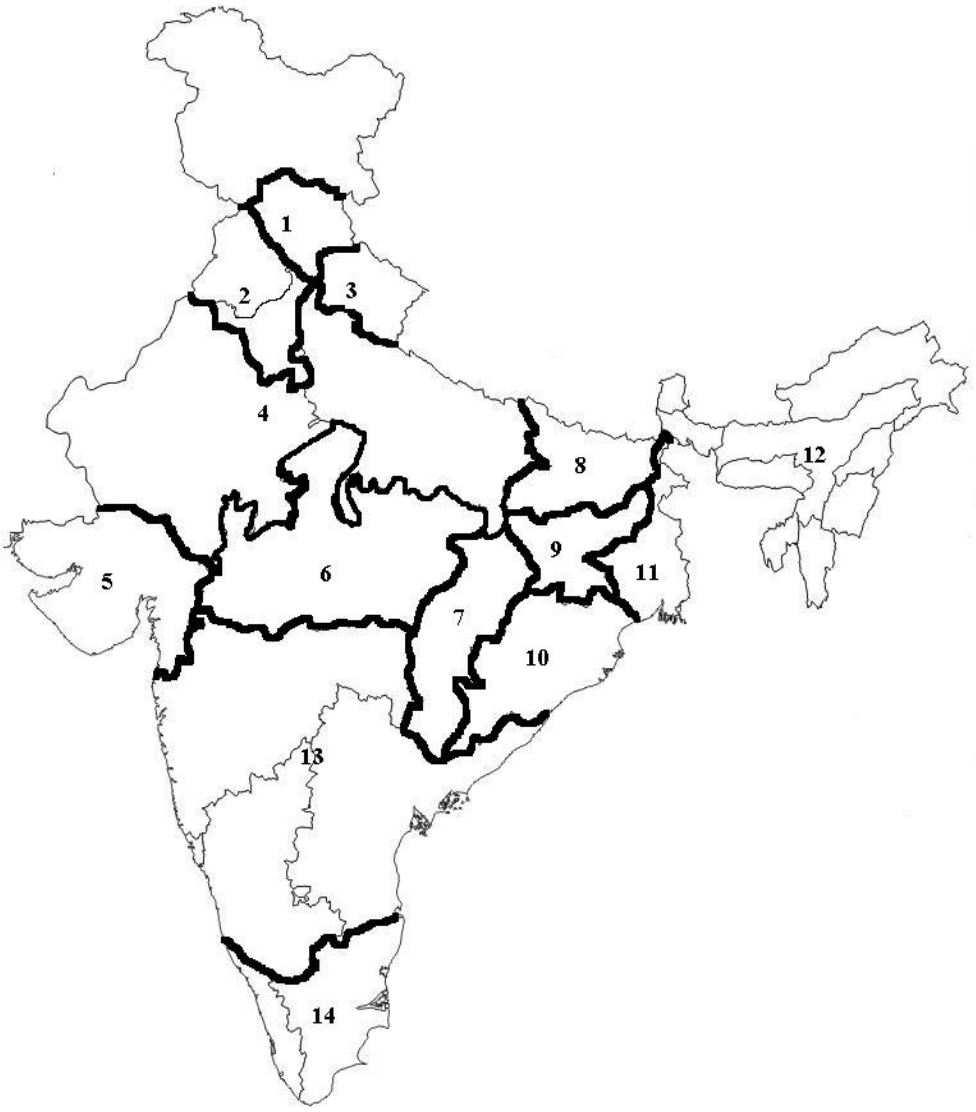

Figure 11. Producing and Consuming Regions in India

Mathematical Model

The spatial equilibrium model for this study is similar to the model used by Koo and Taylor (2009). The objective function of the model is to minimize the production cost of wheat, corn, rice, and soybeans in each producing region and the distribution costs (transportation costs) associated with shipping crops from production regions to both domestic consuming regions and foreign consuming regions. The objective function is mathematically presented as follows:

(1) $$W = \sum_{c}\sum_{i}(PC_{ci})A_{ci} - \sum_{c}\sum_{i}\sum_{j}t_{ij}Q_{cij}$$
$$- \sum_{c}\sum_{i}\sum_{p}t_{ip}Q_{cip} - \sum_{c}\sum_{p}\sum_{q}t_{pq} - Q_{cpq}$$
$$- \sum_{c}\sum_{p}\sum_{q}t_{pq} - \alpha - \lambda_{q}^{p}{}_{cpq} - \sum_{c}\sum_{q}\sum_{j}t_{qj}Q_{cqj}$$

i = the index of producing regions in exporting countries

j = the index for consuming regions located in both importing and exporting countries

p = the index for ports in exporting countries

q = the index for ports in importing countries

PC_{ci} = cost of producing crop c in producing region i

A_{ci} = the area used to produce crop c in producing region i in hectares

t = per metric ton transportation cost

Q = the quantity of crop shipped in metric tons

α = represents the tariff applied for shipping through the Panama Canal

λ_q = import duty imposed by importing country

The first term represents the total production cost, which is the product of production cost of crop c in producing region i and harvested area of crop c in the production region. The second term represents the cost of transportation from producing region to consuming region within the exporting country. The third term represents the transportation cost from producing regions to ports for export. The fourth term represents ocean transportation cost from a port in an exporting country to a port in an importing country including import tariffs. The fifth term is similar to the fourth; however, it includes the cost of the required tariffs for utilizing the Panama Canal. The final term represents the interior transportation cost from an importing port to consuming regions within the importing country.

