# Longer-Term Forecasting of Commodity Flows on the Mississippi River: Application to Grains and World Trade

by
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Project titled *Longer-Term Forecasting of Commodity Flows on the Mississippi River: Application to Grains and World Trade* Prime Contract # W912HQ-04-D-0007, DO#15. This report provides the summary for this study and the major results. It has an accompanying Appendix titled *Longer-Term Forecasting of Commodity Flows on the Mississippi River: Application to Grains and World Trade: Appendix* that provides all the background data, manipulations and description of the methodology. This project was conducted as a project contracted directly from the PI's to CDM Carbondale, Illinois and the results are represented as those of the PI's and not necessarily their employer.

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# Longer-Term Forecasting of Commodity Flows on the Mississippi River: Application to Grains and World Trade

## 1. Introduction and Overview

Agricultural commodities are one of the important products in world trade that are shipped on inland water ways. The international distribution of grains and oilseeds are influenced by many factors including agricultural production, consumption which is impacted by tastes, population and income growth as well as agricultural and trade policies. The relative costs of production, interior shipping, handling and ocean shipping costs all have an impact on trade and the competitiveness of interior logistical systems. Changes in any of these variable costs impact the international distribution of grains and oilseeds, and shipments through the US water ways.

The purpose of this study is to develop a methodology and analytical model to forecast shipments through the Mississippi River system. The methodology is generally applicable to a broad range of commodities and was applied to the grain sector. The focus is on the world grain trade and expected changes in response to a multitude of evolving competitive pressures and structural changes. Emphasis is on the competitiveness of the US grain and oilseed sector that is tributary to the Mississippi River system, and to assess impacts of critical variables on its competitiveness, and to project changes in flows for 50 years. Finally, the forecasts will be caste using stochastic optimization methods to measure distributions of future flows and explicit measures of risks.

To analyze these effects, a spatial optimization model of world grain trade was developed. Important parameters for the model are forecasted for relevant periods forward and used to evaluate changes in flows through the targeted logistical channels. Projected import demands are based on consumption functions estimated using income and population and accounting for intercountry differences in consumption dependent on economic development. Each of the competing supply regions and countries were represented by yields, area potential that could be used in production of each grain, costs of production and interior shipping costs where relevant. Crucial in this project is the interior spatial competition between the US Pacific Northwest and shipments through the US Gulf as well as inter-reach competition.[1]

***Methods*** The research and model development was the result of three major steps including:

1) Collection and analysis of data impacting world trade in grain and oilseeds. These include data on production, consumption, imports, interior shipping and handling costs, and international shipping costs. All data were assembled and are available on an accompanying CD-Rom.

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[1]This contrasts with other recent studies focusing on grain exports through the US Mississippi river system. Without being exhaustive, some of those used historical data from US production and/or exports to make projections into the future. The distinction here is that we make projections in demand, by country world wide, and use these to determine the most efficient flows and production activities to meet those demands.

2) Development of an analytical model to analyze world grain and oilseeds trade. Specifically, a large scale nonlinear programming model was developed.

The spatial optimization model was built for purposes of analyzing prospective changes in grain shipments as a result of exogenous changes in factors impacting world grain trade and other competitive factors. In addition, it was used to generate forecasts of changes in shipments over the next 50 years.

The model has the objective of minimizing costs of world grain trade, subject to meeting demands at 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 model was solved jointly for corn, soybean and wheat. Costs included in the model are production costs for each grain in each exporting region and country, interior shipping and handling costs and ocean shipping costs. First a base case is evaluated and interpreted relative to current grain trade. Forecasts of varying periods forward, up to 50 years, were generated. The base case uses values for the 2002 world crops marketing year for calibrating domestic consumption and production, as well as for interior and international shipping costs.

3) Stochastic optimization procedures were integrated into the model for purposes of evaluating the impacts of the critical uncertain variables and to derive the distributions about the forecasts. Important uncertain variables are error terms in the consumption functions and production forecasts. Distributions about these variables were derived and integrated into the stochastic simulations.

Development of the model confronted several major challenges. One was that in some years the supplies produced were inadequate to meet demands. Thus, the deterministic model was infeasible our base year. Second were the peculiarities of the wheat market. Finally, the model was a large scale model of world grain production and transportation to determine intercountry levels of production and trade flows, as well as the determination of production of each crop in each country and region. In addition to these, the model had to explain the simultaneous allocation of shipments among modes and among different segments, or Reaches in the U.S. river and transportation system. Thus, there was a high degree of international aggregation that was solved simultaneously with a highly micro focused U.S. domestic shipping industry.

## 2. Background

***2.1 River System Issues*** Numerous studies focused on issues related to the Mississippi River and grain transportation (see summary of studies below). In addition, there are a number of recent initiatives to expand various components of the river system. This study however, was motivated in part by the National Academy of Sciences (2004). In their review, the National Academy of Sciences noted

*Such scenarios will always contain a degree of uncertainty, and uncertainty alone should*

*not justify the delay of investment decisions. But the magnitude and the potential effects of investments being considered in the feasibility study require scenarios that are consistent with the key drivers in global and national grain markets, that are supported by credible model results, and that are consistent with the knowledge of credible and independent experts*. (p. 9).

In commenting on the issues related to the analysis, the National Academy of Sciences indicated

*Model development efforts have not adopted, for example, realistic assumptions regarding spatial variation in grain production and shipping costs, the range of ports that might be accessed by regional grain production, domestic processing demands and the location of these demands, or global grain supplies and demands. The restructured study also assumes that the division of grain exports among available ports will not change, which is an unlikely assumption. As lock congestion builds on the U.S. inland waterway system, domestic markets and alternative ports and routing become increasingly feasible and likely ...Moreover, since 80 percent of U.S. corn production is domestically consumed, some dimension of this demand should be explicitly modeled. With some improvements and adjustments, existing spatial grain models could be adapted to give superior insight to the approaches currently considered by the Corps. ...Our committee has not sufficiently studied the Panama Canal transportation demand model to be able to recommend it specifically for use in the UMR-IWW study; however, it is a fully developed model that goes a long way toward incorporating the elements of a full spatial equilibrium model and it merits investigation by the Corps*. (p. 15)

Finally, in suggesting issues the issues that should be considered if the Corps develops its own spatial price model, they suggested

*...forecast the amount of grain grown in the upper Midwest, which will be a function of the cost of growing grain and other commodities compared to prices at which grains and alternatives commodities could be sold. Another module should examine grain production in other grain-producing regions around the world (especially Argentina and Brazil) and associated prices. Another module should focus on world demand for grain, which is a function of population, income , domestic production, and global market prices of meat import.*

***2.2 Ethanol, Brazil and China*** In addition to traditional factors that impact the distribution of world grain trade, there are a number of outstanding factors that impact the spatial distribution of trade. While there are numerous structural changes occurring in the world grain trade, three are particularly apparent and are elaborated upon.

<u>Ethanol</u> An important change in US 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 types of increases will impact demand for domestic consumption of corn in future.

For perspective on growth and changes in this sector, indicated that the demand of corn for ethanol is projected to increase by one billion bushels in the next 10 years (Feltes) and the United States will need another 40 or 50 ethanol plants and that would divert another one billion bushels of corn to match the same billion bushels devoted to ethanol production today (ProExporter 2004). And, "over one billion bushels of corn will be used to produce ethanol in 2003/04, and this approaches two billion bushels by the end of the decade (USDA 2003 Outlook Conference)." These assertions were made prior to the specifications in the recent Energy Bill which in fact expanded the future roles of ethanol and biodiesel.

There are two important aspects of the growth in demand for ethanol production. One is that while the industry in concentrated in the eastern corn belt, it appears its growth is concentrated in the western corn belt region. Results from two separate studies (Guebert; California Energy Commission) were used to form projections on future ethanol capacity and corn consumption. Industry projections for total ethanol demand for ethanol 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, the projected consumption of corn by producing/consumption regions was derived. This procedure resulted in the added corn required to meet expected ethanol production demands over that in the current year for both 2010 and 2025. These results indicate that as a result of the accelerated ethanol demand for corn, that 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 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 into corn. For each of these regions, this increase in domestic demand will reduce their exportable surplus, which otherwise would have been shipped offshore.

Changes in Brazil Soybean Production Soybean production and productivity in Brazil are changing and will impact world production and trade. Production has traditionally been concentrated in the Southern provinces of Brazil and the Central West regions. These were typically used for domestic crushing and the production of soybean oil and meals which were used locally for food and/or feeds, or were exported as products; or, the soybeans were exported directly. Typically, these soybeans were exported from the Southern ports of Santos and Paraguan.

Soybean production expanded rapidly in the traditional south region, increasing from less than two million ha in 1970, to nearly eight million ha in 1975. Since then, area planted in this region has remained in the 6-7 million ha level. The regions in which most of the expansion is occurring are in the Central West, and North. Area planted in these regions has increased from nil through the mid-1970s, and now has more than seven million ha planted, exceeding that in the traditional south.

In recent years there have been two major changes. One is for a sharp increase in production, the other for a shift in production to more northerly regions. This has resulted in

simultaneous pressures for development of transport infrastructure for exports from these regions. Schnepf, Dohlman and Bolling indicated that ".... Brazil, in addition to having the world/s largest pool of undeveloped land (roughly equal to all US cropland)...." In addition to the growth in production potential, there are changes occurring in shipping economics within Brazil. In particular, there are several infrastructure projects underway, being planned, and/ or being discussed. All of these are focused on developing lower costs means of exporting soybeans, generally through the Northerly ports. These include interior truck/water shipments to Itacoatiara and Santarem (a port facility was opened in April 2003) which is fully adopted. The BR163 is a highway to Santarem which is in the process of being developed.

Taken together, these will lower shipping costs from these otherwise high-shipping cost regions, change the flows of exports within Brazil, and increase returns to producers by about $10/mt. Specifically, analysis by ANTAQ indicated that by 2015 shipments to the north would become more competitive (Governo Federal). The results also indicated a change in the advantage in shipping north that is apparent. In most cases the Northern shipments of soybeans from Brazil would be natural tributary to Rotterdam, the traditional market, or to Asia and China via the Panama Canal.

<u>China Growth in Import Demand</u> China is a large market with rapid growth in population and income. Both of these have the impact of rapid growth in domestic demands. Though China is also a large grain and oilseed producer, their productivity growth rate is not expected to keep pace with demand. In particular, in our base case to 2025, demand exceeds production.

Sparks (2003) expects Chinese corn exports to eventually taper off to only two mmt by 2006. The central planners are trying to increase soybean acres to reduce dependency on imports but have registered little success to date. Chinese soybean area has advanced only .4 million ha since 1998 despite declines in wheat/feed grain area. 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 to increase that country's need to import wheat (*Milling and Baking News*, February 18, 2003, p. 39) USDA sees the sharp uptrend in Chinese imports continuing unabated for the next 10 years, eventually rising above 25 mmt by 2011. However, ProExporter (2005) labeled this projection "not remotely plausible," instead seeing Chinese imports stabilizing between 16-18 mmt over the next 10 years.

## 3. Previous Studies[2]

A number of studies have conducted longer-term forecasts on flows on the Mississippi River system, e.g., FAPRI, Sparks, USDA, etc. These models are for policy purposes and generally use econometric-based models for projections. Most important is that they do not address issues related to spatial competition, transportation and intermodal competition. As a result, they are generally limited in terms of providing estimates for infrastructure planning. Other studies (Baumel, 2001 and Baumel and Van Der Kamp, etc.) caution about the use of these types of models for infrastructure planning.

Some studies forecast trade flows, either internal or seaborne, utilizing past relationships for flows. Studies that have focused on Mississippi river traffic include Babcock and Xiahhau; Jack Faucett Associates (1997, 2000); and Tang. Others include Veenstra and Haralambides who focused on major seaborne trade flows. Babcock and Xiannau address short term forecasting of inland waterway grain traffic. Faucett and Associates forecast barge traffic on the Upper Mississippi and Illinois River system where shares of barge traffic (inland) were allocated based on fixed shares of exports. Veenstra and Haralambides developed multivariate autoregressive time series models to forecast seaborne trade flows for crude oil, iron ore, grain and coal using data from 1962-1995 to develop forecasts for 1978-2005.

Several studies have focused specifically on transport infrastructure and trade flows. Fellin and Fuller (1997) developed a model to examine effects of waterway use tax on U.S. grain flows for corn and soybean sectors. A quadratic programming model of corn and soybean sectors was developed that maximizes net social payoffs or consumer plus producer surplus minus grain handling, storage and transportation costs. Barge costs were estimated by simulating movement of a barge over the complete cycle where transit times were estimated based on length of haul, number of locks encountered and prospective delay times at given locks. Fuller et al. (1999) developed a spatial equilibrium model to examine the effect of grain transportation capacity on the upper Mississippi and Illinois rivers on trade flows. The model maximizes net social payoff of consumer plus producer surplus minus costs for grain handling, storage and transportation. The model utilized a regression equation to determine average lock delay time for shipping where:

$$\text{Average delay} = f(\text{Portion of lock capacity utilized})$$

Barge transportation costs for selected loading sites on the two rivers were estimated for different capacities with the tow delay equation, annual lock capacity information and a barge costing model. They indicate 58% of traffic would be diverted due to increased congestion. They indicated that this model is only relevant for short term forecasts as they do not include elasticities between transport modes which may have significant effects over longer terms.

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[2]The Appendix contains a detailed description of each of these studies.

Numerous studies have examined supply and demand elasticities for modes of transportation. Oum et al. reviewed over 70 studies that report elasticities of demand for several modes of transit and market situations. They indicate that since transportation is a derived demand, it tends to be inelastic. They list range of elasticities from studies for rail freight for corn, wheat of 0.52-1.18 (3 studies), truck for corn, wheat of .73-.99 (2 studies), inland waterways for grain of .64-1.62 (2 studies), and ocean shipping for dry bulk shipments of .06-.25. Yu and Fuller (2002) estimated elasticity of grain barge shipments on the UMR-IWW and found elasticities were inelastic for (-.2 for Illinois river, -.6 for reach 3 (Mpls to IA)). Dager et al., estimated elasticities for barge shipment as -.7, -.3, -.42 and -.57 for lower Mississippi, middle Mississippi, Illinois and Upper Mississippi river waterways.

