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Fundamental Factors Affecting World Grain Trade in the Next Two Decades

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Abstract

Changes are occurring in the world grain trade that are impacting the spatial distribution of grain flows. Important amongst these are developments in ethanol production in the United States, soybean production in Brazil, and increased imports of soybeans for China. This article develops a spatial optimization model based on a longer-term competitive equilibrium to make projections in the world grain trade and shipments from individual ports to the year 2025. Results indicate that world trade should increase by about 47%, with the fastest growth occurring in imports to China and Pakistan. Japan and the EU, traditionally large markets, have the slowest growth. Most of the increases are expected in soybeans (49%), followed by corn (26%), and most of the U.S. export growth is expected through the U.S. Gulf.

Highlights

Important structural changes are occurring in the world grain trade that will impact the longer-term competitiveness of countries and regions. These changes include developments in North American ethanol, the rapid growth in income and population in China, and the structural changes in production and shipping of soybeans in Brazil.

Corn use for ethanol will approach 2 billion bushels by the end of the decade. Since 1993, ethanol production has grown 143%, and it is forecasted to grow an additional 38% by 2013. Most of the growth in ethanol consumption will be concentrated in the Central and Northern Plains and the Western Corn Belt. Over time, this increase in domestic demand will result in a shift in production from soybeans and traditional small grains to corn.

Soybean production in Brazil expanded rapidly in the traditional South region, increasing from less than 2 million hectares (mha) in 1970, to nearly 8 mha in 1975. The regions in which most of the recent expansion is occurring are in the Central West, and North. The area planted in these regions has increased from nil through the mid-1970s to more than 7 mha, exceeding that in the traditional South. Soybean production in Brazil has increased 258% since 1987, from less than 20 mmt to almost 65 mmt today.

The rapid increase in domestic demand for soybeans in China has led to an increase in imports from almost zero in 1994 to over 20 million metric tons in 2004. In 1996, the U.S. had 65% of the Chinese soybean market, but the U.S. market share fell to 49% in 2003. Brazilian and Argentine exports to China have increased from 0.5 million metric tons in 1996 to 8.7 million metric tons in 2003.

World import demand for corn is expected to increase about 26% for the 2001-2025 period. Japan is the largest importer of corn, followed by North Africa and S. Korea in 2001. China will be the second largest importer in 2025, with an import of 9.9 mmt.

Corn production is expected to increase mostly in the three dominate regions: the Eastern Corn Belt, the Western Corn Belt and the Central Plains. Soybeans will increase primarily in the Eastern Corn Belt and the Western Corn Belt. Wheat production will increase in Saskatchewan, the Central Plains, and the Northern Plains by about 2 mmt each.

U.S. exports from the Gulf are expected to increase by about 26 mmt, whereas the level of exports from the U.S. PNW will increase only marginally. There is also substantial growth in exports from Brazil, primarily soybeans. Most of these exports are expected to come Northern Brazil export ports, whereas Southern Brazil exports will grow by a lesser amount. Exports from Argentina are expected to grow by 23 mmt, primarily in soybeans and wheat. Growth in wheat exports is mostly from Argentina and Australia.

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INTRODUCTION

Important structural changes are occurring in the world grain trade that will impact the longer-term competitiveness of countries and regions. These changes are influenced by many factors, including production, consumption which is impacted by tastes, population and income growth, and agricultural and trade policies. In addition, relative costs of production, interior shipping, handling and ocean shipping costs all have an impact on trade and competitiveness. Changes in any of these costs impact the international distribution of grains and oilseeds. Some of the variables that have particular importance in the dynamics of production and trade are differential population and income growth impacting demand, differential growth rates in yields, and differences in costs of production and/or marketing. In addition to these, we highlight three structural changes that are particularly important in the longer term. These include developments in North American ethanol, the rapid growth in income in China, and the structural changes in production and shipping of soybeans in Brazil. Interest in these and other factors impacting the longer-term evolution of world grain trade are particularly important for policy planners, as they provide information for infrastructure investments and an understanding of the structural changes in production and trade that impact intercountry competitiveness.

The purpose of this study is to analyze the longer-term competitiveness of agricultural production and trade of six major grains (wheat, corn, soybeans, barley, sorghum, and rice). We develop a spatial optimization model based on longer-run competitive equilibrium of the world grain trade using very detailed data. Changes in production and trade are simulated to the year 2025. The first section of the paper describes historical production, consumption, and trade for corn and soybeans; in the next section, we describe the background of the important structural changes. The paper focuses on corn and soybeans because changes in production and consumption of these two crops are expected to be dynamic in the future. Then, we describe our model and data sources. Base case results are then presented and forecasts are made to the year 2025. Finally, we summarize and discuss the implications of some of the major factors impacting trade in the longer term.

RECENT CHANGES IN THE WORLD CORN AND SOYBEAN INDUSTRIES

While numerous structural changes are occurring in the world grain trade, there are three that have particularly important impacts on longer-term competitiveness.

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Ethanol

An important change in U.S. grain consumption is corn use for ethanol. This industry has been expanding during the past decade, and its rate of expansion is expected to accelerate in the coming decade. These increases will impact demand for domestic corn consumption in the future and decrease exportable supplies.

For perspective on growth and changes in this sector, Feltes (2003) indicated that the demand of corn for ethanol is projected to increase by 1 billion bushels in the next 10 years. ProExporter (2003) indicated that the United States will need another 40 or 50 ethanol plants, which would divert another 1 billion bushels of corn, doubling the amount of corn devoted to ethanol production today. Similarly, the U.S. Department of Agriculture (USDA, 2003 Outlook conference) indicated that "over 1 billion bushels of corn will be used to produce ethanol in 2003/04, and this approaches 2 billion bushels by the end of the decade." Figure 1 shows the bushels of U.S. corn which were converted to ethanol from 1993 to 2003, and FAPRI's projections to the year 2013. Since 1993, ethanol production has grown 143%, and it is forecasted to grow an additional 38% by 2013.