The objective function is optimized subject to the following constraints:

(2) $$Y_{ci}\ A_{ci} = \sum_{j} Q_{cij} - \sum_{p} Q_{cip}$$

(3) $$\sum_{c} A_{ci} \leq A_{i}$$

(4) $$A_{ci} \geq MA_{ci}$$

(5) $\sum_i Q_{cij} - \sum_q Q_{cqj} \geq D_{cj}$

(6) $\sum_c \sum_i Q_{cip} \leq PCA_p$

(7) $\sum_c \sum_p \sum_q Q^p_{cpq} \leq PCC$

(8) $\sum_i Q_{cip} = \sum_q Q_{cpq}$

$\sum_p Q_{cpq} = \sum_j Q_{cqj}$

Y = crop yields per hectare in producing regions of exporting countries
TA = the total arable land in each producing region of an exporting country
MA = the minimum land used for each crop in producing regions of exporting countries
D = the demand for each crop in consuming regions of both importing and exporting countries
PCA = represents the handling capacity in each port of an exporting country
PCC = the handling capacity of the crop through the Panama Canal

Equation 2 indicates that the production of crop c in producing region i must be equal to or greater than the quantity consumed of the crop that is transported to domestic consuming regions and to exporting ports. Equation 3 makes the provision that production is limited by the amount of arable land, indicating that the total area harvested for all crops in a production region cannot exceed that of total arable land available in a production region. Equation 4 makes the assumption that crops produced in a production region will not change considerably, due to soil type, grower knowledge, and capital availability, and thus the area harvested for crop c will be greater or equal to the minimum land used for the crop in the producing region. Equation 5 states that demand for crop c is less than or equal to the amount produced and imported in a consuming region. Equations 6 and 7 indicate handling capacity at export ports and the Panama Canal, respectively. The total amount of agriculture commodities shipped through export ports and the Panama Canal should be less than its handling capacity. Equations 8 and 9 state that ports in exporting and importing countries cannot store grain and are considered as transshipment points. Thus, Equation 8 indicates that the quantity sent from a producing region to an export port must be equal to the quantity exported to an importing port, and Equation 9 indicates that the quantity sent from an exporting port to an importing port must be equal to the quantity sent from the importing port to the consuming region(s).

The Base and Alternative Scenarios

The Base model is based on average production conditions in the 2005-2007, period. Consumption data are based on 2007 data. The exception in both production and consumption data are China and India, in which data availability requires that production estimates be based on an average of the 2003- 2005 data and consumption data on 2005. Production data are expressed in 1000 hectares (area harvested) and metric ton/hectare

(yield) and consumption data are expressed in 1000 metric ton. The Base model is calibrated using theoretical data for the supply of and the demand for crops in importing and exporting countries given supply and demand conditions in these years to determine the optimal solution under the Base model. The Base-20 model is the same as the Base Model; however, with projected production and consumption of the four crops in the year 2020.

Six alternative scenarios are developed to evaluate the impact of different supply and demand conditions on the production of the crops in exporting countries and trade flows from exporting countries to importing countries. Scenarios 1, 2, 3, and 4 determine the impact of changes in technology. Scenario 1 uses the same production and consumption data from the Base-20 model; however, yields in India are increased by 20 percent from the 2020 projection. Scenario 2 is similar to Scenario 1, except yields for China are increased by 20 percent from the 2020 projection. Scenario 3 is similar to the previous two; however, yields in India are decreased by 20 percent from the 2020 projection. Scenario 4 is the same as Scenario 3; however, yields in China are decreased by 20 percent from the 2020 projection. These four alternative scenarios are developed mainly due to uncertainty associated with crop yields resulting from weather conditions.

Scenarios 5 and 6 are used to evaluate the effect consumption in China and India surpass what is projected. The model is the same as the Base-20 model in both scenarios; however, Scenario 5 increases consumption by five percent in each of India's consumption regions and Scenario 6 increases consumption by five percent in each of China's consumption regions.

Data Collection

The data required for this model can be broken down into five categories: production cost for all of the crops in all producing regions, domestic transportation cost (including rail, truck and barge), ocean shipping rates, production (crop yields and area harvested) in producing regions, and consumption (per capita consumption, per capita income and population data) in consuming regions.

Cost data include the cost of production, domestic transportation cost (using rail, barge, and truck), and ocean shipping rates. Production costs for all crops in all regions were obtained *The Cost of Producing Crops Around the World* (Global Insights, 2004). Domestic transportation costs were obtained primarily from the *Grain Transportation Report* (Agricultural Marketing Service, 2002, 2003). Additional domestic transportation information for China was obtained from the Henan University of Technology, Zhengzhou, China. U.S. and Canadian rail transportation rates were obtained from the *Public Waybill* data (Surface Transportation Board, 2002). Additionally, U.S. domestic transportation data were obtained from the *Grain Transportation Digest* (ProExporter, 2004). Ocean shipping rates were obtained from *Ocean Shipping Rates for Grains* (Maritime Research, Inc., 2004). Tariffs are also added as a cost in the model, and thus import tariffs were obtained from the publication *World Tariff Profiles 2008* (World Trade Organization, 2008).

In order to determine agricultural trade, it is necessary to determine what and how much each region produces and consumes. Production data were obtained using crop

yields and area harvested to determine the amount of available production. Crop yields are expressed in metric ton/ hectare and area harvested is expressed in 1000 hectares, which is consistent with most international agricultural data sources. Crop yields and area harvested for most producing regions were obtained from the *Production, Supply, and Distribution* online database (Foreign Agricultural Service, 2009). Production data for regions in China were obtained from the Henan University of Technology, Zhengzhou, China. Production data for regions in India were obtained from *State Wise Area Production and Yield Statistics* online database (Department of Agriculture and Cooperation of the Ministry of Agriculture for the Government of India, 2009). Production data for regions in the United States were obtained from the *Crops* online database (National Agricultural Statistics Service, 2009). Production data for regions in Canada were obtained from various volumes of their *Field Crop Reporting Series* (Statistics Canada).