Two studies analyzed short term supply and demand for rail and barge shipments to the US Gulf and PNW (Miljkovic 2001 and Miljkovic et. al., 2000). Elasticities were not reported but the inverse relationship between rail rates and demand were significant in two cases. There was also an important relationship between the Gulf-PNW corn price spread and rates from different origins. Export levels were significant and inversely related to rail rates. In Miljkovic et al, the competition between barge and rail were analyzed and supply and demand equations were estimated. Price variables in the demand and supply equations had mixed results with some being significant and others not, and the Gulf-PNW price spread variable was significant.

Sweeney (2003) examined issues related to elasticity of demand for transportation services. He provides a comparison of the results of the traditional ACE economic model estimate of benefits for UMM-IRW ($128 million) and contrasts them with one utilizing elasticity of demand for freight ($25 million). The difference is largely due to inaccurate forecast of future use without the project.

## 4. Deterministic Model of World Grain Trade

***4.1 Model Overview*** A model was developed of the world grain trade to evaluate longer term flows, and assess impacts of intermarket and intermodal competition on flows through different reaches of the Mississippi river system. The model is a large scale cost minimization problem and solved using nonlinear optimization. Consumption is estimated, from which import demand is determined and from this flows and production are determined. Grains included are corn, soybeans and wheat.

The model is used to evaluate longer-run solutions. This is critical and contrasts with other studies. This is truly a longer-run solution in that it simultaneously allows for changes in cropping patterns domestically and internationally, trade flows, as well as intermodal, interport and inter-reach allocation of shipments. Longer-term decisions regarding investments in the river system should be evaluated using analysis that allows for these longer-term adjustments, as opposed to many other studies which generate more shorter-run conclusions. However, by imposing restrictions, the model can also be adjusted to evaluate short-run flows, given production levels and consumption are predetermined.

Consumption and Import Demand: For each country, consumption functions are estimated from historical values. For the forecast period, estimates of consumption were generated based on incomes, population and the change in income elasticity as countries mature. Consumption functions were generated for each country and grain. Import demand was defined as consumption less production.

Export Supply: For each exporting country and region, export supply is defined as the residual of production and consumption.

Regions: The model comprises producing and consuming regions. Consuming regions included individual regions in the United States and Canada, as well as seven other importing countries and seven importing regions. Producing regions included 24 individual regions within the United States, approximating USDA crop regions with additional segments in river cachement areas. There were five regions included for Canada and Brazil included Brazil South and Brazil North. In addition, there were 13 other producing regions and/or countries.

Model Dimensions: The model was defined in GAMS and included 12,979 variables and 742 constraints

***4.2 Costs Included***: Elements of costs included in the cost minimization problem included the following:

Production costs The direct costs of production excluding land, taxes and others were included for each country and region where appropriate. These were from *Global Insights* (2004b) and were available for the period 1990 to 2002 with projections to 2025 which were retained for the remaining projection period. These were combined with actual and/or projected yields to derive costs/hectare by crop and region.

Modal shipping costs Costs were defined for shipping amongst each of the nodes in the model. These included matrixes for rail, truck and barge, as well as ocean shipping for international trade.

Handling costs for exporting Handling costs were defined throughout the system for each exporting country. These included country handling costs, barge transfer costs as well as extra costs for double handling associated with shipping on the Great Lakes.

Production and export subsidies, and import tariffs: For each of the major producing and exporting countries, a set of production and import tariffs that existed during the base period was included. Specifically, the production subsidies were used to adjust the cost of production and the import tariffs were included.

***4.3 Destinations and Port Areas:*** In the United States, there were 10 domestic consuming regions that generally coincide with the USDA destinations.

Each importing and exporting country was defined by one port area which was the dominate port. The exceptions include Canada (west and east) and Brazil North and South. In the United States four export port areas were defined including Pacific Northwest, Texas Gulf (rail), Center Gulf and the East which include the shipments through the St. Lawrence.

***4.4 Modal Costs and Rates*** For each mode, the shipping costs were defined as below.

Truck: Rates were defined from USDA AMS data. Rate functions were estimated and combined with distances to define truck rate estimates for each origin and destination in the United States. These were applied to each of the domestic destinations, barge transfer points and export ports. However, for shipments exceeding 350 miles, were forced to be shipped by rail.

Rail: Rail rates derived for periods 1995-2002 from the Waybill data set. Average rates derived for each year, origin and destination including barge reaches. Separate rate matrixes were derived for domestic and exports. In addition, rail rate functions were estimated for each grain and for each of domestic and export shipments. These were used to replace what would otherwise be nil values in the Waybill data set during the projection period.

Barge: Six origins were defined on the Mississippi river system. These were defined as Reaches and encompassed all origins within that geographic region. These were defined below and illustrated in Figure 4.1:

Reach 1 Cairo to LaGrange (St. Louis);
Reach 2 LaGrange to McGregor (Davenport);
Reach 3 McGregor to Minneapolis (Mpls);
Reach 4 Illinois River (Peoria);
Reach 5 Cairo to Louisville (Louisville) and
Reach 6 Cincinnati (Cincinnati).

Barge rates from these origins to the US Gulf were derived from USDA AMS and for each year.

Ocean shipping: Rates for ocean shipping were taken from Maritime Research Inc. for the period 1994 to 2004. These were for grain only and included rates on different size ships, varying origins and destinations and a multitude of grains. From these, average rates were defined for each origin/destination combination which would reflect the average ship size. For missing values, and/or for origin/destination combinations for which rates were not observed, these were replaced with rates from a regression model and defined as estimated.

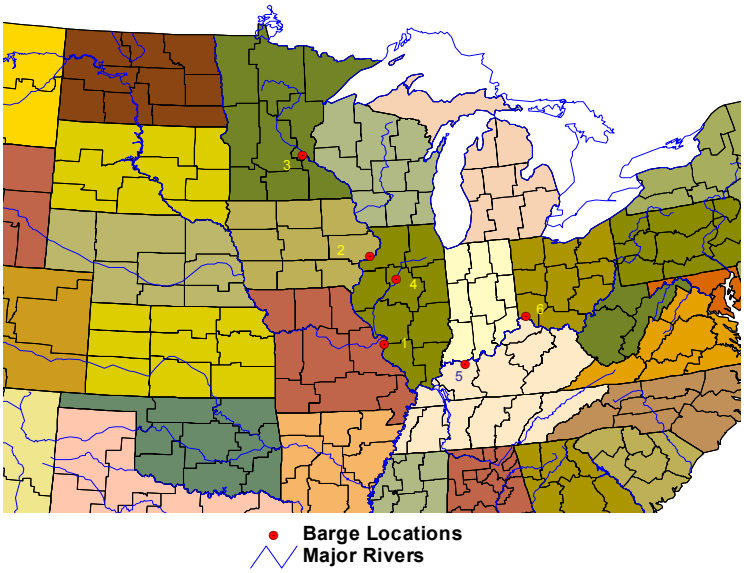


**Figure 4.1 Center Points for Barge Reach Locations**

***4.5 Barge Capacities, Delay Costs and Transfer Restrictions*** The barge shipping cost was defined to include the market barge rate, plus a delay cost. A delay curve was derived through simulation for each of Reaches 1-4. For Reach 5 and 6, it was assumed that there was not enough traffic to incur costs associated with congestion and delay.

The delay costs were derived through simulation assuming normal levels of other traffic. These were derived for current capacity, as well as for planned capacity. Figure 4.2. shows a summary of these delay costs and how they are impacted by volume.

In addition to these, it was necessary to impose two other restrictions on the interior logistics system. One of these is the volume of grain that could be transferred by rail to barge at St. Louis. The other was the amount of grain that could be unloaded at New Orleans by rail. During the base period, in each of these cases there were important movements that would be lower cost by rail with transfer to barges or export elevators than by barges. While not drastic, the cost difference would have been enough to result in large scale shifts from barges to rail on these flows. Most drastic is corn and soybeans from targeted origins in the Upper River reaches to St Louis. Without imposing these restrictions, the results suggest far greater movements by rail to St Louis and the US Gulf than is actually observed. These were imposed on the model and retained as maintained assumptions, but, were relaxed in the sensitivities and the stochastic model.

***4.6 Restrictions/trade*:** For each of the major countries and/or regions varying types of interventions were included. These included agricultural subsidies, export subsidies and taxes, and import tariffs. In addition, some additional bilateral tariffs were included as appropriate.

Wheat trade restrictions: Due to a cumulation of peculiarities on wheat trade and marketing, mostly due to cost differentials and quality demands, we imposed a set of restrictions. These were intended to ensure that countries trade patterns were represented, and to allow some inter-port area shifts in flows within North America. The restrictions applied for a group of countries include:

1) X% of their imports must originate from the HRS producing Regions of North America;
2) Y% of their imports must originate from the SWH producing regions of North America;
3) Max Z % of their imports could originate from Canada

Values for X, Y and Z were derived from actual shipments for the period 1995-2002

Other restrictions: US was not allowed to trade with N. Korea or Iran.

***4.7 Base Case Assumptions*:** The model was run using a Base Case and all projections and sensitivities were compared to that model. The base case was defined as 2002 base year values. In addition, restrictions were imposed on inter-crop adjustments in area devoted to each crop in each country or region. The maximum land available for planting in each region/country was 110% of previous 3 year average and the minimum area is ≥ 100% of 3 year average area

## 5. Critical Relationships Impacting Results

***5.1 Changes in Consumption*** The analysis and model are driven by consumption of different grains in each of the importing countries, regions and the U.S. domestic market. These were estimated and a summary of those estimates is shown in Table 5.1 and Figure 5.1-5.3.

**Table 5.1 Estimated Percent Change (to 2025) in World Consumption**

| | Wheat | Corn | Soybean |
|---|---|---|---|
| | | Percent Change | |
| United States | 0.19 | 0.22 | 0.20 |
| Canada | 0.20 | 0.27 | 0.21 |
| Europe | 0.08 | 0.16 | 0.09 |
| Australia | 0.19 | 0.28 | 0.20 |
| China | 0.82 | 1.54 | 0.89 |
| Japan | 0.00 | 0.06 | 0.01 |
| Argentina | 0.35 | 0.58 | 0.38 |
| Brazil | 0.56 | 0.82 | 0.58 |
| Mexico | 0.53 | 0.81 | 0.56 |
| South Korea | 0.17 | 0.46 | 0.22 |
| Latin | 0.67 | 0.95 | 0.70 |
| N Africa | 0.82 | 1.17 | 0.85 |
| FSU-ME | 0.52 | 0.78 | 0.54 |
| S Africa | 0.87 | 1.06 | 0.88 |
| S Asia | 1.00 | 1.52 | 1.04 |
| SEA | 0.47 | 0.73 | 0.50 |
| World | 0.55 | 0.71 | 0.46 |