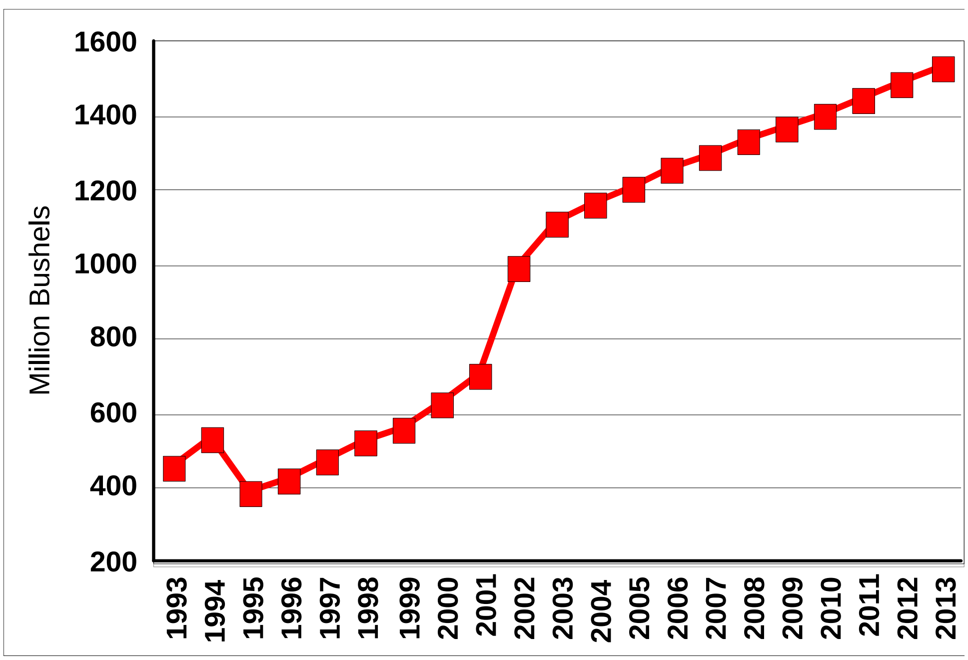

Figure 1. U.S. Corn Used for the Production of Ethanol

There are several important aspects of the growth in demand for ethanol production. The most important one is that it is concentrated in the Western Corn Belt. Results from two separate studies were used to form projections for future ethanol capacity and corn consumption. Guebert (2002) cites industry projections that total ethanol demand in 2012 will be 5.5 billion gallons/year. The California Energy Commission surveyed current and prospective firms on plans for ethanol capacity to the year 2005 and derived expected plant capacity by region in

2005. Using these projections and some technical assumptions, we derived the projected consumption of corn by producing/consuming regions for the year 2005 and 2010. These results indicate that as a result of the accelerated ethanol demand, corn consumption will increase another 13% by 2010, versus what would otherwise be natural consumption growth. Most of the growth in ethanol consumption will be concentrated in the Central and Northern Plains and the Western Corn Belt. Over time, this increase in domestic demand will result in a shift in production from soybeans and traditional small grains to corn. For each of these regions, this increase in domestic demand will reduce their exportable surplus, which otherwise would have been shipped off-shore.

Changes in Brazil's Soybean Production

Soybean production and productivity in Brazil is changing and will impact world production and trade. Major producing states in Brazil include Parana in the South and Matto Grosso in the Central West. Soybean production in Brazil has traditionally been in the southern regions. These soybeans were typically used for domestic crushing and the production of soybean oil and meal used locally for food and feed or exported as products. Soybeans were also exported directly, typically from the southern ports of Santos and Paraguan.

Soybean production expanded rapidly in the traditional southern region, increasing from less than 2 million hectares (mha) in 1970 to nearly 8 mha in 1975. Since then, the area planted in this region has remained in the 6-7 mha level. Most of the recent expansion is occurring in the Central West and North regions. Area planted in these regions has increased from nil through the mid-1970s to more than 7 mha, exceeding that in the traditional South. Figure 2 shows the production, consumption, and exports for Brazilian soybeans. Production has increased 258% since 1987, from less than 20 mmt to almost 65 mmt today. Domestic consumption of soybeans has increased 156% during the same time period and exports of soybeans have increased 721% from 2.7 mmt in 1987 to 22.3 mmt in 2004.

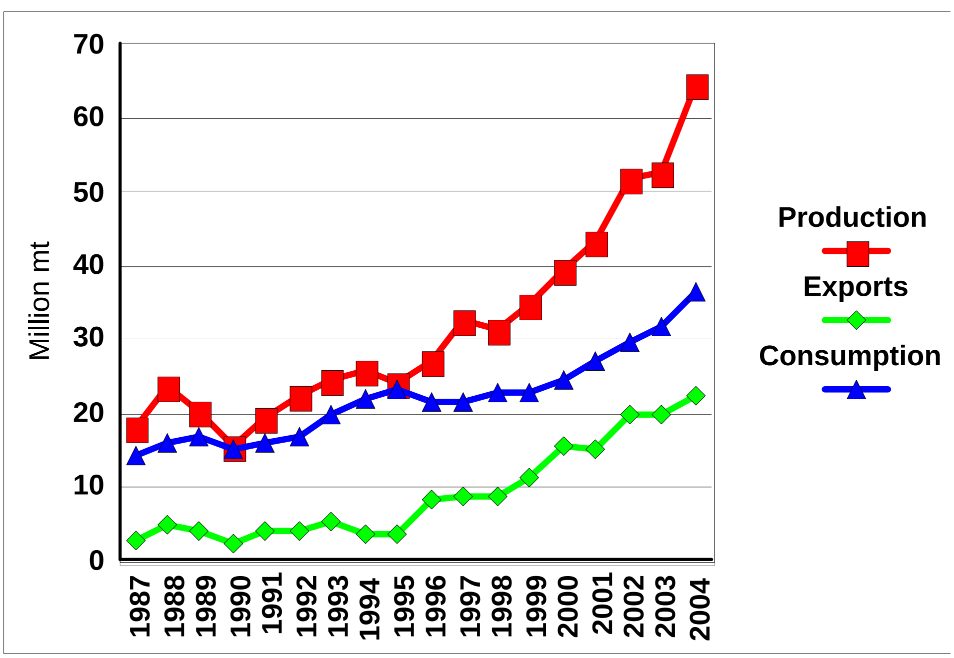

Figure 2. Brazil's Soybean Production, Consumption, and Export

In recent years, there have been two major changes. One is a sharp increase in production and the other is a shift in production to more northerly regions. These changes in production have resulted in simultaneous pressure for the development of a transportation infrastructure to carry exports from these regions. In addition to the growth in production potential, changes are occurring in shipping economics within Brazil. Several infrastructure projects are underway, being planned, or being discussed. All of these projects are focused on developing lower-cost means of exporting soybeans, generally through the northerly ports. Among these projects is the development of interior truck/water shipments to Itacoatiara and Santarem (a port facility that opened in April 2003). The BR163 is a highway to Santarem which was recently proposed, but is now under environmental review. In addition to these measures, a number of other projects are being planned (Governo Federal).

Taken together, these projects would lower shipping costs from these otherwise high-shipping cost regions, which would change the flows of exports within Brazil and increase returns to producers by about $10/mt. Analysis by ANTAQ (Governo Federal 2002) indicated that by 2015 shipments to the north would become more competitive. The results also indicated an apparent change in the advantage in shipping north: for shipments from a central city of Sorriso, the freight rate advantage increases by about $11/mt, from -1$/mt to +10/mt by 2015.