Domestic consumption is calculated using per capita consumption and population. Data for most regions were obtained from the *World Development Indicators Quick Query* (The World Bank Group, 2009) and the *Production Supply and Distribution* online database (Foreign Agricultural Service, 2009). Population data for regions in India were obtained from the *Domestic Product of States of India 1960-1961 to 2006-2007* (EPW Research Foundation, 2009). Population data for regions in China were obtained from the *China Statistical Yearbook 2008* (China National Bureau of Statistics, 2008). Population data for regions in the United States were obtained from the U.S. Census Bureau and for region in Canada from Statistics Canada.

Crop Production in 2020

In order to project forward from the Base model, crop yields are estimated for all four crops for the year 2020. The forecast model is linear for all crops based on historical data from 1990 through 2007. To do this, a standard time trend regression is used to determine the change in yields in the projected year. Data were obtained for the years 1990 to 2007 from the aforementioned sources to determine the trend. However, in some cases the period of time varies based upon data availability. The time trend regression is represented by:

(10) $Y_{ci} = \beta_0 + \beta_t T$

Y_{ci} = yield of crop c in region i.

T = time trend variable.

The estimated coefficient of the time trend variable is used to project crop yields for each crop in 2020. The projections for yields in all four crops are then evaluated to obtain the average yield increase across all production regions, because the increase in estimated yields are substantially different in the producing regions, and thus the yields are averaged under the assumption that production technology will spread from one region to another due to the exchange of technology. Average increased in yields are 15 percent of the 2005-2007 average for wheat, 18 percent for corn, 14 percent for soybeans, and 18 percent for rice. These percentage increases are then applied to the yield data in the Base Model to determine crop yields in 2020.

Consumption in 2020

The objective of this research is to evaluate the impact on global agriculture of structural changes of demand in China and India. A demand model for each crop is specified as a function of income and trend to represent consumer taste and preference as:

$$(11) \quad C_{it} = \alpha_0 + \alpha_1 Y_t + \alpha_2 TR + e_t$$

C_{it} = per capita consumption of crop t in region i
Y_t = per capita income in region t
TR = time trend variable
e_t = error term

Equation 11 represents per capita consumption, which is determined by per capita income and a time trend variable. Since the error term of Equation 11 is serially correlated, an AR (1) model is used to estimate the equation.

The estimated model is used to project per capita consumption for 2020. Per capita income in 2020 was calculated using the *Real GDP Growth Projections* from FAPRI's *World Macroeconomics,* available in their publication *FAPRI 2009 U.S. and World Agricultural Outlook*. To determine per capita income, and later to determine consumption as a whole for the region, population projections were also taken from *FAPRI 2009 U.S. and World Agricultural* Outlook.

Once consumption of each crop was determined, the results were compared to the projections of FAPRI and the USDA to evaluate whether the projections are consistent. The results from all three sources for wheat, corn, rice, and soybeans are presented in Table A.1.

The final domestic consumption projections used in the analysis for the Base-20 model and Alternative Scenarios 1-6 are taken primarily from the econometric analysis conducted in this study. The final domestic consumption projections are then divided into consuming regions, which is only of importance for countries with multiple consuming regions, China and India, based on the proportion of the country's population that resides in that consuming region. These proportions can change over time. Therefore, a time trend regression, similar to Equation 10, is run on regional populations. The final domestic consumption projections for 2020 are shown in Table 2 along with those used in the Base model.

Table 2. Total Domestic Consumption in the Base and Base-18 Models

	Wheat		Corn		Soybean		Rice	
Region	Base	Base-18	Base	Base-18	Base	Base-18	Base	Base-18
----------1000 Metric Ton----------								
ARG	5130	5158	7000	8521	36163	56586	375	505
AUS	6200	8252	320	433	43	48	346	563
BRZ	10480	11894	41500	52511	33820	55905	8317	8691
CAN	7317	7608	11149	17579	1784	2603	320	488
CHN	100122	106003	136352	181348	44540	62356	127111	127450
EUR	116536	134580	63400	58955	16113	17340	3240	3773
FSU-ME	117132	134702	26721	34000	4882	6473	8348	10121
IND	76839	85369	14291	19616	9458	11423	91053	108456
JAP	6000	5517	16600	16418	4218	3913	8177	7779
KOR	3000	2682	8633	11295	1386	1575	4670	4295
LAT	8619	10405	15378	18715	3929	3791	5315	5691
MEX	5500	6155	32000	41570	3710	5099	759	941
NAF	35894	41278	15664	18834	1575	1582	3721	4952
SA	33065	33065	5274	5274	175	175	38934	40405
SAF	28770	35000	48860	54270	1383	1660	57898	58000
SEA	10995	14294	28499	39405	5096	6383	97233	138367
US	27597	33110	252719	312396	49801	65348	3917	5488

Transportation Costs

Transportation costs are divided into three categories:

1. Inland shipping costs from producing regions to consuming regions or ports
2. Costs for shipping from an exporting country's ports to an importing country's ports
3. Inland shipping costs from importing port to consuming region

Inland shipping costs from producing regions to consuming regions and ports are only applicable to countries with multiple producing and consuming regions, such as China, India, Brazil, Canada, and the United States. In other countries/regions, the producing and consuming regions are the same and thus domestic shipping costs are not needed. These inter-country shipments are typically done by rail, though truck shipments are also used primarily for inter-country shipments in the United States. The model does allow for some shipments from producing regions in the United States and Canada to consuming regions in the United States, Canada, and Mexico. Inland shipping from consuming regions to ports is done by truck and rail; however, the United States also utilizes barge transportation in the Mississippi River system. The inland transportation costs are obtained from various industrial sources.