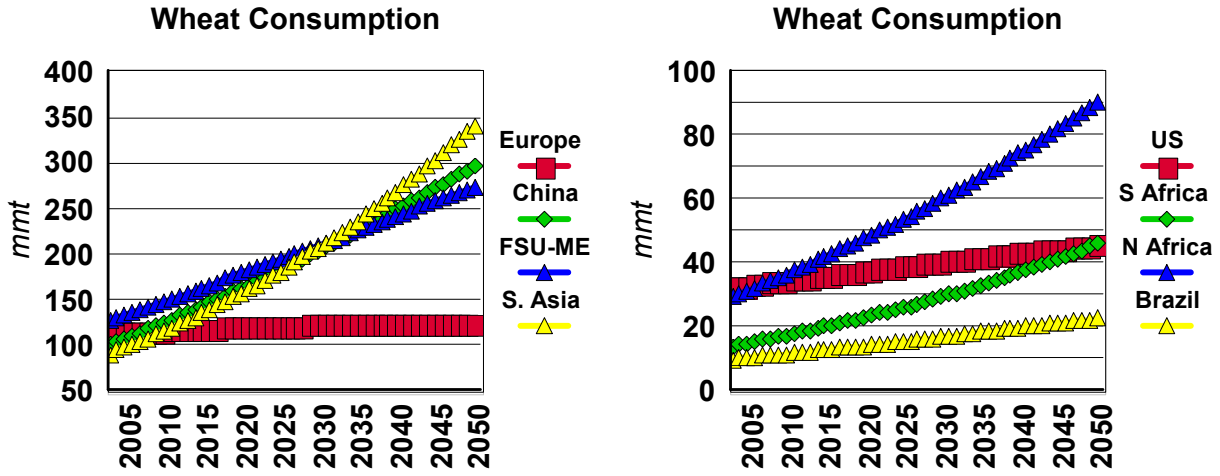


**Figure 5.1 Forecast Wheat Consumption for Selected Importing Countries/Regions.**

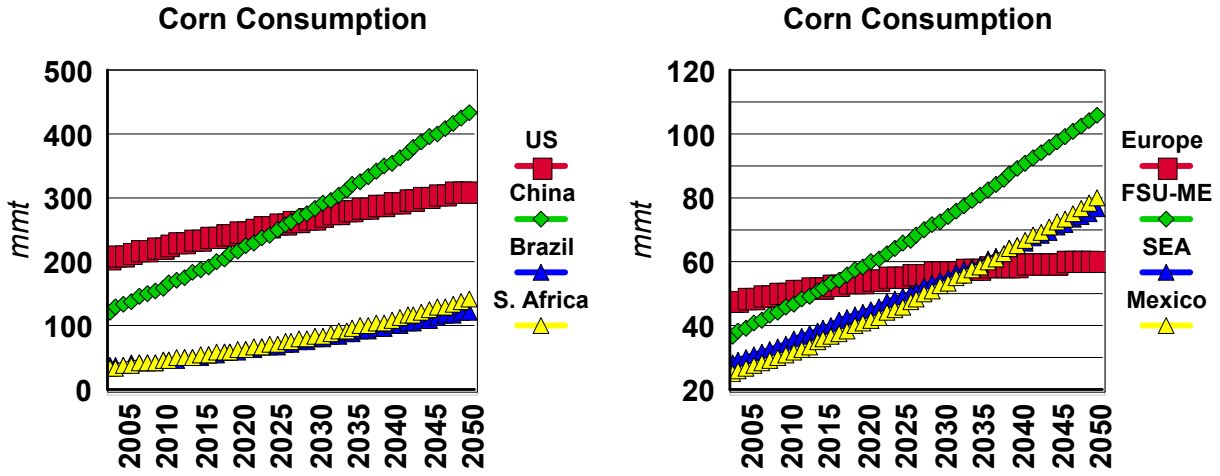


**Figure 5.2 Forecast Corn Consumption for Selecting Importing Countries/Regions.**

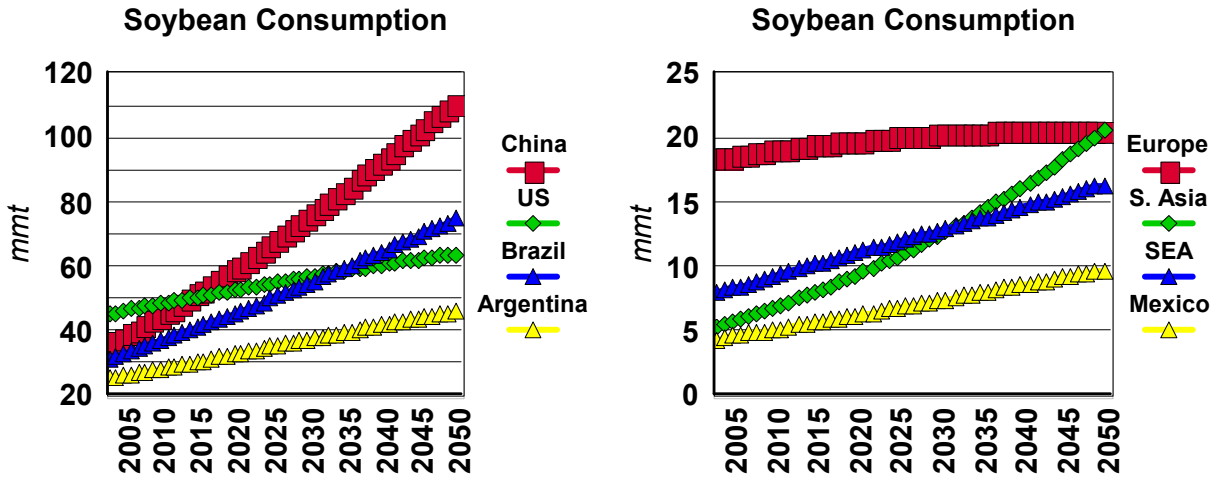


**Figure 5.3 Forecast Soybean Consumption for Selected Importing Countries/Regions.**

***5.2 Production Costs*** There are differences in production and marketing costs around the world. Differences in productions costs are shown in Figure 5.4-5.6. Results illustrate that the United States is the lowest cost producer of corn and soybeans, but, other countries are lower cost in wheat production.

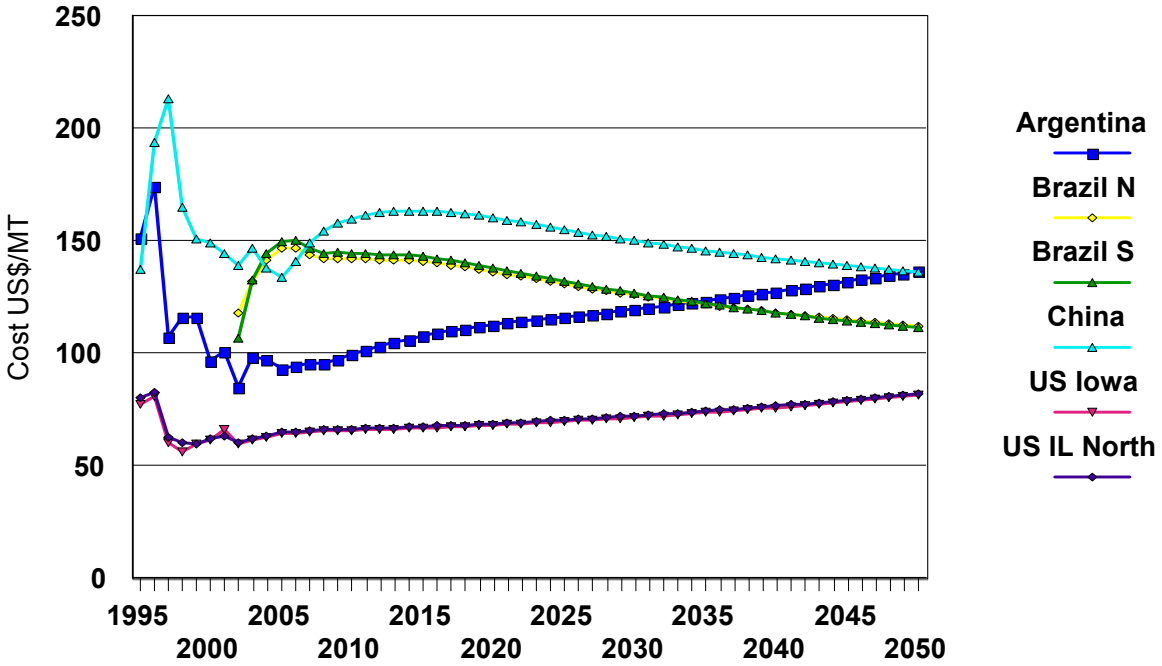


**Figure 5.4 Soybean Cost of Production.**

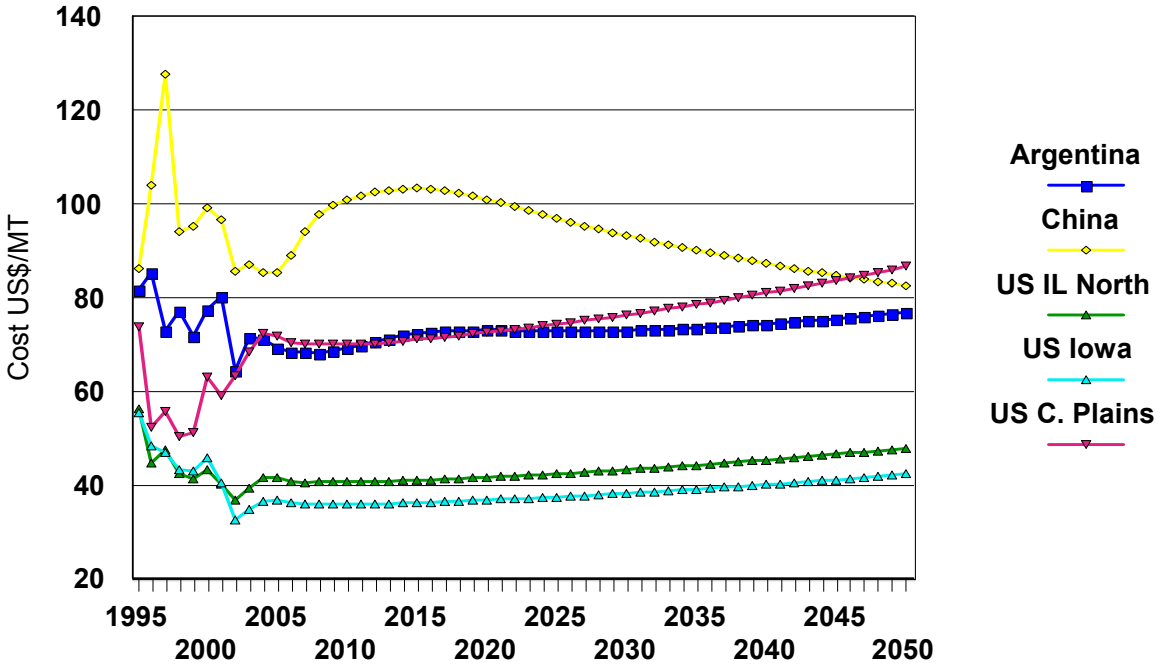


**Figure 5.5 Corn Cost of Production.**

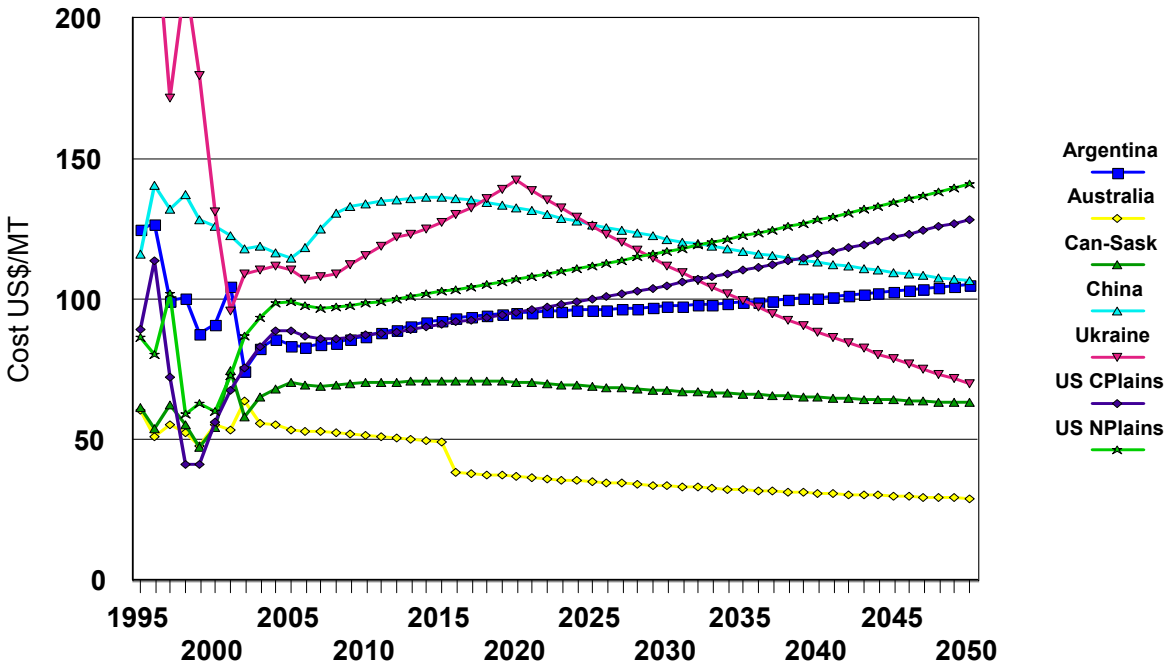


**Figure 5.6 Wheat Cost of Production.**

***5.3 Wheat Marketing and Production Costs*** While trade in corn and soybeans generally coincides with cost differences which is the logic to this model, this is less true for wheat. Several notable differences exist in wheat. These are summarized here first and then we explain how these are handled analytically.

Former Soviet Union. Historically, the Former Soviet Union (FSU) region has been a periodic importer and sometimes an exporter of wheat. Since 2001 however, their exports have increased. Longer term there is concern that this region could become a greater importer. Indeed, the recent USDA Outlook showed this region increasing their exports from 10 to 21 mmt in 2011.

European Union: The EU is both a large importer and exporter of wheat. In part, this reflects that they import higher quality wheats from the northern regions of North America. In addition, they export wheat which is generally lower in protein and gluten content, and in some cases would be considered soft. Imports are governed by an import tariff. Exports are sometimes facilitated by an export subsidy.

To account for these issues adjustments were made to the base case representation using varying restrictions. Specifically, a series of wheat trade restrictions (defined above) were imposed on North America. Though these affect the level of trade, these were defined so as to not affect the intermarket arbitrage.

Second, a restriction on the import and export of wheat to the EU was imposed. Finally,

a restriction was made on the volume of exports that could be made from the FSU because the FSU was combined with the Middle east region in the model and all exportable supples would be absorbed by the Middle east.

***5.4 Rail Rates on Barge Competitive Routes*** There appears to be a notable change in rail pricing that occurred within the time period of this study. In particular, rail rates from Northern Regions have declined to Reach 1 relative to rail rates to contiguous barge origins within the region. The effect of this is to improve the competitiveness of shipping rail to Reach 1 and transfer to barge.

For illustration Table 5.2 and Table 5.3 shows some of these results. For shipments from Illinois North, there appears to be a major change in rail pricing in about 2000. Prior to then, the average rail rate to Reach 4 on the Illinois river exceeded that to the Reach 1, by from $1.20 to $4.42/mt. Then, beginning in 2000, the rail rates to Reach 1 declined and in fact were less than those to Reach 4. Of course, this increased rail flows. During this period the rail flows from Illinois North to Reach 1 increased from less than 10,000 mt to nearly 400,000 mt. Further, since the barge shipping cost from Reach 1 to the US Gulf is less than that from Reach 4, the implicit advantage of rail to Reach 1, by-passing the Illinois river increased substantially.

Table 5.3. shows comparable information on shipments from Minnesota (river origins). Prior to 2000 the railroads did not have a reported rate on shipments to Reach 1. Beginning in 2000, a rate in the area of $12/mt was introduced. This combined with the lower barge shipping rate from St Louis had the impact of inducing shipments by rail to St Louis, thereby bypassing the Upper Mississippi river. Upon a closer look, it appears the rate relations from Reach 3 to Reach 1 changed, the effect being to induce more shipments to Reach 1 by rail.