Currently, shipping costs from Mato Grossa via the northern ports are lower than those going through the traditional southern ports. The advantage of northern shipments is expected to expand to other producing regions if/as some of the infrastructure projects are completed. In most cases, northern shipment of soybeans from Brazil would be natural outlet for exports to Rotterdam, the traditional market, or to Asia and China via the Panama Canal. Both routes would be considered non-traditional export markets.

The United States dominated the world soybean export market until about 1996. Previously, the United States exported about 65% of the world's soybeans. Today, the United States exports about 42%. Both Brazil and Argentina have increased their export share during the late 1990s and early 2000s. Today, Brazil exports 35% of the world's soybeans and Argentina exports 11%. Figure 3 shows the level of soybean exports for the United States, Brazil, and Argentina.

China's Growth in Import Demand

China is a very large market with rapid growth in population and income, leading to continued rapid growth in domestic demand. Though China is also a large grain and oilseed producer, their productivity growth rate is not expected to keep pace with demand.

Sparks (2003) expects Chinese corn exports to eventually taper off at only 2 mmt by 2006. The Chinese central planners are trying to increase soybean acres to reduce their dependency on imports but have registered little success to date. The Chinese soybean area has increased only 1.4 mha since 1998, despite declines in wheat and feed grain area of 5.1 mha and 1.0 mha, respectively.

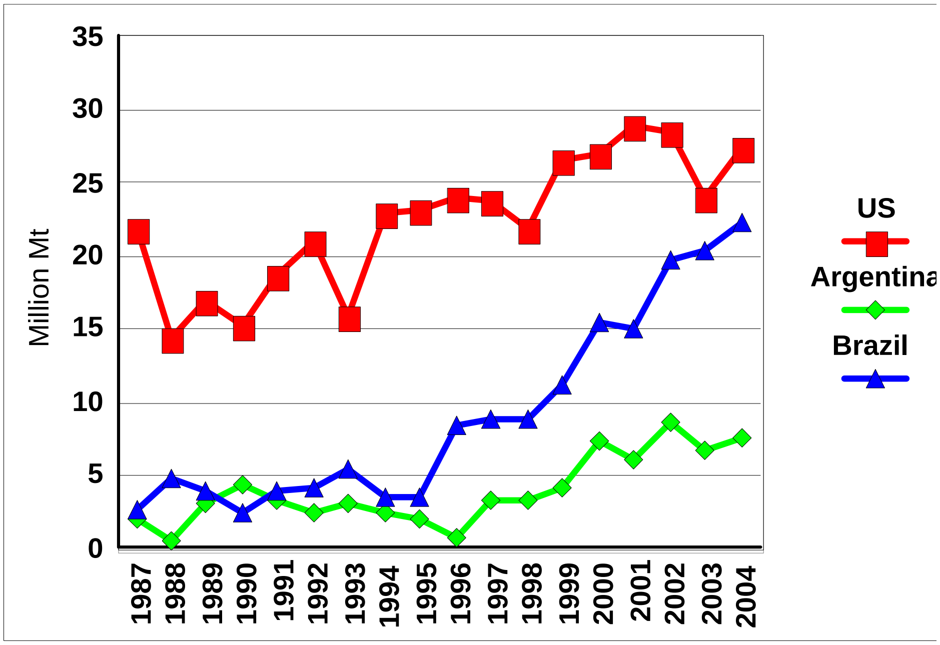

Figure 3. World Soybean Exports, Major Exporters

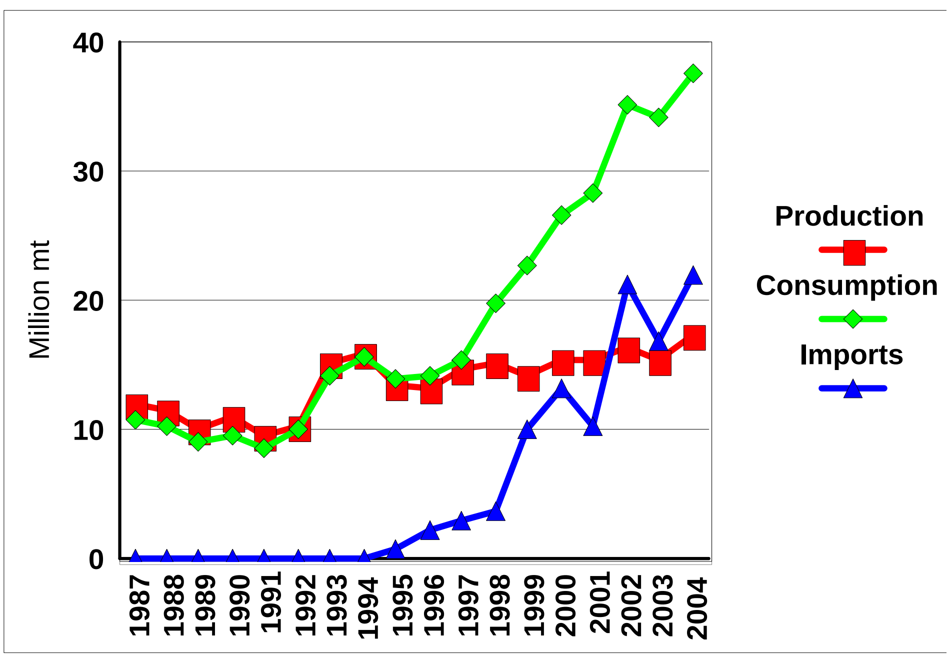

Figure 4. China's Soybean Production, Consumption, and Imports

The rapid increase in domestic demand for soybeans in China has led to an increase in imports from almost zero in 1994 to over 20 million metric tons in 2004. In 1996, the United States held 65% of the Chinese soybean market, but the U.S. market share fell to 49% in 2003. Brazil and Argentine exports to China have increased from 0.5 million metric tons in 1996 to 8.7 million metric tons in 2003.

The 2003 USDA Agricultural Baseline Projections suggested Chinese imports of wheat would increase from 1.5 mmt in 2003/04 to 9.1 mmt by 2012/13. They cite land use competition and increasing water limitations in China as causes for the country's need to import more wheat (*Milling and Baking News,* February 18, 2003, p. 39). The 2003 USDA Outlook suggested a sharp uptrend in Chinese imports of soybeans which would continue unabated for the next 10 years, eventually rising above 25 mmt by 2011. However, ProExporter labeled this projection "not remotely plausible," instead seeing Chinese imports stabilizing between 16-18 mmt over the next 10 years.