The cost of shipping from exporting countries to importing countries is calculated using ocean freight rates. The data are obtained from Maritime Research, Inc.

Inland shipping costs from import ports to consuming regions are only applicable to China and India. Since other countries that are divided into multiple production/consumption regions are not importing countries the inland shipping costs from ports to consuming regions is not included. The mode of transportation from importing ports to consuming regions is done primarily by rail.

EMPERICAL RESULTS

Base and Base-20 Model

This section will evaluate the production, consumption, and trade flows for the Base model, under current supply and demand conditions, and the Base-20 model with supply and demand conditions estimated for the year 2020, for all four crops in all producing and consuming regions. Because the focus of this study is China and India, the results for these two countries will be evaluated independently to show the change over time. In addition, production and trade in the United States and Canada will be outlined, because these two nations are large exporting countries and due to the diverse production conditions within these countries.

China's Production, Consumption and Trade

China is evaluated on its production, consumption, exports, and imports for the current period and in 2020. Table 3 presents the results from both models. Production in the Base model demonstrates that corn is the leading crop, comprising 36 percent of all grain production. Rice, wheat, and soybeans account for 33, 26, and 4 percent, respectively. In relation to trade, China only imports and does not export in the Base model. Imports are primarily soybeans, with imports accounting for 65 percent of domestic consumption. China imports a small amount of wheat, with imports accounting for 0.8 percent of domestic consumption. Rice is also imported and accounts for 2.9 percent of domestic consumption.

Table 3. Production, Consumption, and Trade for China in the Base and Base-20 Models

	Model	Production	Consumption	Export	Import
	----------million metric ton----------				
Wheat					
	Base	99.31	100.12	-	0.76
	Base-20	106.00	106.00	-	-
Corn					
	Base	136.35	136.35	-	-
	Base-20	176.77	181.35	-	4.58
Soybean					
	Base	15.52	44.54	-	29.02
	Base-20	17.96	62.36	-	44.40
Rice					
	Base	123.47	127.11	-	3.63
	Base-20	128.57	127.45	1.12	-

In the Base-2020 model, it is evident that consumption patterns have changed since the base year. In 2020, corn accounts for 38 percent of total grain consumed, compared with 33 percent in the Base model. Soybeans account for 13 percent of total grain consumed, which is a 40 percent increase in the amount of soybeans consumed compared to the Base model. Rice and wheat are staples in the Chinese diet; however, between the base year and 2020, the amount of rice and wheat consumed has increased by only 0.2 and 5.8 percent, respectively. This could be interpreted to mean that as income increases, Chinese consumers will consume less rice and wheat and more meat products. Since consumers in China are consuming more meat, shown by its growing livestock industry, the result is an increased demand for corn and soybeans to be used as feedstuffs.

Grain production has also increased, due mainly to the advancement of farming technology. Corn remains the primary crop, accounting for 41 percent of grain production. Rice, wheat, and soybeans account for 30, 25, and 4 percent, respectively. China's role in trade has also changed. Despite the increase in corn production, China imports a small amount of corn in 2018 with imports accounting for 2.5 percent of domestic consumption. In addition, China has increased its imports of soybeans with imports accounting for 71 percent of domestic consumption. China has also become a small net exporter of rice with 0.9 percent of its rice production being exported to Japan.

India's Production, Consumption and Trade

The results of the Base and Base-20 models for India, shown in Table 4, indicate the changes in production, consumption, and trade. In the Base model, the primary grain consumed is rice, which accounts for 47 percent of the total grain consumption. This is followed by wheat, corn, and soybeans, which account for 40, 8, and 5 percent of grains consumed, respectively. Production in the Base model indicates that rice is the primary crop produced, as it accounts for 47 percent of all grain production. This is followed closely by wheat, which accounts for 41.5 percent, and distantly by corn and soybeans, which account for 7.5 and 3.8 percent, respectively. Trade in the Base model demonstrates that India exports wheat and imports soybeans, with imports accounting for almost 24 percent of domestic soybeans consumption.

Table 4. Production, Consumption, and Trade for India in the Base and Base-20 Models

	Model	Production	Consumption	Export	Import
	----------million metric ton----------				
Wheat					
	Base	80.02	76.84	3.62	-
	Base-20	92.00	85.37	6.63	-
Corn					
	Base	14.29	14.29	-	-
	Base-20	19.62	19.62	-	-
Soybean					
	Base	7.23	9.46	-	2.23
	Base-20	10.87	11.42	-	0.56
Rice					
	Base	91.05	91.05	-	-
	Base-20	108.46	108.46	-	-

In the Base-20 model, consumption of the four major grains in India has changed, though not as severely as seen in China. Rice and wheat remain the staple grains in the Indian diet. Consumption of rice has increased slightly in 2020 and accounts for 48 percent of all grain consumed. Wheat consumption in 2020 has decreased to 38 percent of all grain consumption, from the previous 40 percent of grain consumption in the Base model. Consumption of corn and soybeans has increased by 37 and 21 percent, respectively, since the base year; however, the amount is still relatively small.

Production in 2020is similar to that in the base year. Rice remains the largest crop accounting for 47 percent of total production, which is the same as the base year. Wheat is the second largest crop, but has now decreased slightly to account for 39.8 percent of grain production, compared to 41.5 percent in the base year. Corn has grown to account for 8.5 percent of all grain production, an increase of 37 percent since the base year. Soybeans production has expanded by 50 percent since the base year and now accounts for 4.7 percent of the total grain production. Production has shifted to meet changing demands; however, the Indian diet has not changed significantly to require a large shift in domestic production.