**Table 5.2 Average Modal Shipping Costs from Illinois North to Reach 4 and Reach 1 and the Implied Advantage of Rail ($/mt) for Corn**

| Year | Rail to: | | Difference | Barge to US Gulf From | | Implied Advantage of Rail to Reach 1 |
|---|---|---|---|---|---|---|
| | Reach 1 | Reach 4 | | Reach 1 | Reach 4 | |
| 1995 | 6.35 | 5.14 | 1.21 | 8.40 | 12.92 | -3.31 |
| 1996 | 11.58 | 7.16 | 4.42 | 5.20 | 8.96 | 0.66 |
| 1997 | 7.99 | 4.28 | 3.71 | 4.50 | 7.56 | 0.65 |
| 1998 | 5.68 | 4.34 | 1.34 | 5.71 | 8.84 | -1.79 |
| 1999 | 6.25 | 4.78 | 1.47 | 5.83 | 9.76 | -2.46 |
| 2000 | 3.33 | 4.86 | -1.53 | 6.06 | 9.55 | -5.02 |
| 2001 | 3.19 | 3.82 | -0.63 | 6.14 | 9.82 | -4.31 |
| 2002 | 3.98 | 5.74 | -1.76 | 4.99 | 8.27 | -5.04 |

**Table 5.3 Modal shipping costs from Minnesota (River) to Reach 3 and Reach 1 and to the US Gulf ($/mt) for Corn**

| Year | Rail to: | | Difference | Barge to US Gulf From | | Implied Advantage of Rail to Reach 1 |
|---|---|---|---|---|---|---|
| | Reach 1 | Reach 3 | | Reach 1 | Reach 3 | |
| 1995 | na | 6.24 | | 8.40 | 19.94 | |
| 1996 | na | 8.14 | | 5.20 | 12.12 | |
| 1997 | na | 7.37 | | 4.50 | 11.87 | |
| 1998 | na | 5.99 | | 5.71 | 14.79 | |
| 1999 | na | 5.65 | | 5.83 | 15.63 | |
| 2000 | 12.59 | 5.04 | 7.55 | 6.06 | 13.99 | -0.38 |
| 2001 | 11.62 | 6.75 | 4.87 | 6.14 | 14.56 | -3.55 |
| 2002 | 11.29 | 7.34 | 3.95 | 4.99 | 12.60 | -3.66 |

These results have a critical impact of the model solution. In particular, they suggest that it is lower cost to ship from origins to Reach 1 by rail, and then transferred to barge. This is particularly true in the eastern corn belt going to Reach 4 versus Reach 1. It is very apparent that rail carriers in these regions had a distinct change in pricing strategy commencing in about 2000. The same conclusion exists for corn shipments from Minnesota to St Louis, though the magnitude of the change is not as great.

Of course, these suggest discrete differences in cost of different flows. In practice that does not exist for a number of reasons. These include that origin territories are continuous, as opposed to discrete as implied in our model. Second, there are service differences that vary over time, within a year and as well as across barge origins which are not included in our model. Third, these simple comparisons do not include the impacts of delay costs.

Nevertheless, these suggest a distinct change in competitive rivalry. Whereas prior to about 2000 the railroads seemed complacent to ship to regions within the northern portions of the Upper Mississippi and Illinois, this seems less true in more recent years. In the latter period, the railroads seemed to be pricing their service to encourage grain to bypass the northern regions of the river and terminate directly at Reach 1 for barge shipment to the US Gulf.

***5.5 Delay Costs*** With existing infrastructure, costs increase at each reach beyond some level of volume, and, eventually evolve toward capacity. Notably, Reaches 1, 2 and 4 experience clear capacity limits at about 45 mmt, 32 mmt and 38 mmt respectively. On Reach 3, a capacity constraint is not so apparent, but, costs escalate throughout the observed range.

These results are shown in Figures 5.7 for each Reach. Interpretation of these values differs across reaches. For Reach 3 costs increase slightly with increases in traffic. For Reach 2, The increased costs associated with delay for traffic less than about 28 mmt is near nil. Costs increase very sharply for traffic greater than about 32 mmt. For Reach 1, which reflects the cumulative traffic of grain entering in either Reach 1 (above lock 27), 2 or 3, costs begin to increase for volumes greater than about 42 mmt. At traffic of about 48 mmt, the increase in delay costs is very sharp. Finally, at Reach 4, delay costs are near nil up to about 38 mmt and then increase sharply.

Interpretation of these is that for movements greater than these values, the delay costs increase become exponential at different levels for each reach. It is this value that is defined as the capacity in the model. Finally, the results illustrate the impact of the proposed improvements. Specifically, in each case the proposed improvements would have the impact of shifting the delay function rightwards meaning that near-nil delay costs would exist for a broader range of shipments.

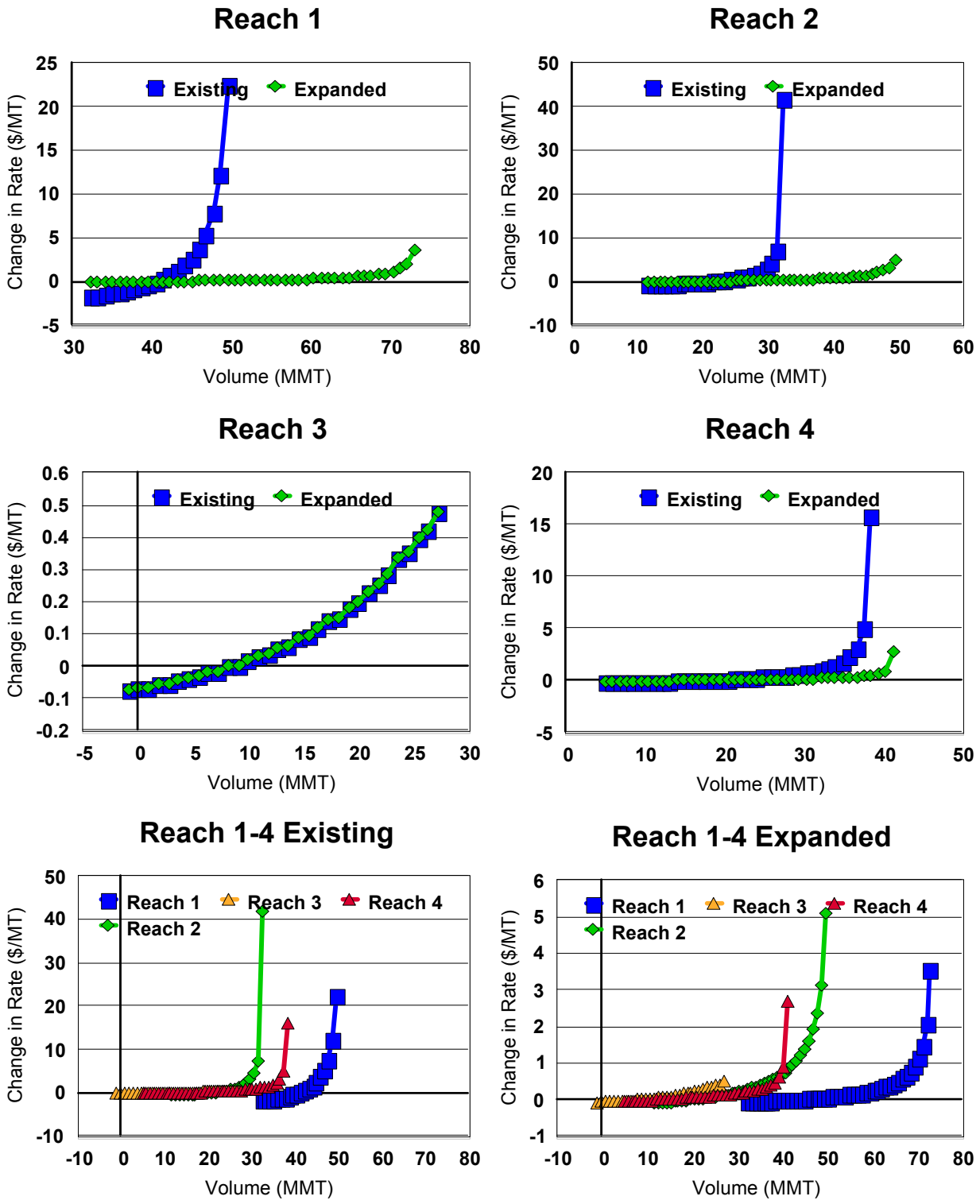


**Figure 5.7. Relationship Between Change in Barge Rate and Volume by Reach and Existing vs. Expanded Capacity.**

This approach differs from Fuller et al., 1999. In that study, they estimated capacity delay function like transit curves for the entire river system and for a narrow range of capacity. They assumed that below 20% capacity, delay was negative, at 100% the maximum delay was 6 hours. Finally, they assumed an exogenous increase in traffic, i.e., with 50% increase in traffic, 30% of corn was shifted off river. However, it was unclear where the exogenous 50% increase in traffic come from.

For calibration purposes and to put perspective on these delay costs, we assembled data on grain entering the river system on each of these reaches. For example, on Reach 2 grain entering the River ranged from 9 to 12.6 mmt over the past 9 years, and averaged about 10.6 mmt. This compares to delay costs that are near nil at that level and do not increase till volume approaches 30 mmt. Generally, for each of the reaches, the normal level of grain volume entering the river is far less than the point at which the delay costs become important.

***5.6 Ocean Rates*** The relationship amongst ocean shipping costs have an important impact on shipments through the river system. Amongst all the variables in the model, one of the most important is the ocean rate spread between the US Gulf and Asia vs. the PNW and Asia. This is typically monitored closely by grain merchants and rail carriers and is normally quoted in terms of the Gulf-PNW to Japan spread. The historical values of this spread are shown in Figure 5.8.

Typically, this value trades in the range of about $5/mt, though there was quite a bit of volatility in more recent years. This result shows the general trend, but, values for individual trades to other Asian countries show similar but not exactly comparable behavior. Nevertheless, as illustrate, the rate spread increased sharply in the period following January 2004.

For comparison, the value used in our analysis for 2002 was $4.97/mt ($22.57 vs. 17.60). Since then, the spread widened, and then more recently declined. In our projections to 2025, rates are nearly unchanged and the spread remains at $4.96/mt (22.49 vs. 17.53).

This variability impacts spatial flows within North America. Basically, shipments through the river system have to compete with rail direct shipments to the Pacific Northwest. This is particularly true for corn where buyers can readily substitute PNW for US Gulf corn. This is less true for soybeans. And for wheat, such intermarket arbitrage, though appealing, does not function due to the multitude of factors impacting quality and shipping demand.

The longer term outlook for this spread is less clear. Some highlights from the Drewry Report (August 2004) indicated that much of the spike in ocean rates is attributable to China's demand for raw materials, i.e., "the China factor." In addition, the rate of growth in imports will slow with waning demand growth and the grain trade is not driving this market. Instead, it is the demand for iron ore and coal. In contrast, the global shipments of both wheat and coarse grains are remarkably stable. Shipping rates are expected to decline from their highs in 2004 through at least 2005. Finally, the number of new-build ships is important. The current backlog of new builds is particularly strong in the case of Capsize and Panama. The order book for Panamaxes exceeds 250 ships while the Casesize backlog is around 100 ships. And both of these are a large

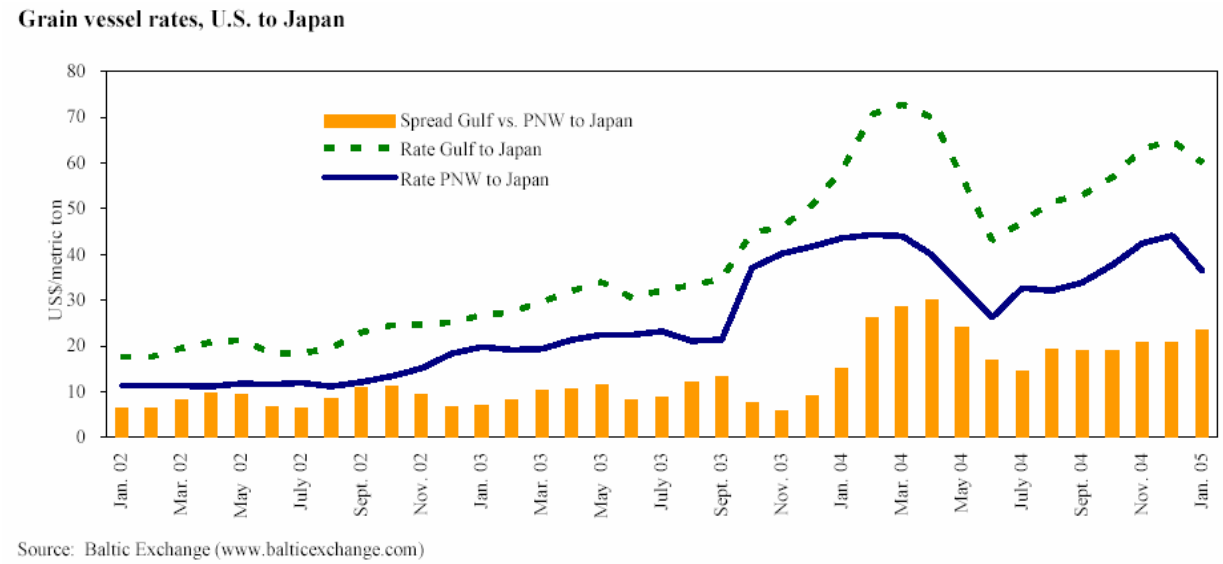


**Figure 5.8 Grain Vessel Rates, U.S. To Japan.**

percent of the current fleet. In summary, these new builds will cause rates to fall, beginning in 2006.

## 6. Results

First we describe the base case, the process of calibrations and backcasting. Then we illustrate the projections. These are presented under several scenarios. Then, we conduct and illustrate a number of interesting sensitivities. In each case, charts are used to summarize the results. The appendix includes numerical details as well as the international trade flows for each set of results.

***6.1 Base Case, Calibration and Backcasting*** The base case is reported along with the "back-caste" results which were used to evaluate its performance in identifying movements for key shipments.

The base case model was used with the following assumptions 1) Actual production and consumption for each period fixed at actual values; 2) Production costs were included, but, as illustrated were not overly critical and 3) Modal rates that existed for each period. The reason for this is to facilitate backcasting which is typically a shorter-run analysis. The unrestricted model provides a longer-run solution which would likely be less appropriate for comparing the shorter-run results in particularly years. Taken together, these specifications are for the calibration and should be interpreted as "short-run" assumptions. Given production and consumption, and the rates that existed during those years, what would be the optimal flows?