EMPIRICAL MODEL: SPATIAL GRAIN FLOWS, SIMULATIONS, PROJECTIONS, AND IMPACTS

A large number of factors impact the distribution of world grain trade. These include supply and demand in individual countries and regions, production costs, trade and agricultural policies, interior shipping and handling costs, and ocean shipping costs. To analyze these, a spatial optimization model of world trade in grains was developed. Twenty importing and exporting countries and 11 regions were identified and selected for six crops: barley, corn, rice, sorghum, soybeans, and wheat. Within North America, there were 15 producing regions and 15 consuming regions, conforming with traditional production/consumption regions. Agronomic characteristics and consumption were estimated econometrically and are described first. We then describe the spatial optimization model and data sources.

Harvested Area, Yields, Domestic and Import Demand

Harvested area (HA) was obtained for the six crops in 31 countries/regions and the 15 North American regions. HA is specified as a function of a trend which represents longer-term changes in arable land for each grain in the individual countries and regions. This was used as a constraint in the empirical model described below. Changes in arable land may be due to changes in economic conditions and availability of water for agricultural production and trade environments. Harvested area is specified as:

$$HA_{ci} = \alpha_{0ci}+\alpha_{1ci}Trend + e_{cit} \quad (1)$$

where c = 1 to 31 and represents producing regions, and i = 1 to 6 and represents crop. The model is estimated with time series data of HA from 1980 to 2001, and the estimated model is used to forecast HA for the 2002-2025 period. The estimated amount in each country was the upper limit used in the model.

Yield (YLD) for each crop in individual countries/regions is specified as a function of the trend which represents advancement in farming technology. Since crop yields have increased at a decreasing rate in most countries, a double log functional form was used. The yield equation is specified as:

$$\text{LnYLD}_{cit} = \alpha_{0cit} + \alpha_{1ci}\text{LnTrend} + e_{cit} \tag{2}$$

where c = 1 to 31, i = 1 to 6, trend = 1980 to 2001. Annual data for HA and YLD for the years 1980-2001 were obtained from the USDA PS&D database (USDA, Foreign Agriculture Service 2002). The estimated model was used to forecast yields of each crop from 2002-2025.

Consumption functions were estimated for the six crops in the 20 countries and 11 multi-country regions. A double log functional form was used because of the nonlinear relationship between income and consumption.

$$\text{LnPCC}_{cit} = B_{0cit} + B_{1ci}\,\text{LnTrend} + B_{2cit}\,\text{LnPCI} + e_{cit} \tag{3}$$

where c = 1 to 31, i = 1 to 6, trend = 1980 to 2001, PCC is per capita consumption, and PCI is per capita income. The estimated PCC model was used to forecast PCC from 2002-2025. Future forecasts of PCI were derived from WEFA Macroeconomics (2002). From these results, we derived the total domestic demand for each grain in each country or region.

Import demand (MD) for each crop in the countries/regions was defined as:

$$\text{MD}_{cit} = \text{DD}_{cit} - \text{DP}_{cit} \tag{4}$$

where DP is total production and DD is domestic consumption. If MD is positive, country c is an importing country, while country c is an exporting country if MD is negative.

Spatial Optimization Model

The objective of the model is to minimize production costs of grain and oilseeds in major producing countries and marketing costs from producing regions to consuming regions, subject to meeting demands in importing countries and regions, available supplies and production potential in each of the exporting countries and regions, and currently available shipping costs and technologies. The logic to the objective function is that it reflects what would be considered a longer-term competitive equilibrium whereby spatial flows are determined by costs, technical restrictions, and other relationships. In the long run, it is more likely that a large portion of subsidies given to producers in both exporting and importing countries under the globalizing trade environment will decrease, and are otherwise non-discriminatory. Under these conditions, trade flows of agricultural commodities would be determined by demand, production costs in exporting countries and marketing costs from exporting to importing countries. In addition, yields in producing regions of exporting countries are included to measure efficiency in the production of grain and oilseeds. Demand is projected and the least-cost means of meeting that demand is derived. This differs from econometric models that use functional relationships to project equilibrium trade levels, which are generally incapable of capturing spatial elements of competition. Given that our objective is to make longer-term forecasts with greater emphasis on spatial and modal distributions, a model based on longer-term competitive equilibrium was used.

The model is solved jointly for each of the six grains. Costs included in the model are direct production costs for each grain in each exporting country and region; interior shipping and handling costs for each grain in each exporting region; and ocean shipping costs, including tolls for shipments through the Panama Canal.

The model contains 13 exporting countries and 26 importing countries, with each type of grain and oilseed having different sets of exporting and importing countries. Some exporting countries are further divided into producing and consuming regions to capture the inter-dependency between the transportation system and agricultural production. Transportation modes included truck, rail, and barges for inland transportation and ocean vessel for ocean transportation. The model contains 16 ports in exporting countries and 32 ports in importing countries for the transit of grains and oilseeds from producing regions in exporting countries to consuming regions in importing countries.

The objective function is optimized subject to a set of constraints, including arable land constraints in exporting countries and demand constraints for each type of grain and oilseed in consuming regions in both exporting and importing countries. The objective of the model is to minimize production costs in producing regions in exporting countries and shipping costs from producing regions in exporting countries to consuming regions in importing countries. This objective function is:

$$W = \sum_{c} \sum_{i} PC_{ci} \; A_{ci} + \sum_{c} \sum_{i} \sum_{j} t_{cij} \; Q_{cij}$$
$$+ \sum_{c} \sum_{i} \sum_{p} t_{cip} \; Q_{cip} + \sum_{c} \sum_{p} \sum_{q} t_{cpq} \; Q_{cp}$$
$$+ \sum_{c} \sum_{p} \sum_{q} \left(t_{cpq} + \alpha \right) Q^{p}_{cpq}$$

where i=index for producing regions in exporting countries, j=index for consuming regions in both exporting and importing countries, p=index for ports in exporting countries, q=index for ports in importing countries, PC_{ci}=production cost of crop c in producing region i, A_{ci}=area used to produce crop c in producing region i, t=transportation cost per ton, Q=quantity of non-Panama Canal grains and oilseed shipped, Q^p is the quantity of grains and oilseed shipped through the Panama Canal, and α=tariff used in the Panama Canal.

The first term on the right hand side represents production costs in producing regions in exporting countries; the next two terms represent transportation costs for shipping agricultural goods from producing regions to domestic consuming regions and export ports. The next term represents ocean shipping from ports in exporting countries to ports in importing countries. The last term represents ocean shipping through the Panama Canal.