India's trade in the Base-20 model illustrates how production and consumption patterns have altered over time. While India is a net exporter of wheat in the base year, increases in technology have allowed for increased wheat exports in 2020. Soybeans, while not a widely produced or consumed crop in India, becomes the only crop imported in the Base-20 model with imports accounting for 4.9 percent of domestic consumption.

World Trade of Agriculture Commodities

Trade flows for all producing and consuming regions illustrate how changes in production and consumption patterns affect world agriculture. This is evident by comparing imports and exports in the base year to those in 2020. Tables 6 and 7

demonstrate the role and importance of each exporting and importing countries on the world market for each of the four grains. Exports in 2020 have increased for three of the four grains, and most significantly in soybeans with an increase of 28 percent in the volume of total soybean trade since the base year. Rice is the only grain to exhibit a decrease with global rice trade decreasing by 20.8 percent since the base year. This indicates a change in consumption patterns as consumers are demanding less rice and more soybeans globally.

Corn trade increases by 0.8 percent in volume from the base year to 2020. Primary exporting countries in both models are the United States, Argentina, and Brazil. However in the Base-20 model, the United States gains only a small share in the world market, while Argentina's share increases and Brazil's share decreases. The percentage of world corn exports for each exporting country indicates that the United States has a comparative advantage over other countries in exporting corn. Argentina exports about 28 percent of total corn trade in 2020 demonstrates that it also has a comparative advantage in exporting corn. Other shifts come from growth in Canadian exports, as well as the emergence of the EU-27 and South Asia as small exporting countries. Southeast Asia exports a small amount in the Base model, but shifts to become a net importer of corn in the Base-20 model. Exhibiting that Southeast Asia has a comparative advantage in the base year but has a comparative disadvantage in 2020, as it is not able to continue to provide for its growing domestic consumption.

The largest corn importing country in the Base-model is Japan, followed by the EU-27, Mexico, South Korea, and North Africa. In the Base-20 model, Mexico becomes the largest importer accounting for 26 percent of all imports. The EU-27 shifts to export a small amount of corn and China shifts to become an importing country in the Base-20 model.

Wheat exports in 2020, compared to the base year, indicate an increase in the volume of wheat traded by 6.9 percent. The primary exporting countries in both models are the United States, Canada, Argentina, and Australia. The two largest exporting countries are the United States and Canada. U.S. and Canadian exports account for 36.9 and 24.6 percent, respectively, of the world wheat trade in the base year, and 26.5 and 26.8 percent, respectively, in 2020. Over this period, the fact that United States decreases its exports and Canada increases its exports. This indicates that Canada has a comparative advantage in producing and exporting wheat over the United States and the other exporting countries in 2020. As a result, Canada becomes the largest exporter of wheat in 2020. All exporting countries increase exports in 2020, compared to the base year, with the exception of the United States.

In the Base model, North Africa, South Africa, and Southeast Asia are the largest importing regions of wheat. In 2020, South Africa is the largest importer accounting for nearly a third of all wheat imports. Southeast Asia has increased its imports, and North Africa, while still a large importer, has decreased its imports compared to the base year. China, Japan, and South Korea decrease their wheat imports in the Base-20 model, indicating a decrease in consumption.

Table 5. Exports in the Base and Base-20 Models

	Exporter	Base		Base-20	
		----------million metric ton----------			
Corn		Actual	Percentage	Actual	Percentage
	Argentina	17.39	24.4	20.25	28.2
	Brazil	17.07	24.0	10.39	14.5
	Canada	4.19	5.9	7.89	11.0
	EU-27	-	-	0.07	0.1
	South Asia	-	-	0.42	0.6
	Southeast Asia	0.19	0.3	-	-
	United States	32.40	45.5	32.85	45.7
	Total	71.24		71.86	
Wheat					
	Argentina	14.44	18.6	17.68	21.3
	Australia	11.28	14.5	13.46	16.2
	Canada	19.17	24.6	22.27	26.8
	Former Soviet Union /Middle East	0.54	0.70	1.06	1.3
	India	3.62	4.7	6.63	8.0
	United States	28.74	36.9	22.06	26.5
	Total	77.80		83.17	
Soybean					
	Argentina	14.00	21.7	4.14	5.0
	Brazil	19.50	30.4	31.52	38.3
	Canada	0.26	0.4	0.45	0.6
	Latin America	3.23	5.0	8.16	9.9
	United States	27.28	42.5	38.09	46.2
	Total	64.24		82.36	
Rice					
	Argentina	0.54	1.0	0.53	1.3
	Australia	0.06	0.1	-	-
	Brazil	0.03	0.06	-	-
	China	-	-	1.12	2.8
	Latin America	11.71	24.4	2.61	6.6
	Southeast Asia	29.96	62.4	27.23	68.4
	United States	5.74	12.0	8.30	20.9
	Total	48.04		39.80	

Soybean trade, as mentioned, increases the most significantly in Base-20 model. The largest exporting countries are the United States and Brazil. Both countries expand their exports and account for a larger share of total world exports in 2020. Argentina is also a large exporting country in 2020. However, Argentina shifts to produces more corn,

and as a result, it has less of a presence in the world soybean market. This exhibits that Argentina has a comparative advantage in producing corn rather than soybeans. Soybean imports in both models demonstrate the large presence of China in global soybean trade.

While in the Base model China accounts for 45.3 percent of all soybean imports by volume, in the Base-20 model it is importing more than half of the global soybean trade. In 2020, China will import 53 percent of soybean imports, which is a growth of 53 percent in its imports during the period. Another large importing country is the EU-27, which increases its imports between the two periods; however in 2020, its imports account for a lesser share of the total soybean trade. Between the two periods, all importing countries increase their imports, except India, Japan, and South Africa, which reduce their imports due to advances in farming technology.