The model generates numerous results. These include area devoted to each crop in each

region and country, yields, production and consumption in each country, and export supplies and import demand for each country. In addition, it provides trade flows from each country, and within the United States provides the optimal shipments through each port area, by each mode, and through each of the individual Reaches on the river as well as delay costs. Since our concentration is on the flows through the barge system primarily, we report the flows on each Reach. In addition, the export levels by port area and grain are reported.[3]

The results are shown in Figures 6.1 and 6.2 and comparisons are made to actual shipments in the appendix.[4] The results are somewhat robust with respect to total movements and relative shipments by reaches. However, in some years it overstates the actual movements for each of the three commodities. The results indicate that corn shipments are concentrated from Reach 4, followed by shipments from Reach 3, 2 and 5. Soybean shipments are largest on Reaches 4, 2 and 1. Finally, wheat shipments are relatively minor and concentrated from Reach 1, 4, and 6. However, the overall volume of wheat shipments has been declining through time. This contrasts with actual shipments which are smaller, and there is no apparent trend. In total, shipments are in the area of 60-65 mmt which is comparable to the actual shipments. These are concentrated in Reaches 4, 2, 3 and 1, in rank order, followed by 5 and 6.

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[3]The appendix provides these details as well as the level of exports and imports for each country and region.

[4]The EU includes EU shipments to FSU/ME that are in the EU25. Countries from the former Yugoslavia, Albania, (i.e. Balkans), are in the FSU-ME, not the EU.

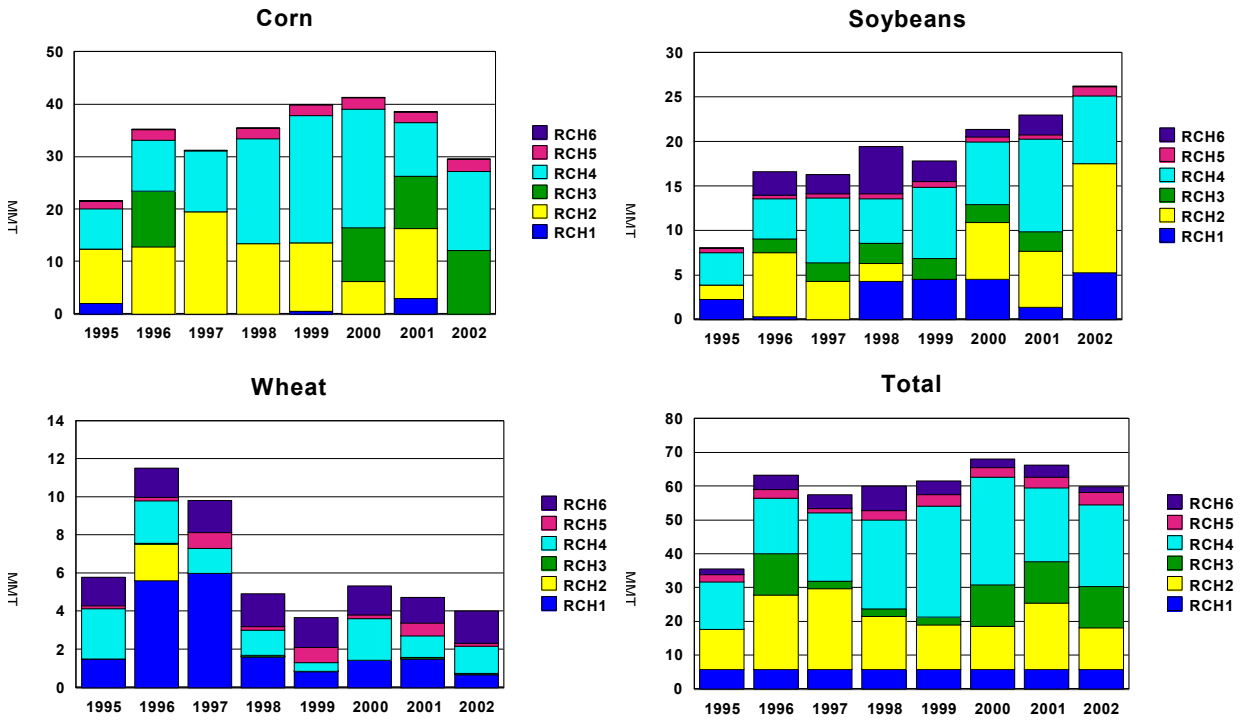


**Figure 6.1 Reach Volumes by Crop and Total.**

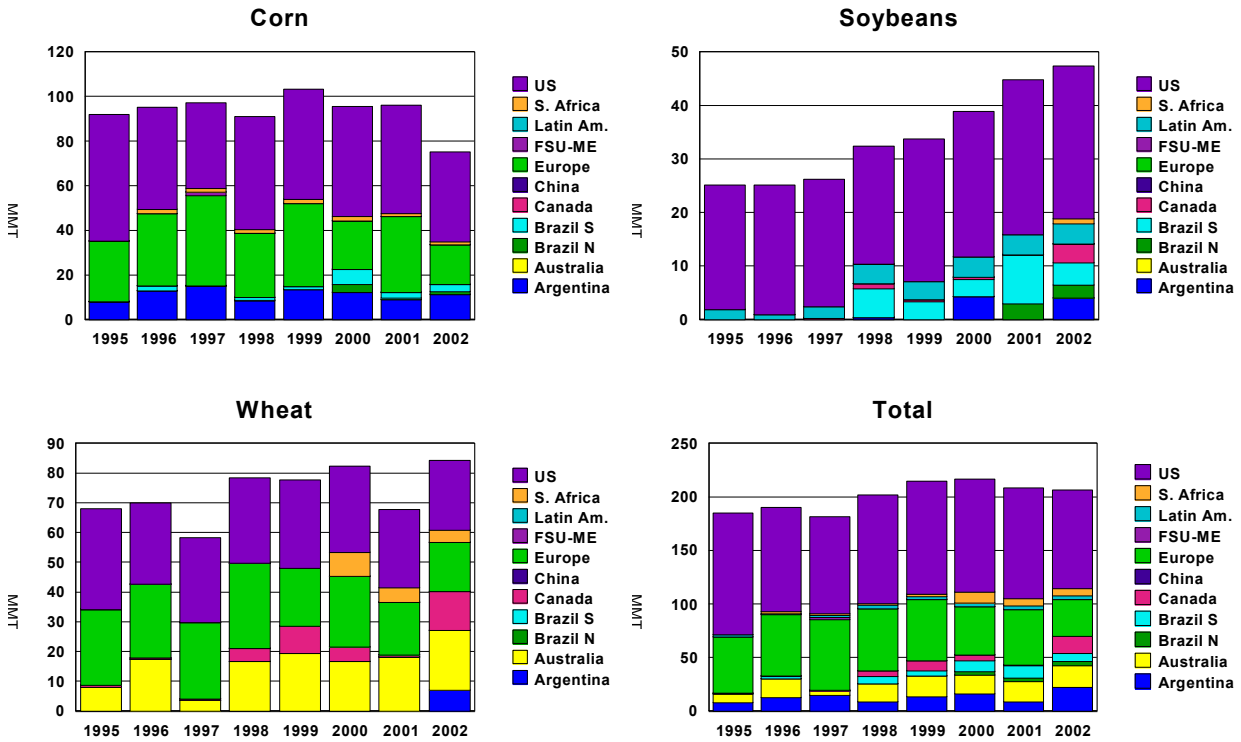


**Figure 6.2 Export Volumes by Exporting Region by Crop and Total.**

***6.2 Projections:*** The model was used to make projections on flows through the River system. The logic of the analysis involves first projecting demand, along with costs and yields and then the model was solved to determine optimal flows. Consumption is estimated based on income and demographics and using projections for these variables from *Global Insights (2004a)*. Yields were projected based on nonlinear trends and production cost projections are those from *Global Insight (2004b)*. Modal rates are assumed at base period values, but, ocean rates were allowed to increase due to increase fuel costs. In each case, projections were made in 10 year increments for 50 years.

The model was first simulated assuming existing capacity on the barge system, then with the proposed expanded capacities. Finally, a number of sensitivities were conducted on these projections.

***Projections with Existing Capacity:*** The model was first solved assuming existing capacity. Results are shown in Figure 6.3. Results suggest that shipments on the barge system would increase from about 60 mmt in 2002 to about 85 mmt in 2010. Increases thereafter would continue, but the growth rate would slow. A crucial reason for the sharp increase in 2010 relates to an anticipated shift in corn production in the EU commencing about that time period resulting in a shift to the US. Details behind this shift are analyzed and described in detail below.

Most of the increase is expected to be from corn and soybeans and much of this growth is concentrated in Reach 2 and 4. The growth in wheat is relatively minor and concentrated in Reach 6 suggesting it is for soft red winter wheat. In period through 2040, US yields increase faster than those in FSU/ME. As result, costs in FSU/ME increase on per mt basis. By 2040, there is a shift from these countries to the US, resulting in increased barge flows. While important in the wheat sector, these are relatively minor shifts in the world grain market.

Export growth is expected for each of the US Gulf as well as the PNW port area, with near-nil growth in the eastern ports (which in this case includes the Great Lakes). The growth at the PNW would primarily be wheat and corn.

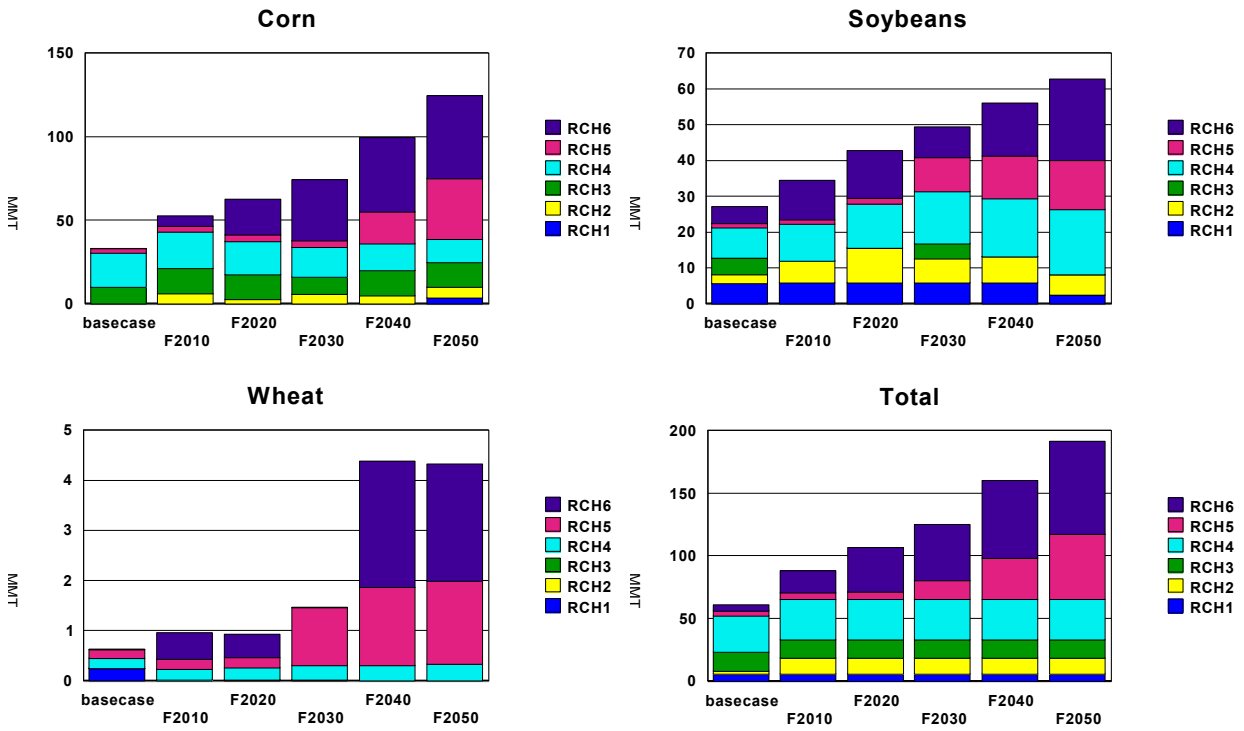


**Figure 6.3 Forecast Reach Volumes, by Crop and Total.**

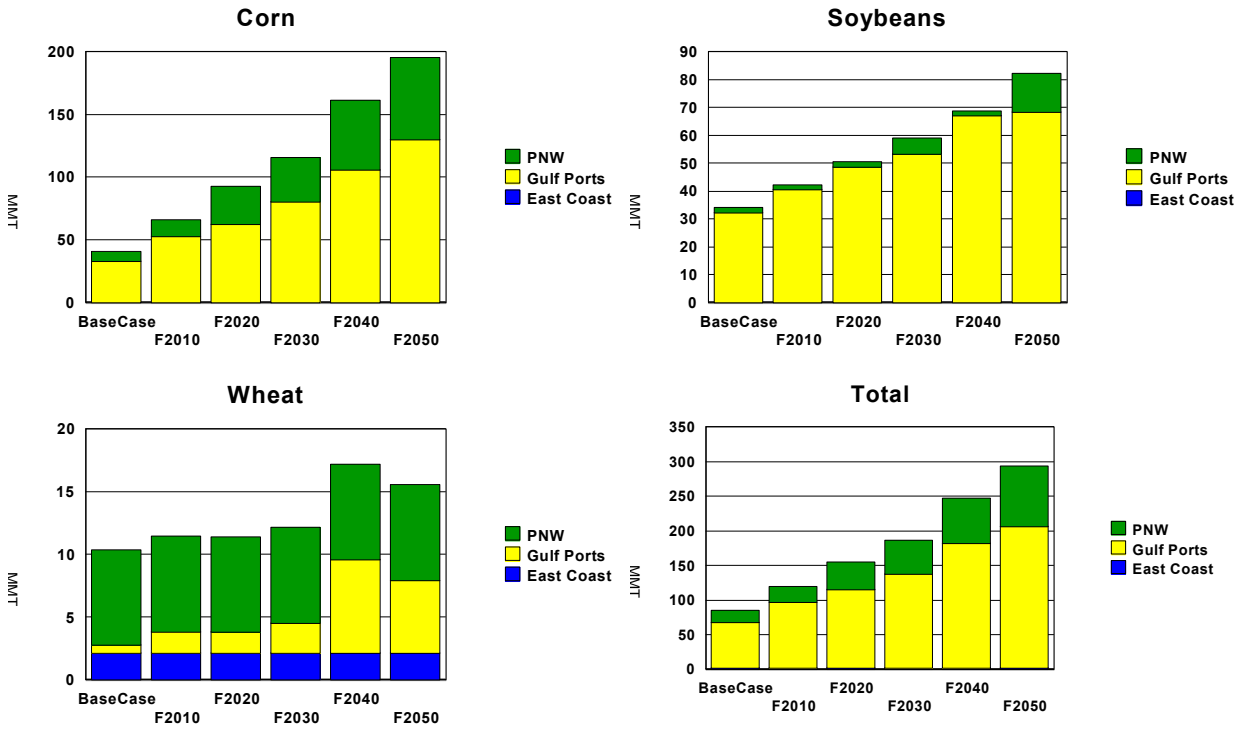


**Figure 6.4 Forecast U.S. Export Volumes by Port Area, by Crop and Total.**

***Projections with Expanded Capacity:*** The model was also run assuming the capacities at each of the Reaches were expanded as illustrated in Figure 6.5 and 6.6 with comparison to a no expansion solution.