This objective function is optimized subject to the following constraints:

1) $Y_{ci}\ A_{ci} \geq \sum_{j} Q_{cij} + \sum_{p} Q_{c}$

2) $\sum_{c} A_{ci} \leq T$

3) $A_{ci} \geq MA$

4) $\sum_{i} Q_{cij} + \sum_{q} Q_{cqj} \geq MD$

5) $\sum_{c} \sum_{i} Q_{cip} \leq PC$

6) $\sum_{c} \sum_{p} \sum_{q} Q^{p}_{cpq} \leq PC$

7) $\sum_{i} Q_{cip} = \sum_{q} Q_{c}$

8) $\sum_{p} Q_{cpq} = \sum_{j} Q_{c}$

where y=yield per hectare in producing regions in exporting countries, TA=total arable land in each producing region in exporting countries, MA=minimum land used for each crop in producing regions in exporting countries, MD=forecasted domestic demand in consuming regions in exporting countries and import demand in consuming regions in importing countries,

PC=handling capacity in each port in both exporting and importing countries, and
PCC=throughput capacity for grains and oilseeds at Panama Canal.

Equation 1 indicates that total grains and oilseeds produced in each producing region in exporting countries should be equal to or larger than the quantities of grains and oilseeds shipped to domestic consuming regions and export ports. It is assumed that a country exports grains and oilseeds after satisfying its domestic consumption. Under this assumption, exportable surplus is total domestic production of each type of grain and oilseed minus domestic consumption of the individual crops. Equation 2 is the physical constraint of arable land in each producing region. Since total arable land is normally fixed, production activities should be optimized within the physical constraint of arable land. However, Brazil is expanding harvested area into non-traditional regions in the north; therefore, Brazil’s area is allowed to expand. The next constraint (Equation 3) represents characteristics of production activities in each producing region in exporting countries. In general, producers in a region tend to produce certain crops due mainly to their experience in production practices of the crops and soil types, even though producing the crops is not economically optimal. To incorporate this characteristic, Equation 3 provides the minimum production constraint for each grain or oilseed. Since demand for grains and oilseeds is estimated to 2025 using econometric techniques, the estimated demand for grains and oilseeds in each consuming region in importing and exporting countries is introduced to the model. Equation 4 represents the import and domestic demand constraints in importing and exporting countries, respectively.

Equations 5 and 6 represent grain and oilseed handling capacities at ports in exporting and importing countries and the Panama Canal, respectively. Total quantities of grain and oilseeds handled by each port and the Panama Canal should be equal to or smaller than their annual handling capacities. The last two constraints are inventory clearing constraints at ports in exporting and importing countries. Ports in exporting and importing countries are not allowed to carry inventories and are considered as transhipment points in exporting or importing grains and oilseeds. Excess supply of a grain is calculated by subtracting domestic consumption from production under an assumption that carry-over stocks remain constant over time.

A base case is defined first and is used for comparison to results of prospective exogenous and endogenous changes, as well as changes in inter-regional and intermodal competitive factors. The base case is interpreted as that case reflecting the most likely (current) scenario. The base case uses values for the 2000/01 world crops marketing year for calibrating domestic consumption and production, as well as for interior and international shipping costs. In later simulations, assumptions are relaxed and values of variables in the model are changed, and the results are evaluated relative to the base case.

In addition to the restrictions implied above, some selected restrictions were imposed on the model to calibrate it to current trade patterns. These are summarized in Table 1. These were applied in order to capture some of the peculiarities associated with world grain shipments.

Table 1. Constraints Imposed on Model: Market and Trade Policy Restrictions

Exporter	Importer	Grain	Restriction	Reason	Impact	Duration
United States	Cuba	All grains (rice)	No trade	Trade Policy Restriction	Maintained assumption. Rice is imported from China.	Relaxed in 2005 forward.
U.S. Ethanol	None	Corn	None	Accelerated expansion. Reduced exportable supplies concentrated in western regions.	Exports favored from eastern regions through U.S. Gulf to Asia, versus U.S. PNW.	Commencing in base case with existing production; expanding in 2010.
U.S. West Coast	China	Wheat	Not allowed	TCK Smut	Forces China wheat to U.S. Gulf-relax in 2005.	Relaxed in 2005 forward.
U.S./Canada West Coast	Japan, Korea, Philippines, Singapore, Thailand	Wheat	Only allowed from West Coast N. America, despite higher cost.	Quality requirements	Disallows Gulf to these Asian markets at lower cost	Maintained
Australia	Japan, Korea, Philippines, Singapore, Thailand	Wheat	Max shipments only allowed at recent values.	Quality requirements	Forces hard wheats from N. America. No direct impact on Canal.	Maintained
Argentina, India	Japan, Korea, Philippines, Singapore, Thailand	Wheat	No shipments allowed	Quality requirements	Forces hard wheats from N. America. No direct impact on Canal.	Maintained
E. Europe	Japan	Wheat	No shipments allowed	Quality requirements	Forces hard wheats from N. America. No direct impact on Canal.	Maintained
China	Korea	Corn	Imports of 3 mmt	Reflect recent trade	Reduce exports from U.S. Gulf/Canal	Maintained
United States and Argentina	EU	Soybeans	Minimizes U.S./Arg to EU, thus making Brazil dominant supplier to EU.	GM-free soybeans are required in EU and produced only in Brazil.	Reduces exportable supplies for Canal shipments to Asia.	Relaxed in 2005 forward.

Most of the restrictions affect the wheat sector and relate to costs and quality differences among suppliers and importers. The restrictions are due in part to numerous lower-cost alternative suppliers in competition with North America. However, at least currently, importers have entrenched purchasing and import practices; imports from these regions are mostly due to quality differences, despite the higher cost.

There is an important restriction related to genetically modified oilseeds produced in Brazil. During the base period, the EU required non-GM specification, and the government of Brazil provided a certificate indicating that soybeans exported from the country were GM-free. None of the other major soybean producers were GM-free during the base period. Thus, we impose the restriction that a minimum volume must be exported from Brazil to the EU. This is despite the fact Brazil is a lower-cost supplier to some Asian markets relative to the EU and to alternative supplies from the United States. This restriction has been relaxed in 2005, in anticipation of GM adoption by Brazil and a relaxation of import requirements in the EU.

Data

Production costs of grains and oilseeds are obtained from WEFA Macroeconomics. Yields of grains and oilseeds are estimated using an econometric technique and forecasted on the basis of expected development in farming technology for 2010 and 2025. The data used for the yield estimation was from USDA, Foreign Agriculture Service and National Agriculture Statistics Service. The estimated demand equations for each category of grains and oilseeds are used to forecast consumption in each country. Income forecasts by WEFA Macroeconomics are used to forecast consumption.