Table 6. Imports in the Base and Base-20 Models

	Importer	Base		Base-20	
		----------million metric ton----------			
Corn		Actual	Percentage	Actual	Percentage
	China	-	-	4.58	6.4
	EU-27	14.84	20.8	-	-
	Former Soviet Union /Middle East	3.78	5.3	-	-
	Japan	16.60	23.3	16.42	22.8
	Latin America	7.01	9.8	7.87	11.0
	Mexico	12.41	17.4	18.65	26.0
	North Africa	8.07	11.3	10.84	15.1
	Southeast Asia	-	-	2.31	3.2
	South Korea	8.54	12.0	11.18	15.6
	Total	71.24		71.85	
Wheat					
	Brazil	5.98	7.7	6.94	8.3
	China	0.76	1.0	-	-
	EU-27	2.66	3.4	2.66	3.2
	Japan	5.21	6.7	4.81	5.8
	Latin America	5.11	6.6	5.75	6.9
	Mexico	2.53	3.2	2.86	3.4
	North Africa	16.65	21.4	13.87	16.7
	South Africa	22.09	28.4	26.47	31.8
	Southeast Asia	10.82	13.9	14.14	17.0
	South Korea	2.99	3.8	2.67	3.2
	United States	3.00	3.9	3.00	3.6
	Total	77.80		83.17	
Soybean					
	China	29.02	45.2	44.40	53.9
	EU-27	14.86	23.1	16.24	19.7
	Former Soviet Union /Middle East	3.35	5.2	4.39	5.3
	India	2.23	3.5	0.56	0.7
	Japan	4.02	6.3	3.55	4.3
	Mexico	3.61	5.6	4.96	6.0
	North Africa	1.53	2.4	1.53	1.9
	South Africa	0.47	0.7	0.22	0.3
	South Asia	0.07	0.1	0.17	0.2
	Southeast Asia	3.76	5.9	4.98	6.0
	South Korea	1.21	1.9	1.35	1.6
	Total	64.24		82.33	
Rice					
	Australia	-	-	0.03	0.1
	Canada	0.32	0.6	0.49	1.2
	China	3.63	7.6	-	-
	EU-27	1.12	2.3	1.85	4.7
	Former Soviet Union /Middle East	4.10	8.5	5.11	12.8
	Japan	0.99	2.0	1.12	2.8
	Mexico	0.59	1.2	0.76	1.9
	South Africa	37.29	77.6	30.44	76.5
	Total	48.04		39.80	

Rice trade in 2020 demonstrates the change in global consumption patterns, as the volume of rice traded decreases by one-fifth between the two periods. The largest exporting region is Southeast Asia accounting for 62.4 and 68.4 percent of global rice trade in the Base and Base-20 models, respectively. The second largest exporter in the Base model is Latin America; however, in the Base-20 model it decreases its exports by 78 percent as it shifts more acres to the production of soybeans. The United States is also an exporter of rice, accounting for nearly 21 percent of global rice trade in 2020. Australia and Brazil export a small amount of rice in the base year; however, Australia shifts to import rice in 2020.

The largest rice importer is South Africa, though it does reduce its imports between the two periods by 18.4 percent. Other importing countries increase their imports over the period by a small amount. China imports rice in the base year, but shifts to be a small net exporter in 2020.

Alternative Scenarios for China

This section compares the results of the alternative scenarios to those of the Base-20 model, which is summarized in Table 7. The alternative scenarios indicate what will happen to Chinese production, consumption and trade as a result of changing technology and increased demand. Scenario 2 explains the resulting conditions if crop yields were to increase by 20 percent above what has been forecasted for 2020. Scenario 4 explains the resulting conditions if crop yields were to be 20 percent lower than the forecast for 2020. Scenario 6 indicates the resulting conditions if domestic consumption in China were to be 5 percent higher than the forecast for 2020.

In Scenario 2 where yields are increased by 20 percent, China produces the same amount of wheat and rice as in the Base-20 model. However, it shifts more acres to corn and soybeans to increase its production to meet the demands of its growing livestock industry. As a result, China produces 2.6 percent more corn and 23.7 percent more soybeans compared to the Base-20 model. Because domestic consumption remains constant and its production increases, China is now able to decrease its soybean imports by 9.6 percent and become self-sufficient in corn. The reductions in China's imports of soybeans affects world soybean trade. Argentina and Brazil decrease their soybean exports to China.

Table 7. Production, Consumption and Trade for China in the Base-20 and Alternative Scenarios

	Base-20	Scenario 2 (+20%)	Scenario 4 (-20%)	Scenario 6 (+5%)
	----------million metric tons----------			
Production				
Wheat	106.00	106.00 (0.0)	97.08 (-9.2)	111.31 (5.0)
Corn	176.77	181.35 (2.6)	143.43 (-23.2)	179.44 (1.5)
Soybean	17.96	22.21 (23.7)	13.94 (-28.8)	18.20 (1.3)
Rice	128.58	128.58 (0.0)	108.60 (-18.4)	134.95 (5.0)
Consumption				
Wheat	106.00	106.00	106.00	111.31 (5.0)
Corn	181.35	181.35	181.35	190.42 (5.0)
Soybean	62.36	62.36	62.36	65.47 (5.0)
Rice	127.45	127.45	127.45	133.82 (5.0)
Imports				
Wheat	-	-	8.91	-
Corn	4.58	-	37.92	10.98
Soybean	44.40	40.15	48.42	47.27
Rice	-	-	18.85	-
Exports				
Rice	1.13	1.13	-	1.13

In Scenario 4, yields are decreased by 20 percent from the 2020 projection in China resulting in China being a net importer of all four crops. Production of wheat, corn, soybeans, and rice decreases by 9.2, 23.2, 28.8, and 18.4 percent, respectively. As a result, China now imports 8.4 percent of its domestic consumption of wheat, 20.9 percent of its domestic consumption of corn, 77.6 percent of its domestic consumption of soybeans, and 14.8 percent of its domestic consumption of rice. The impact of the changes in China's imports on world agriculture trade is significant.