Results indicate that total flows in 2010 would increase from 88 to 89.4 mmt. Most of this change would come from an increase in corn shipments originating on Reaches 2 and 4. Much of this is from a net increase. However, part of it is from a shift from shipments originating on Reaches 6 and 5 to the other Reaches. Thus, with existing capacity, delay costs on Reaches 2 and 4 are sufficient to divert traffic to Reaches 5 and 6. There are also increases in soybeans on Reach 2, but a slight decline in shipments on Reach 6. Wheat shipments increase on Reach 1.

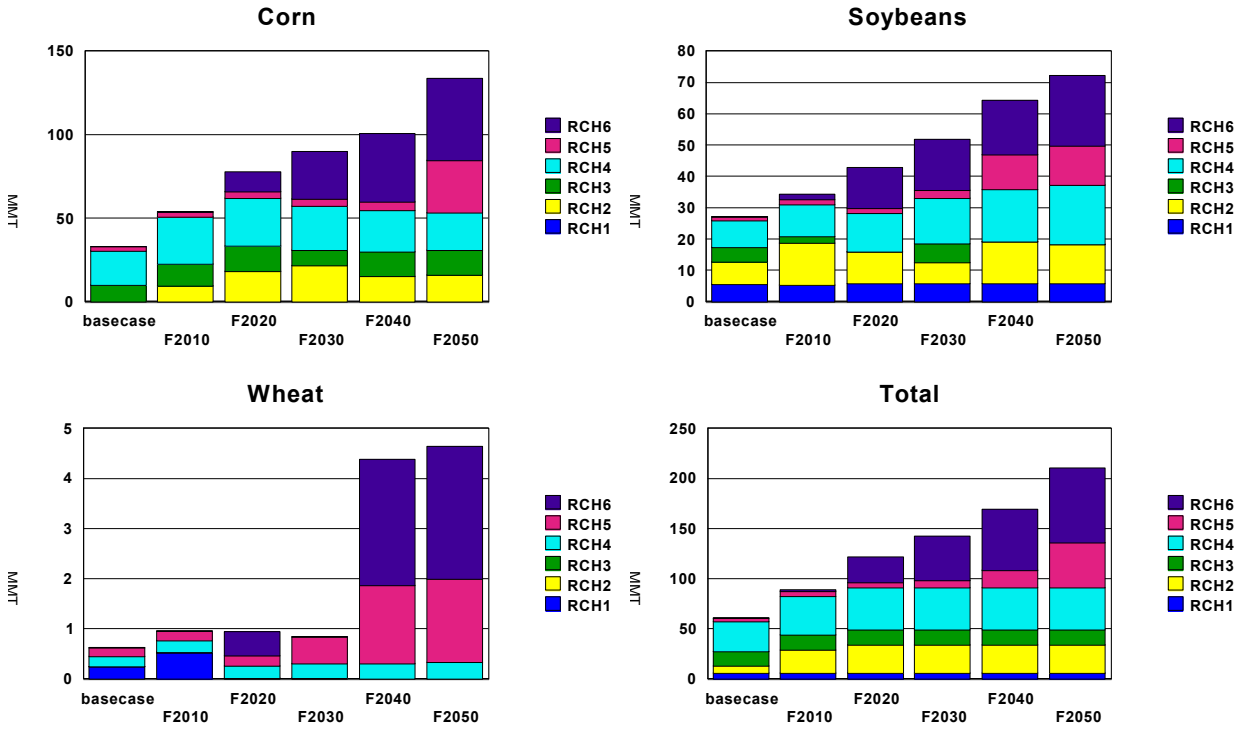


**Figure 6.5 Forecast Volume by Reach, Expanded Capacity, by Crop and Total.**

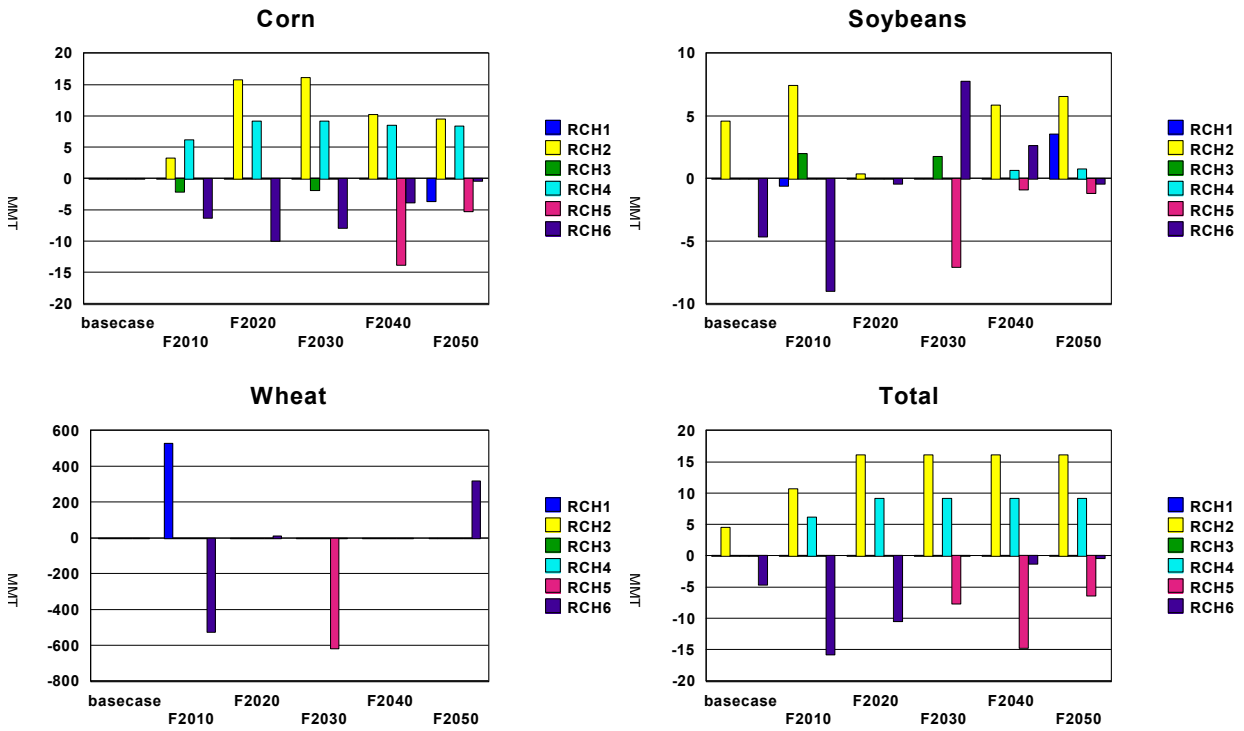


**Figure 6.6 Change in Forecast Volume With Expanded Capacities by Reach, by Crop and Total.**

***Projections with nil Production Costs***: One of the important costs included in this analysis is the variable cost of production in each region and country. These are projections and their source was very comprehensive. However, these are variable across regions and are important. To illustrate the impacts of production costs, the projections were also estimated assuming production costs were nil. This results in a model in which trade flows are determined nearly completely by shipping costs.

Results are shown in Figures 6.7 and 6.8. There is only an inconsequentially minor impact of production costs. This results in a near nil increase in barge shipments, and that in 2010 is only slightly greater. These results suggest that production costs while important, are not overly critical in terms of barge shipments. Thus, most of the international shipping as well as barge shipments is due to shipping costs, as opposed to production costs.

There are a multitude of reasons for this. First, the world supply and demand for each of these grains are relatively balanced. There is limited excess supply beyond demand. In addition, the land area in the United States is limited and in most countries, including the United States, there is a significant decline in land devoted to these crops.

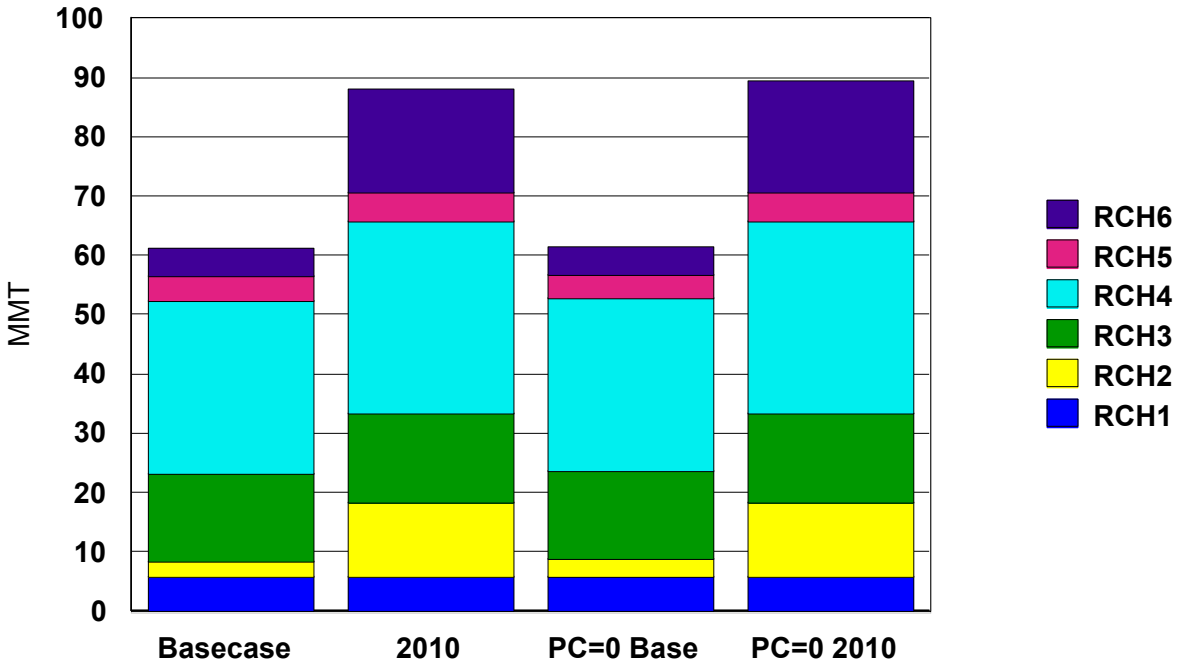


**Figure 6.7 Reach Shipments With and Without Production Costs.**

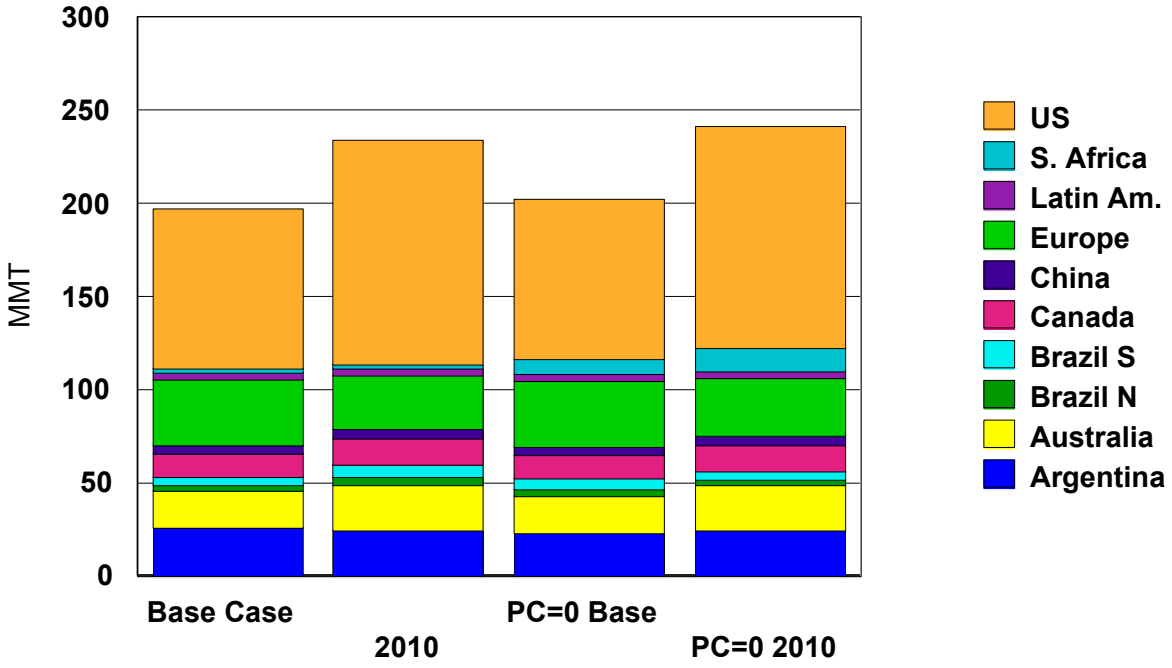


**Figure 6.8 Export Shipments With and Without Production Costs.**

***Projections: Sensitivity about EU Corn***: These projections indicate a notable shift in 2010, resulting in an increase in barge shipments. Virtually all of this is corn and results from a subtle shift in EU production costs. See Table 6.1. EU production costs increase relative to the US and the rest of the world in the case of corn by 2010.