Interior shipping costs were derived from the major producing regions in the United States, to major consumption regions, and to export ports. These were done for both rail and for barges from the primary barge origin points. For shipments from the Eastern and Western Corn Belts and Northern Plains to export ports, an additional alternative was added for shipment via barge to the U.S. Gulf. Ocean shipping costs were derived by Richardson Associates for each movement using typical vessel sizes and characteristics serving those markets. For future years, ship sizes and associated costs were allowed to change reflecting adoption of some routes.

BASE CASE RESULTS AND PROJECTIONS

Import Demand

World import demand for all grains is expected to increase about 47% for the 2001-2025 period (Figure 5 and Table 2). Pakistan (322% growth) and China (217% growth, from 19.8 mmt in 2001 to 62.6 mmt in 2025) would be the fastest growing markets in percentage terms. Japan and the EU will have the slowest growth in import demand (less than 1%). Among crops, import demand for wheat is expected to grow slightly faster than other crops.

Import demand for corn is expected to increase about 26 % for the 2001-2025 period. Japan is the largest importer of corn, followed by North Africa and S. Korea in 2001. China will be the second largest importer in 2025, with an import level of 9.9 mmt. China is expected to produce as much meat as possible to meet rapidly increasing domestic demand rather than importing the shortages from major meat producing countries. Because of this, China's imports of corn are expected to increase rapidly.

The increase in import demand for soybeans is about 49% for the 2001-2025 period. The largest soybean importer is the EU, followed by Japan. Import demand for wheat is expected to increase 61% for the 2001-2025 period. The largest importers are the Middle East, followed by North Africa. However, China's import will increase faster than other countries and the country will be the third largest importer of wheat in 2025, with an import volume of about 15.7 million metric tons. This is mainly due to a continuous decrease in wheat production in China, in contrast to the increase in consumption.

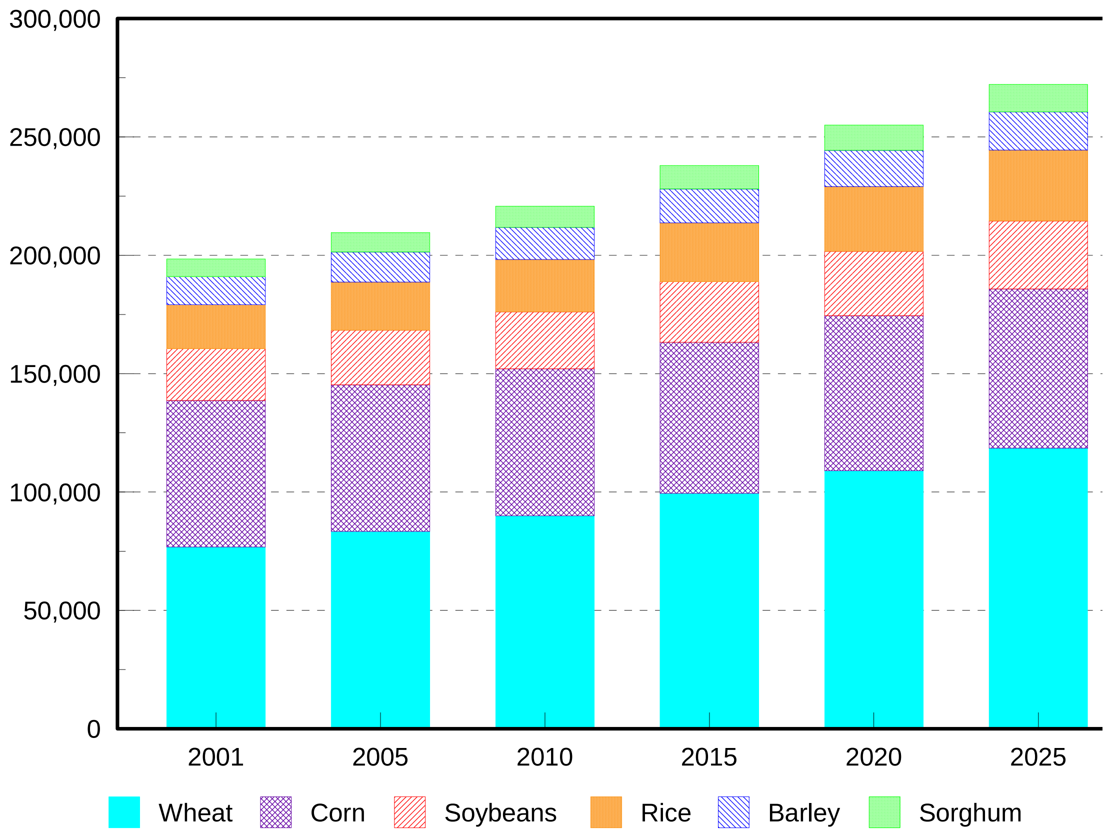

Figure 5. Total Import Demand, 2001-2025, All Grains (1,000 mt)

Table 2. Estimated Import Demand for All Grains, 2001-2025, 1,000 mt

	2001	2005	2010	2015	2020	2025	% Change
Africa East	4,770	5,306	5,843	6,970	8,097	9,224	0.93
Africa North	26,664	28,370	30,077	33,391	36,705	40,019	0.50
Africa South	2,263	2,423	2,583	2,832	3,081	3,330	0.47
Africa West	7,054	7,780	8,507	9,607	10,707	11,807	0.67
Brazil	9,196	11,058	12,358	13,367	11,626	13,702	0.49
Canada	4,055	4,294	4,532	4,977	5,422	5,868	0.45
Caribbean	4,505	4,681	4,857	5,120	5,383	5,645	0.25
Chile	2,046	2,158	2,271	2,466	2,661	2,856	0.40
China	19,793	26,638	44,213	50,098	56,457	62,648	2.17
East Europe	567	1,052	1,570	2,433	3,138	4,012	6.08
EU	20,907	19,157	19,516	19,908	20,202	20,701	-0.01
FSU	667	780	821	903	986	1,069	0.60
India	0	2,655	4,287	203	171	134	
Indonesia	9,924	10,309	10,694	11,324	11,954	12,584	0.27
Japan	31,381	31,546	31,711	31,869	32,027	32,186	0.03
Korea	13,609	13,870	14,132	14,266	14,400	14,534	0.07
Malaysia	4,644	4,918	5,192	5,633	6,073	6,513	0.40
Mexico	17,725	19,301	20,877	22,614	24,352	26,089	0.47
Middle East	37,722	40,788	43,854	48,530	53,206	57,883	0.53
Other South Am	14,850	15,153	15,455	16,222	16,989	17,756	0.20
Pakistan	662	1,197	1,733	2,087	2,441	2,795	3.22
Philippines	4,865	5,433	6,001	6,953	7,905	8,857	0.82
Singapore	660	688	715	752	789	826	0.25
Taiwan	8,572	8,800	9,028	9,410	9,792	10,174	0.19
Thailand	7,134	7,285	7,617	8,099	8,573	9,065	0.27
Venezuela	2,445	2,550	2,655	2,843	3,030	3,218	0.32
Vietnam	680	768	991	1,153	1,336	1,490	1.19
Total	269,364	290,988	324,147	346,119	369,621	397,131	0.47