China imports corn from Argentina, Brazil, the Former Soviet Union-Middle East, and the United States in Scenario 4. Soybean trade volume has also increased, with Argentina almost doubling its exports of soybeans and with a slight increase from the United States. In actuality the increase in exports needed to fulfill China's import demand is coming primarily from Brazil. Wheat trade has increased to accommodate the growing demand in China and is met by increased exports in Argentina, Canada, South Asia, and the United States. The country that supplies China with a significant portion of its wheat is Canada, though the United States also exports a small amount to them. Increases in Argentina's exports are to satisfy the import demand previously fulfilled by Canada, primarily in the South Africa region.

Rice trade has shifted to increase exports from Latin America and Southeast Asia. China, who previously was a small net exporting country, is now importing 18.85 million metric tons. Southeast Asia is exporting nearly 55 percent more than it is in the Base-20 model, with the majority of its exports going to China. Latin America has increased its exports, though this is to fulfill the demand in South Africa, which was previously satisfied by Southeast Asia.

Scenario 6 indicates the impact of a 5 percent increase in consumption in China compared to the Base-20 model. In this scenario, China increases its production of rice and wheat by 5 percent to satisfy domestic demand, showing its comparative advantage in producing these two crops. Imports of corn and soybeans increase, because even though China has expanded its production of these two crops by 1.5 and 1.3 percent, respectively, it was not enough to satisfy domestic demand. As a result, China's imports of corn more than double and soybean imports increase by 6.5 percent. Because China is only increasing its imports of corn and soybeans, the trade of these two commodities is affected.

Alternative Scenarios for India

Alternative Scenario 1 determines the impact of increased technology on domestic production and trade in India. As a result of increasing yields by 20 percent above those in the Base-20 model, production of wheat, corn, and soybeans increase by 12.4, 18.1, and 14.2 percent, respectively. Rice production remains the same as in the Base-20 model. Consumption remains constant, and thus India now exports 17.8 percent of its total wheat production, 15.3 percent of domestically produced corn, and 8 percent of domestically produced soybeans.

Global corn trade alters as India now exports its surplus production to North Africa. As a result, Brazil and Canada export less corn to North Africa. Brazil increases its exports to South Korea. The United States decreases its exports to South Korea but increases its exports to Japan, as Argentina has now reduced its exports to Japan. The net result is a reduction in corn exports from Argentina and Canada.

Table 8. Production, Consumption and Trade for India in the Base-20 and Alternative Scenarios

	Base-20	Scenario 1	Scenario 3	Scenario 5
----------million metric tons----------				
Production				
Wheat	92.00	103.41 (12.4)	80.53 (-12.5)	96.27 (4.6)
Corn	19.62	23.18 (18.1)	19.56 (-.3)	20.60 (5.0)
Soybean	10.87	12.41 (14.2)	8.29 (-23.8)	10.87 (0.0)
Rice	108.46	108.46 (0.0)	108.46 (0.0)	113.88 (5.0)
Consumption				
Wheat	85.37	85.37	85.37	89.64 (5.0)
Corn	19.62	19.62	19.62	20.60 (5.0)
Soybean	11.42	11.42	11.42	12.00 (5.0)
Rice	108.46	108.46	108.46	113.88 (5.0)
Imports				
Wheat	0.00	0.00	4.84	0.00
Corn	0.00	0.00	0.06	0.00
Soybean	0.56	0.00	3.14	1.13
Rice	0.00	0.00	0.00	0.00
Exports				
Wheat	6.63	18.04	0.00	6.63
Corn	0.00	3.56	0.00	0.00
Soybean	0.00	0.99	0.00	0.00

( ) the percentage decrease/increase over the Base-18 model results

In the Base-20 model, India imports soybeans; however as yields increase in Scenario 1, India is able to export soybeans. India now exports soybeans to North Africa, who can now import less from Latin America. The EU-27 increases its imports from Latin America and reduces its imports from the United States. The United States can now export more to China, allowing Brazil to export less to China and more to Southeast Asia. Argentina can reduce its exports to Southeast Asia, and thus achieves the net result for this scenario of reducing its soybean exports by 37 percent.

Global wheat trade has also changed, since exports from India have nearly tripled. The net effect is that Canada and the United States have reduced their wheat exports. There are significant changes in bilateral trade of wheat between major exporting countries (the U.S. and Canada) and major importing countries.

In Scenario 3 crop yields in India are decreased by 20 percent from the Base-20 model. The resulting change in production is that India now produces 12.5 percent less

wheat, 0.3 percent less corn, and 23.8 percent less soybeans, while rice production remains constant. Since consumption of the crops in this scenario remains the same as in the Base-20 model, India now imports more soybeans, a small amount of corn, and now imports wheat. The increased imports impact primarily the global trade of soybeans and wheat. However, its wheat import is very small. The net result on soybean trade is that Argentina and Brazil increases its soybean exports to India and Southeast Asia. The U.S. export increase slightly in this scenario.