Table 6.1 Changes in EU and Corn Production Costs in 2002 and 2010.

| | EU Corn | | | | US Corn |
|---|---|---|---|---|---|
| | Yield mt/ha | Area 000 ha | Production 000 mt | Prod Cost $/ha | Prod Cost $/ha |
| 2002 Input | 5.3 | 10,920 | 58,204 | 811 | |
| 2002 Base | 5.3 | 12,230 | 65,186 | | 339 |
| 2010 Projection | 5.5 | 10,980 | 60,500 | 1310 | 414 |
| % Change 2010 vs 2002 | 3.0 | -10 | -7 | 62 | 22 |

* If EU Production Costs is 2010=$900, then solution area is 11,304.

By 2010, EU production costs increase 62% while those in the US increase by 22%. EU consumption increases by 1 mmt. These have the impact of reducing area planted in EU by 10% and production by 7%.

The reduced production in the EU results in a shift in exports from that country, which reduces EU exports by 6 mmt, mostly to the FSU. This results in an expanded area planted in US Reach 2; and exports through US Gulf to the FSU (about 6 mmt). US exports increase 8 mmt; this comes from reduced EU exports (6.1 mmt 2010), and other natural market growth. The results are fairly detailed and suggest a shift in FSU imports from the EU to the United States. The United States then reduces its exports to Southeast Asia, which results in a decline in PNW exports. These are shifted to Argentina. In total, there is not a major impact on barge shipments, though, the total shipments by barge increase due to the overall increase in corn demand.

To verify these changes, the model was run assuming EU production costs in 2010 were $900. In this case the area planted would be 11,304, or more near normal and would detract from the shift to the US and US river system.

***6.3 Barge System Scenarios*** A multitude of issues concern the barge system. The base case model was use to evaluate selective impacts. Results from each are described below.

***Demand for barge shipments.*** The barge rates were changed by a scalar for each reach to evaluate how shipments change. To do so, all barge rates were increased simultaneously from 20 to 200% from their base case value. See Figure 6.9. Results indicate that extent of the reduction in total barge shipments as rates increase. As illustrated, most of the decline is first for shipments from Reach 3, then from Reach 4.

This is the longer-term demand function for barge shipments, and contrasts from many of the previous studies which are shorter term elasticities. In this case, virtually all the relevant adjustments are allowed as barge rates change. These include changes in cropping patters,

domestic and international flows, modal shipments and interport flows. In this case, the results imply a long-run demand elasticity of about -.8 for a 20% increase in rates. It is inelastic, and compared to the studies using econometric methods, is slightly greater, as expected.

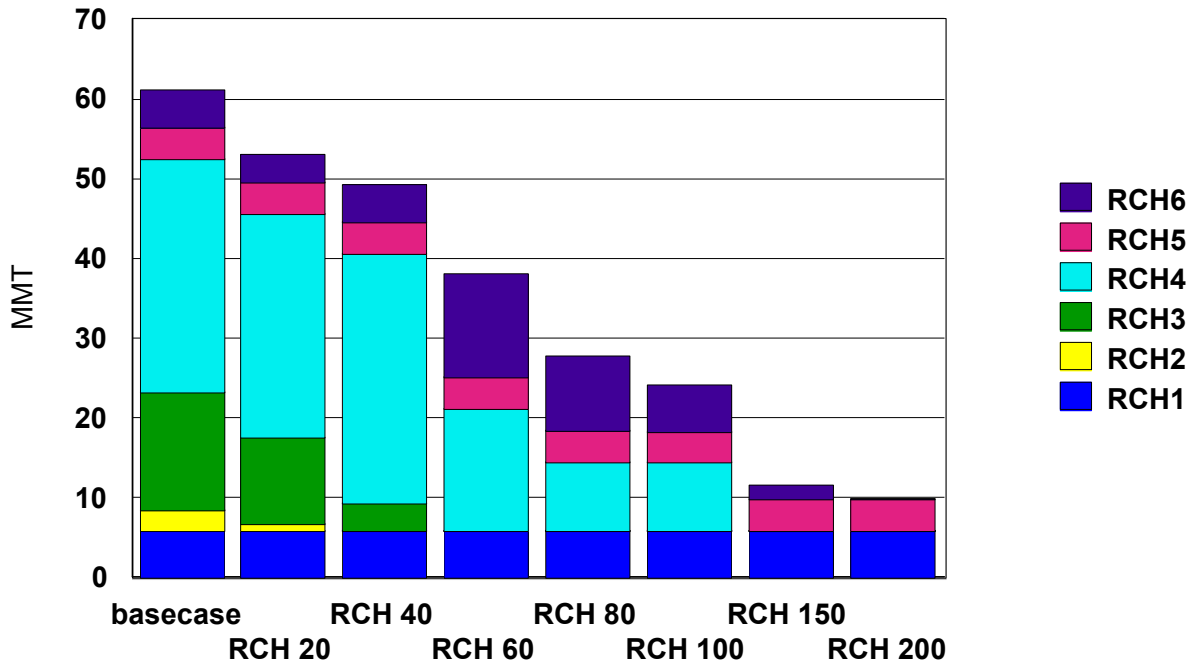


**Figure 6.9 Sensitivities Barge Rates: Long-Run Demand Curve.**

***Logistical constraints at Reach 1 and New Orleans.*** There were two very important assumptions imposed on the model which were retained as part of the base case. One of these is the restriction on barge transfer on Reach 1. These were restricted to the maximum of values that occurred in recent years. The rail and barge rate differentials in our base case were such that if not imposed, would result in a large amount of grain shipped by rail to Reach 1 and then transferred to barge for shipment to the Gulf.

The results when this restriction is relaxed are shown in Figure 6.10. The restriction was increased from the base case of 6 mmt, to 10, 15 up to 30 mmt. The results show that when relaxed, the total barge shipments increase slightly. This no doubt results from the reduced total shipping costs and that some delay costs are avoided. However, there is a notably sharp shift from shipments originating on Reach 4 by barge, to shipments originating on Reach 1 by barge. The latter are the result of rail shipments from the upper reaches to Reach 1 and then transferred to barge. These results suggest that this restriction is very important and if relaxed, and if rail rate differentials retained their 2002 level, would result in a sustained and large shift from the Upper Reaches to St. Louis.

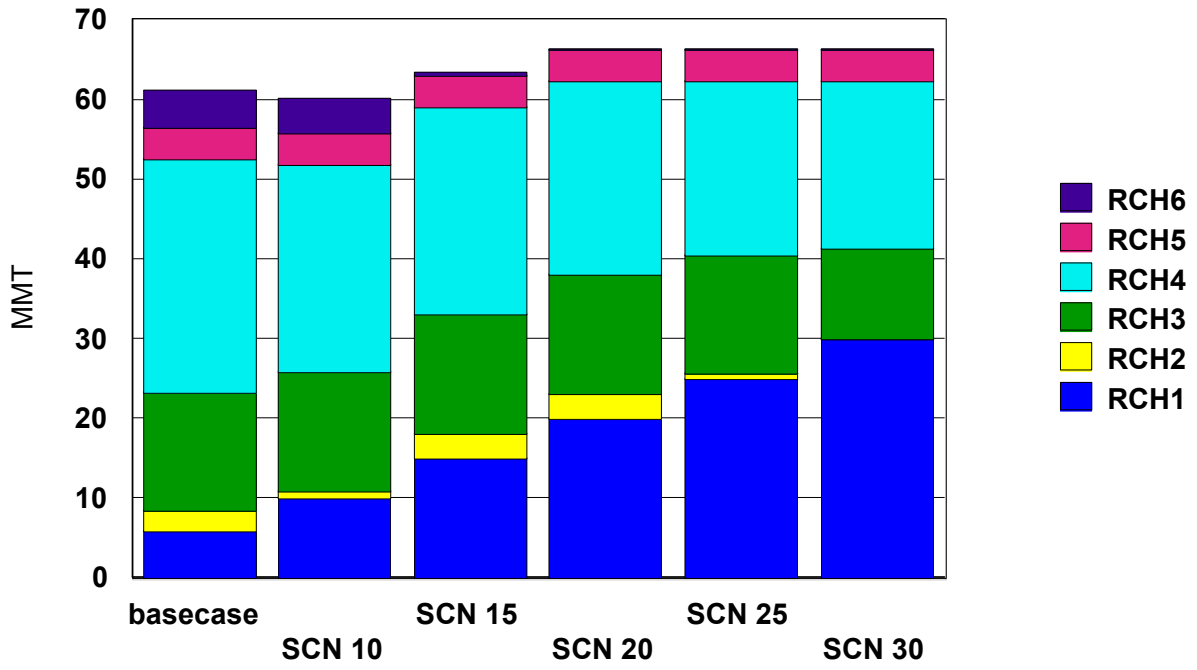


**Figure 6.10 Sensitivities Reach 1 Capacity.**

The other restriction was on rail transfer at the US Center Gulf. The base case had a maintained assumption that the railroads would or could only transfer 6 mmt at that port area. This is equal to the historical maximum for that flow. This restriction was imposed even though for some movements, direct rail was a lower cost alternative relative to barges. The model was run assuming this restriction was increased to 8, 10, 12 up to 18 mmt to evaluate how flows shift.

The results are shown in Figure 6.11. Total barge shipments decrease slightly as this restriction is increased. But stabilize when the restrictions reach about 10 mmt. The biggest change is a shift from Reach 2 to Reach 4. This reflects that some of these shipments would ship by rail and bypass barge system if this transfer restriction were relaxed.

Both of these restrictions are critical to the longer term results. They were imposed in part to more accurately reflect historical shipments. The relevance of these restrictions can be justified for several reasons. These include that there may in fact be a physical restriction on transfer, there may be environmental impacts that would favor more direct barge shipments, or there may in fact be rail car restrictions. Another may reflect that the rail carriers restrict their own shipments to St. Louis and/or direct to the US Center Gulf for profit-maximizing reasons, which would support increased movements to other port areas. It was beyond the scope of the current study to unravel these, but, as noted in these simulations, these are important restrictions. The fact that they were retained for the longer-term projections was in part to reflect historical shipments. Irrespective, this is suggested as an area of further research for verification and validity of these restrictions.

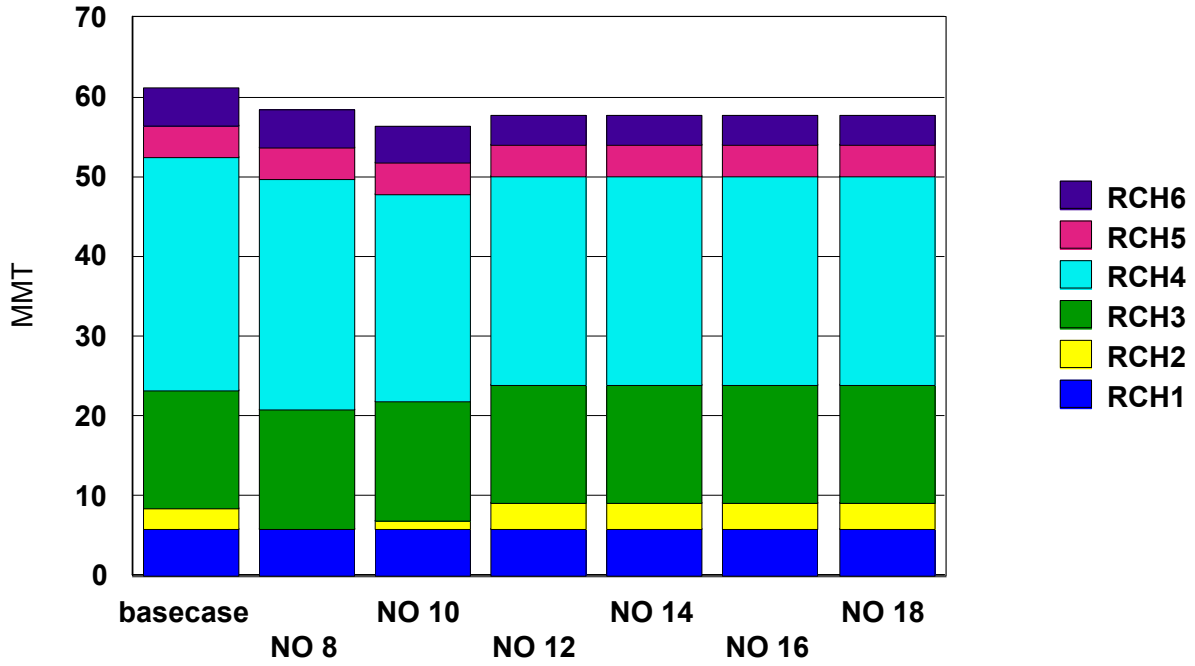


**Figure 6.11 Sensitivities: New Orleans Rail Capacity.**

***Impact of ocean rate spreads on barge shipments:*** The base case results assumed an intermarket ocean rate differential from US Gulf to Asia vs. PNW to Asia of about $5/mt. This is an approximation as the actual differential varied slightly across the different Asian destinations. Nevertheless, these were based on 2002 values and highly reflective of ocean shipping differentials at that time, and historical values to that time. Since then, these differentials have escalated drastically, which has resulted in a radical change in interport competition.

To evaluate this effect, the model was run at different levels of the differential, up to $20/mt. To do this, ocean rates to all Asian destinations from the PNW were reduced accordingly. In addition, the projected rail rate (estimated from regressions) matrixes were used for export shipments. The reason for the latter is that during the period through 2002 there were a high number of non-reported rail rates for many export flows in our sample which would have resulted in limited origins that could shift from the US Gulf to the PNW. By using the estimated rail rate functions, the assumption is that the geographical relationship in rates is retained to allow for an increase in the origins at which grain could be originated for shipment to the PNW, which is reasonable.

The results are shown in Figure 6.12, and, as illustrated these differentials have a drastic impact on the level and composition of barge shipments. Barge shipments decline when the differential increases, and those shipments are shifted to the PNW. The biggest reductions are for shipments from Reach 3 first, then Reach 2 and then Reach 4. In total, at a $10/mt ocean rate

differential barge shipments decline from about 60 mmt to 45 mmt; and at $20/mt ocean rate differential, barge shipments decline to less than 30 mmt.

The reduction in barge shipments is absorbed by an increase shipment through the PNW. However, there is also a capacity restriction at the PNW which appears to be about 30 mmt. When this restriction is imposed on the model (See PNW20L), the results change. In particular, the restriction forces more shipments through US Gulf; an increase from about 24 mmt to 48 mmt at a $20/mt ocean rate differential.