Forecast to 2025

The model was used to generate forecasts for world trade to 2025. The sequence of changes imposed on the model are summarized in Table 3. Income and population changes impact demand, and changes in yields over time impact costs and potential supplies. Three models are run and compared: the base case (most likely), and pessimistic and optimistic cases. We define optimistic and pessimistic using WEFA's definition/interpretation of changes in income. WEFA presents income projections defined as most likely (our base case) and pessimistic and optimistic. The alternative income projections cover all importing and exporting countries. These were applied to our econometric estimates of demand and used to generate alternative projections of consumption, and therefore import demand. Thus, optimistic and pessimistic refer to the impact of income on country/regional demands in our analysis. Specifically, income and population growth affect demand for each grain. For those countries with positive income elasticities, an increase in income causes an increase in demand, and the opposite is true for countries with negative income elasticities.

Table 3. Sequence of Changes in Factors Impacting Canal Grain Shipments

Grain/Factor	Timing	Effect	Most Likely-Base Case
Demand growth due to population and income growth	Continual	Greater expansion for Canal shipments due to China	Projection and scenarios based on WEFA projections for income and population
Soybeans/GM in Brazil	2005	Shift soybeans from Brazil to EU	Maintained assumption in all cases
Rice to Cuba	2005	Liberalized trade will shift Cuban rice to United States, thereby reducing Canal shipments from Asia	Maintained assumption in all cases
Corn/ethanol	Continual, but accelerating in 2010	Reduced supplies for U.S. PNW exports, shifting exports to Asia via the U.S. Gulf and Asia	Maintained assumption in all cases
Brazil transport projects adopted	2010	Reduced shipping costs for northerly shipments	Adopted

The results are shown in Table 4 and Figure 6. The range in world trade in 2025 for these grains is 270 mmt to 360 mmt. There are a multitude of effects impacting these results. For the optimistic scenario, the most interesting and dramatic changes are increases in corn and soybeans to China and wheat to China and Korea. For the pessimistic scenarios, there are a multitude of minor changes. Developments in China are critical. Under the most likely and best cases, additional area in China is shifted into corn production, resulting in an expansion of about 9-10 mmt. This is in contrast to the pessimistic case in which area is removed from corn production (because China is a high cost producer), resulting in reduced production and increased imports.

One of the dramatic changes is the shift in land use in the United States to corn production. This is due to changes in demand which, in addition to natural growth, will accelerate with the increased production of ethanol. These results indicate land used for corn production in the United States will increase to 33.1 mha, versus the actual planting in 2001 of 32.2 mha. Corn production is expected to increase mostly in the three dominant regions: the Eastern Corn Belt (+9 mmt), the Western Corn Belt (+7.5 mmt) and the Central Plains (+5 mmt). Soybeans will increase primarily in the Eastern Corn Belt (+6 mmt) and the Western Corn Belt (+5.3 mmt). Wheat production will increase in Saskatchewan, the Central Plains, and the Northern Plains by about 2 mmt each. Changes in production in all other crops and regions are expected to be minimal, typically less than 1 mmt.

Table 4. Results Summary: All Grain Shipments by Exporter

	2001	2005	2010	2015	2020	2025
All Grain by Exporter						
Argentina	34,430	39,109	44,968	49,781	55,098	57,850
Australia	23,056	25,927	27,495	30,839	32,762	35,030
Brazil North	6,858	8,975	11,299	11,844	14,325	17,615
Brazil South	8,157	8,847	9,600	10,634	10,917	11,429
Canada East	1,326	1,366	1,469	1,653	1,718	1,966
Canada West	4,976	4,801	5,029	5,479	5,574	5,587
China	808	-	-	-	-	374
E. Europe	2,463	2,308	2,797	2,797	2,797	2,797
EU	29,458	33,323	37,124	42,812	49,509	55,331
FSU	10,583	9,150	8,774	11,041	13,496	15,221
India	3,603	4,008	4,008	4,008	4,008	3,910
Thailand	6,982	8,844	9,518	10,497	11,722	13,385
U.S. East	17,435	18,397	18,842	18,388	18,601	19,501
U.S. Gulf	63,392	67,090	77,209	79,903	83,318	89,330
U.S. West	9,793	9,768	9,746	9,869	9,981	10,180
Vietnam	4,948	5,172	6,095	7,670	9,015	9,494
Corn Shipments by Exporter						
Argentina	9,847	9,587	11,969	12,055	12,055	12,055
Australia	112	112	112	112	112	112
FSU	1,515	1,515	1,515	1,515	1,515	1,515
U.S. Gulf	39,351	42,816	51,353	51,285	53,847	56,339
U.S. West	8,100	8,100	8,100	8,100	8,100	8,100
Soybean Shipments by Exporter						
Argentina	10,076	13,240	14,354	16,911	20,041	20,400
Brazil North	6,858	8,959	11,204	11,644	14,010	17,178
Brazil South	8,157	8,828	9,481	10,382	10,521	10,875
Canada East	519	539	623	798	853	900
India	24	97	97	97	97	-
U.S. East	7,000	7,000	7,000	7,000	7,000	7,000
U.S. Gulf	16,046	14,332	14,150	16,709	17,243	19,877
Wheat Shipments by Exporter						
Argentina	13,578	15,041	16,568	18,393	20,297	22,280
Australia	17,020	18,115	19,202	22,059	23,324	25,835
Canada East	777	795	814	828	843	1,049
Canada West	3,596	4,801	5,029	5,040	5,081	5,093
East Europe	2,463	2,308	2,797	2,797	2,797	2,797
EU	25,096	28,006	30,882	35,841	41,848	47,015
FSU	4,122	3,954	3,786	4,822	6,280	7,313
U.S. East	10,215	10,451	10,689	11,034	11,306	11,657
U.S. Gulf	4,340	5,959	8,015	8,205	8,463	8,734
U.S. West	679	608	539	638	723	830