Scenario 5 demonstrates the resulting production, consumption and trade flows if India's consumption increases 5 percent above the Base-20 model. Production in this alternative scenario reveals that India will expand its production of wheat by 4.6 percent, corn by 5 percent, soybeans will remain constant, and rice production will increase by 5 percent. The result is that India is able to stay self-sufficient in rice and is able to maintain its exports of wheat from the Base-18 model. However, soybean imports increase to meet the increase in domestic demand. The impact on global soybean trade for this scenario is minimal. The net result is that Argentina and Brazil increases its soybean exports in this scenario

SUMMARY AND CONCLUSIONS

China and India have both experienced economic growth over the past twenty years, which is resulting in changes in domestic consumption. These changes are expected to alter China and India's trade of agricultural commodities. While both countries have tried to maintain self-sufficiency through policies and the practices of retaining grain stocks, they may be unable to continue these practices in the future and thus will become large importing countries of agricultural commodities. The impact on global agriculture could be substantial as major exporting countries would have to increase production to meet growing global demand.

The objective of this study is to examine the expected changes in China and India's import and export demand of corn, wheat, rice, and soybeans and the impact of these changes on the United States and other major importing and exporting countries. The following are specific objective of this study:

1. To predict Chinese and Indian crop production and trade flows and their impacts on world agriculture under different scenarios.
2. To evaluate the competiveness of the United States and other major exporting countries in exporting grains to China, India, and other major importing countries.

A spatial equilibrium model, based on a mathematical programming algorithm, was developed to conduct the research. The model optimizes production in China and India and other major producing regions and trade flows are determined based on comparative advantage.

Summary

China in the Base model produces 99.31, 136.33, 123.47, and 15.52 million metric tons of wheat, corn, rice, and soybeans, respectively. As a result, China must import 0.76 million metric tons of wheat, 29.02 million metric tons of soybeans, and 3.63 million metric tons of corn to satisfy its domestic consumption. However, in the Base-20 model China produces 106, 177, 128, and 18 million metric tons of wheat, corn, rice, and soybeans, respectively. To satisfy its domestic consumption it must import 4.58 million metric tons of corn and 44.4 million metric tons of soybeans; however, it is now able to export 1.12 million metric tons of rice. China will likely be able to satisfy its domestic consumption of rice and wheat through its domestic production in 2020. Therefore, increases in technology allow China to stay self-sufficient in these cereal grains. However, the results also indicate that despite increased production due to increasing yields, China will have to increase its imports of corn and soybeans in 2020 to satisfy domestic demand.

The alternative scenarios indicate that in most scenarios China is able to maintain its self-sufficiency in wheat and rice. China imports these commodities in the scenario in which yields are decreased by 20 percent from the Base-20 model. In all scenarios, China imports soybeans. China imports corn in most scenarios; however the quantity imported remains relatively small in all but the reduced yield scenario. Thus, China's impact on global agriculture will be most significant in soybeans, with China importing nearly 54 percent of global soybean exports in 2020.

In the Base model, India produces 80.02, 14.29, 91.05, and 7.23 million metric tons of wheat, corn, rice, and soybeans, respectively. Thus, domestic production is enough to allow India to be self-sufficient in corn and rice and export 3.62 million metric tons of wheat. India does have to import 2.23 million metric tons of soybeans to satisfy domestic consumption. In the Base-20 model India produces 92, 19.62, 108.42, and 10.87 million metric tons of wheat, corn, rice, and soybeans, respectively. Therefore, it is able to increase its exports of wheat to 6.63 million metric tons, but must import .56 million metric tons of soybeans to meet growing domestic demand. Increased production in 2020, due to advancements in farming technology, allows for India to remain self-sufficient in rice and corn, expand its wheat exports, and reduce its soybean imports.

The alternative scenarios confirm the conclusions from the Base-20 model. India is not a large importer of any of the four crops and consistently exports wheat and remains self-sufficient in rice and corn in all but the alternative scenario in which yields are decreased 20 percent from the Base-20 model projections. This indicates that India will likely be able to remain self-sufficient in most crops in 2020.

Global agriculture in 2020 reveals an increase in production in order to meet rising global demand. The United States exports the most corn and soybeans in the Base and Base-20 models, as it increases its production in the Base and Base-20 models by 21.1 and 33 percent, respectively. The United States exports the most wheat in the Base model; however, in 2020 Canada surpasses the United States to become the largest supplier in the global wheat market as it exports 22.27 million metric tons of wheat compared to the U.S. exports of 22.06 million metric tons. From the current period to 2020, Argentina becomes a large producer of corn and increases its corn exports substantially. As a result, it

decreases its soybean production and exports, showing its comparative advantage in producing corn. Brazil increases its soybean production in 2020 and as a result becomes the second largest exporting country of soybeans in the world. Southeast Asia is the largest rice producer and exports the most rice in both the Base and Base-20 models. While other countries/regions also contribute to global grain trade, the United States, Canada, Brazil, Argentina, and Southeast Asia play the largest role in supplying the world with these four staple crops.

Conclusions

The following conclusions are drawn based on the discussions above:

1. China is likely to be able to stay self-sufficient in wheat and rice in 2020, but will import soybeans and corn. This is due mainly to changes in consumption patterns in which Chinese consumers are consuming less wheat and rice and consuming more corn and soybeans. While China will be able to produce much of its needed corn, the country will become the world's largest soybean importing country.
2. India will likely remain self-sufficient in wheat, rice, and corn. However, India will import a small amount of soybeans to satisfy its domestic consumption. It is expected that advanced technology in farming will allow India to produce enough wheat, rice, and corn to fulfill its growing domestic demand and allow it to continue to export wheat. India will import soybeans, though not as much China as its structural changes in demand are not as pronounced.
3. The United States has an advantage in exporting soybeans to China; however, India and China will both import soybeans from Brazil. In 2020, the United States will remain the largest corn exporter, though Argentina will increase its exports to meet rising demand in China. Canada will surpass the United States in wheat exports, though both will remain large wheat exporting countries. The United States will increase its rice exports, though exports of rice are not large comparatively. Southeast Asia will still produce and export the most rice in the world.

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