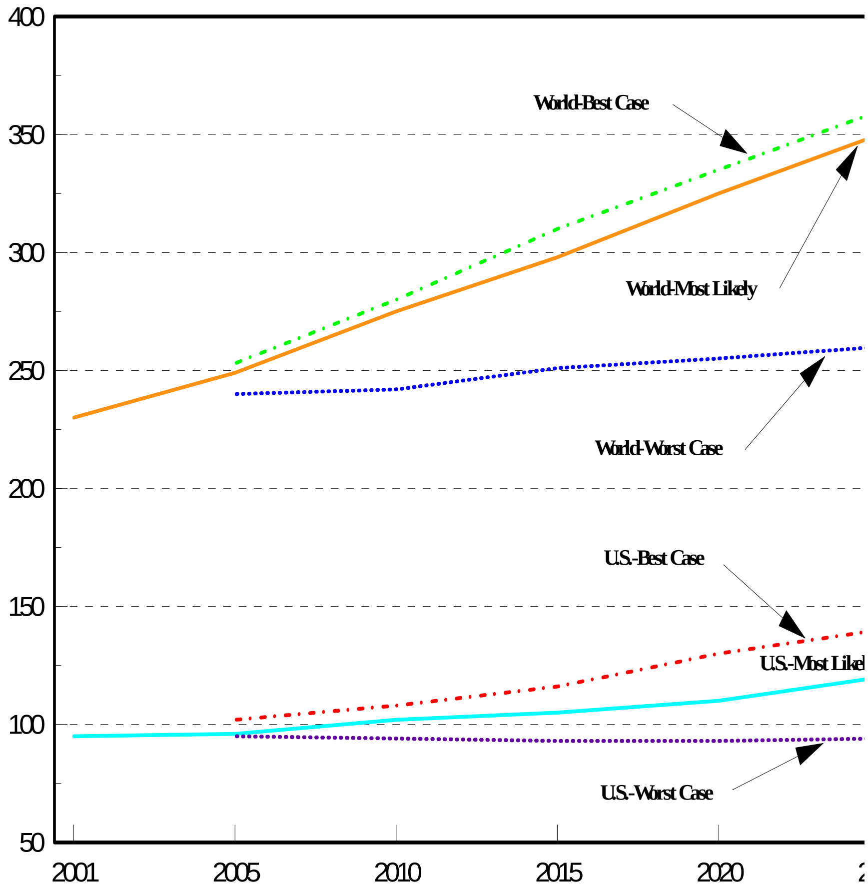

Figure 6. Estimated World Trade and U.S. Exports for Best, Most Likely, and Worst Case Scenarios (mmt)

U.S. exports from the Gulf are expected to increase by about 26 mmt, whereas the level of exports from the U.S. PNW would increase only marginally. Contributing factors include the growth in ethanol production, primarily in the West, shifts in cropping patterns, and the diversion of shipments through the U.S. Gulf.

There is also substantial growth in exports from Brazil, primarily soybeans. Most of this is expected to be from Northern Brazil export ports (growing from 7 to 17 mmt), whereas Southern Brazil exports would grow by a lesser amount. Exports from Argentina are expected to grow by 23 mmt, primarily in soybeans and wheat. Growth in wheat exports comes mostly from Argentina, Australia, and the EU. Of these countries, Argentina and Australia are relatively lower cost producers, while the EU is a higher cost producer that has a transportation cost advantage when shipping to Northern Africa and the Middle East.

CONCLUSIONS AND IMPLICATIONS

The international distribution of grains and oilseeds is influenced by many factors. These include agricultural production; consumption, which is impacted by tastes, population and income growth; and agricultural and trade policies. In addition, the relative costs of production, interior shipping, handling, and ocean shipping costs all have an impact on trade and competitiveness.

In recent years, U.S. market shares in the world soybean market have declined because of competition from Brazil and Argentina. The level of exports has increased mainly because of the strong demand from China. Corn used for ethanol has increased from 400 million bushels in 1995-1996 to over 1.1 billion bushels in 2004. Projections state the quantity of corn used for ethanol will be 1.5 billion bushels by 2013.

We developed a large-scale spatial optimization model based on long-run competitive equilibrium and used it to analyze changes in production and trade to the year 2025. There are numerous results of interest. World import demand for all grains is expected to increase about 47% for the 2001-2025 period. Pakistan and China will have the fastest growth in import demand for all grains. Japan and the EU will have the slowest growth in import demand (less than 1%). Among crops, import demand for wheat is expected to grow slightly faster than other crops. China's import demand for all grains and oilseeds is expected to increase about 217%, which will be a primary factor affecting the distribution of grain shipments.

This analysis suggests that there are numerous changes expected to occur in world grain trade over the next 25 years. Most of these are small, non-drastic changes due to the overall slow rate of consumption growth. However, there are four sources of more radical change that can and will impact the world grain trade.

One of the more dramatic changes occurring in North American agriculture is the development of ethanol. It is important to realize that there will be very rapid growth in this sector; by 2010, there will be about 28 mmt of added demand for corn used for ethanol alone. Most of this growth is concentrated in the Western Corn Belt. As a result, this growth is expected to attract increased land usage for corn, away from other grains, and will reduce exportable surpluses in those regions.

Though China is a large grain and oilseed producer, their productivity growth rate is not expected to keep pace with demand. These results are critical, in that China is expected to increase imports by about 40 mmt. Although a number of markets are expected to have growth rates exceeding 2% per year, the largest is China.

Brazil's production is expected to be able to increase sharply, resulting in soybean exports of up to 50 mmt by 2020. However, in our analysis, Brazil is not a low cost producer in terms of variable costs, which exceed those of the United States. However, because of land constraints in the United States, world production increases take place in Brazil. In our results, Brazil's exports increased from 16 mmt in the base period to 28 mmt in 2025.

The analysis uses both production and logistical costs; intercountry differences among the former are very important. We used variable cost of production and marketing, which in the very long-term is thought to be reflective of the true landed cost. In these analyses, those costs of particular relevance and importance belong to wheat and soybeans. Wheat production costs in most competing regions are lower than those in the major production regions in North America. While this is true of Australia and Argentina, traditional exporters, the differences are even greater amongst the emerging exporters of India, the FSU, and Eastern Europe.

Given that North America is one of the major grain producing regions in the world, these changes have important longer-term implications. Of particular importance is the large positive changes in production of corn and soybeans relative to all the other grains. Most of the positive changes in production are expected to occur in the Northern and Central Plains and the Western Corn Belt.

These changes have the impact of providing a challenge to maintain grain flows from traditional origins. We acknowledge there are quality differences in the case of wheat that will inhibit radical changes in trade flows and that will be immune from normal arbitrage pressures. Over time, we should expect pressures for changes in trade flows to be more reflective of cost differences. In the United States, that will likely result in more area being shifted out of wheat production. Brazil is one of the important targeted origins for growth in soybean production. However, it is important to recognize that Northern Brazil is not a low cost supplier and thus is interpreted as a residual supplier. This is particularly true in northern Brazil if interior shipping costs are included.

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