Again, these results are quite dramatic and warrant further interrogation. If the ocean rate differentials are thought to be sustained at current high values, these results suggest there would be a sustained reduction in barge shipments. The extent of that reduction depends on rail pricing, as well as on PNW export capacity. Should that expand, there would be a more sustained reduction in barge shipments.

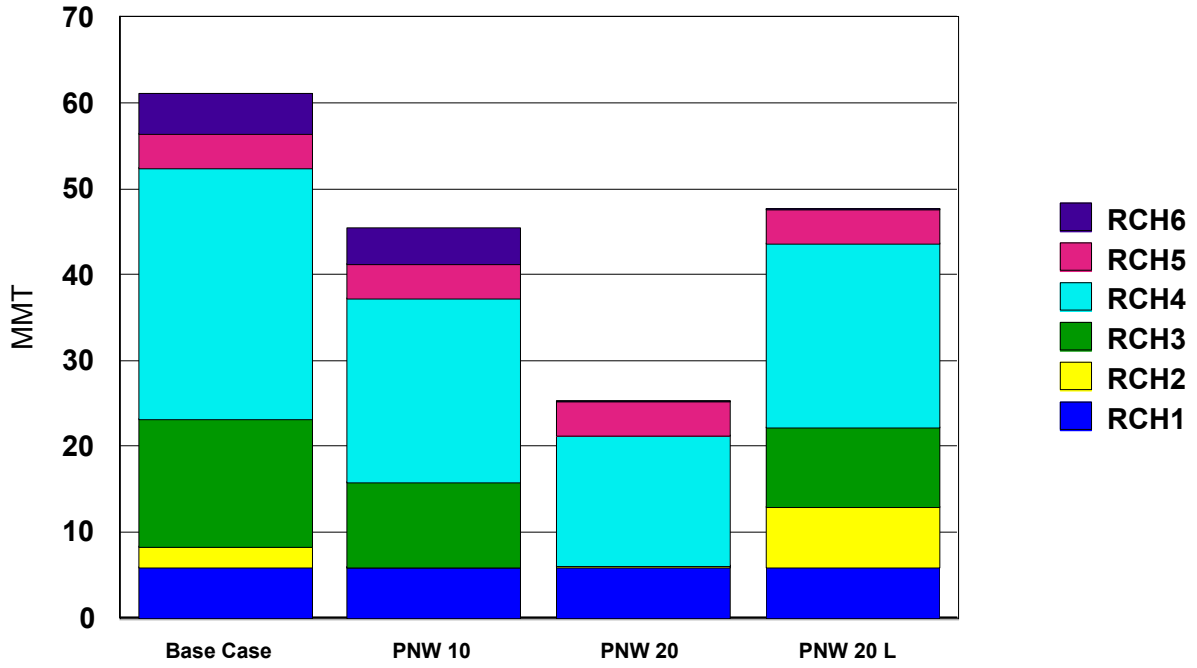


**Figure 6.12 Sensitivities: PNW**

***Other Sensitivities:*** A number of other simulations were conducted in part to illustrate the model, but also to address some of the relevant exogenous impacts on barge flows. Each is discussed below.

Panama Canal Expansion: A large amount of the grain exports from the US Gulf transit to the Asian markets using the Panama Canal. The Panama Canal is proposing to be expanded (Kraul). This decision is expected to be made in 2006. If approved, it would take 10 years or so to finish and result in both an expanded capacity for transits, as well as to allow for larger ships. These

impacts are highly speculative since it is yet unknown if and how tolls would change, and if and how larger ships would impact the grain trade. The latter are relevant since though larger ships have advantages for container shipments, this is not obvious in the case of grains due in part to restrictions at import areas.

Nevertheless, just to explore these prospective issues, the model was revised by lowering ocean shipping costs for shipments through the Canal by $3/mt if through the Panama Canal. The results (See Figure 6.13) suggest only minor changes. There is a slight reduction through Reach 4 and increases in shipments originating on Reach 2 and 3. Since objective values differ, but export movements from ports to consuming regions are unchanged, the reason for this is likely due to that both this strategy and base case strategies appear to have similar costs delivered internally and to export ports and may represent near alternative optimal movements.

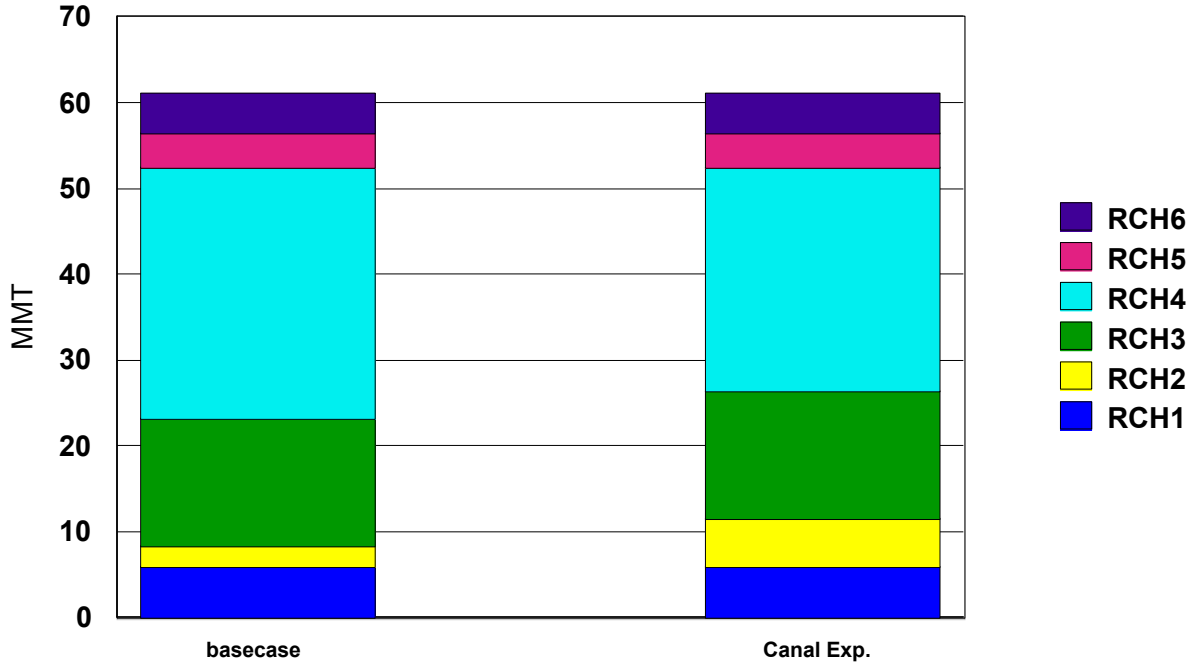


**Figure 6.13 Sensitivities: Panama Canal Expansion.**

Ethanol Expansion One of the major changes in US grain agriculture is emergence of the ethanol industry. The base case allowed expanded ethanol demand for corn based on current projections for ethanol demand for corn in United States. Since then, the Energy Bill was signed and would result in prospectively a greater amount of ethanol to be produced. However, it is not yet clear where these expanded plants would be adopted and hence the analysis is somewhat speculative.

To explore the prospective impacts of further changes in ethanol, the model was revised to allow 10% more demand for ethanol, versus the base case. These were assumed to be equally distributed across all production regions. See Figure 6.14. The impacts are for a slight reduction

in barge demand. The result is an increase in demand from Reach 2, and reduced demand from other Reaches. The model is impacted in part by changes in cropping patterns (increased corn, reduced soybeans) in most regions.

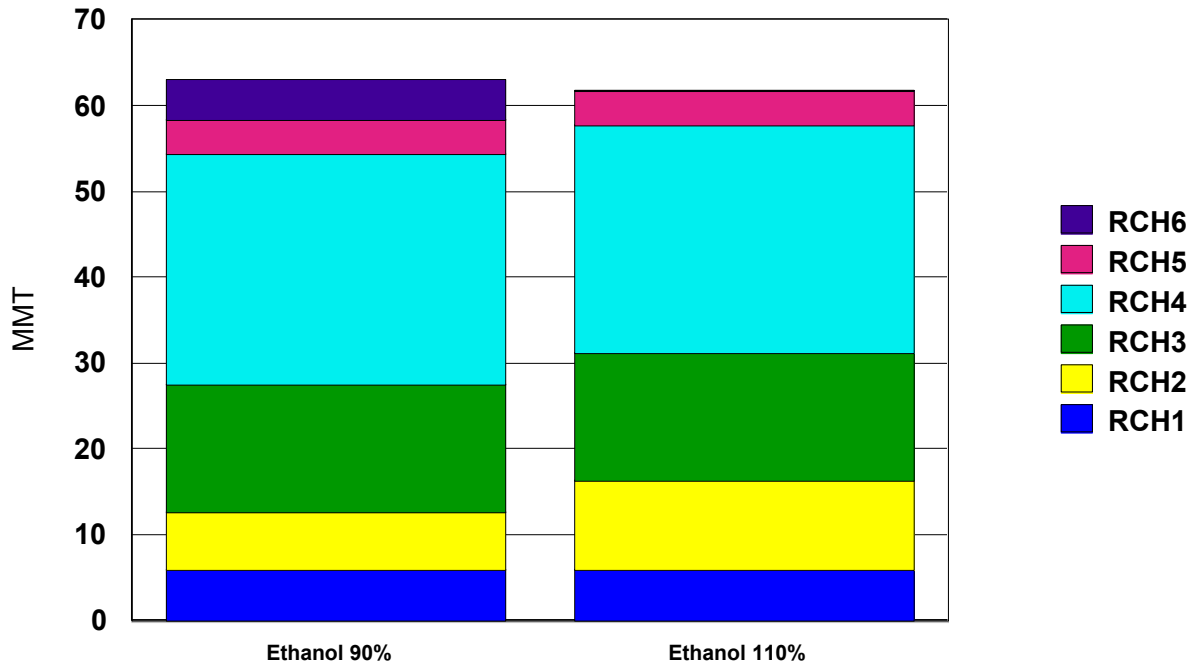


**Figure 6.14 Sensitivities: Ethanol Demand.**

Chinese Soybean Demand: One of the most dynamic countries in the world grain market is China. This country is experiencing rapid increases in income, a large and growing population. In addition, there are changes in consumer patterns. These may be underestimated in our econometric analysis of consumption due to difficulties in fully capturing changes in consumption habit. Most notable in the case of China is the prospect for underestimating the impacts of soybean consumption. The base case assumes normal growth in China demand for soybeans.

The model was relaxed to allow changes in demand, prospectively reflecting a faster growth rate. In particular, the model allowed a further increase in soybean demand by 10 percent beyond that suggested in the base case. See Figure 6.15. The results suggest a slight increase in barge flows. These are mostly due to China demand coming from US PNW. There are increased shipments from Reach 2, and reductions from Reach 4.

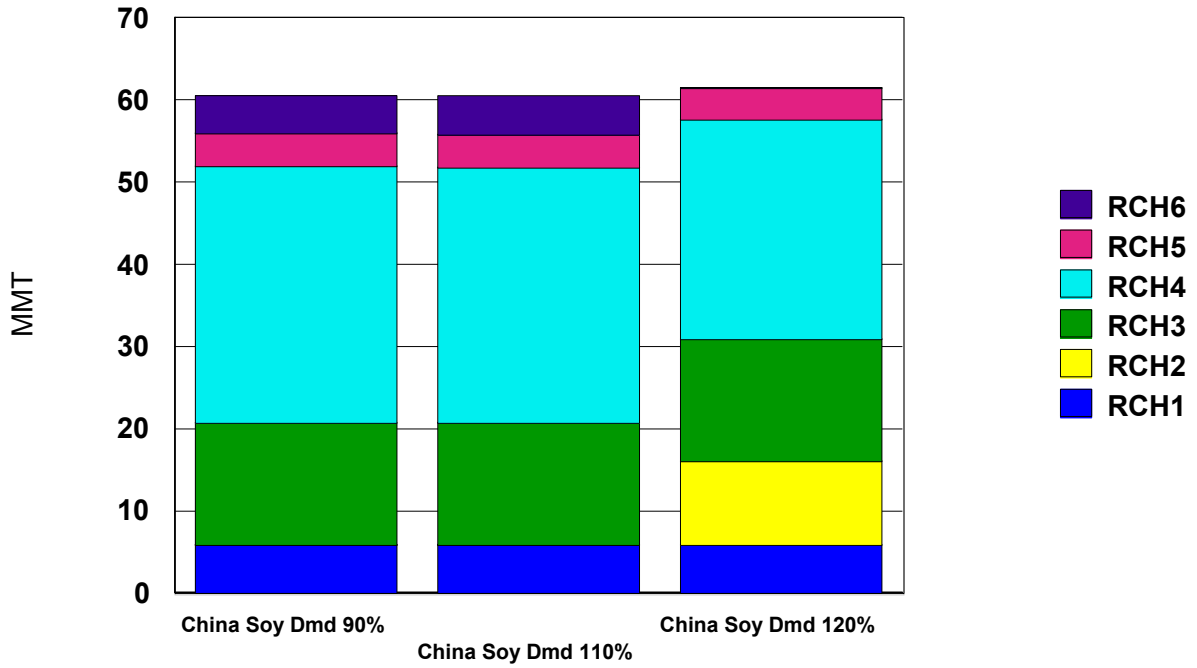


**Figure 6.15 Sensitivities: China Soybean Demand.**

Free Trade: The base case model assumed that export subsidies and import tariffs were equal to the values that existed in 2002. While it is questionable how these will be determined in the future and under future trade regimes, these were retained in the base case and for the projections.

To evaluate the importance of these trade regimes, the model assumed each of the export subsidies and import tariffs were nil commencing in 2010. This would reflect the timing of the completion of the current World Trade Organization negotiations in which agriculture is one of the most important topics. See Figures 6.16 to 6.17. Results illustrate that under free trade with no subsidies, barge shipments would increase (See F2010 NOSUB vs. F2010SUB). In particular, shipments from Reaches 3, 4 and 6 increase sharply, and those from Reach 2 decrease.

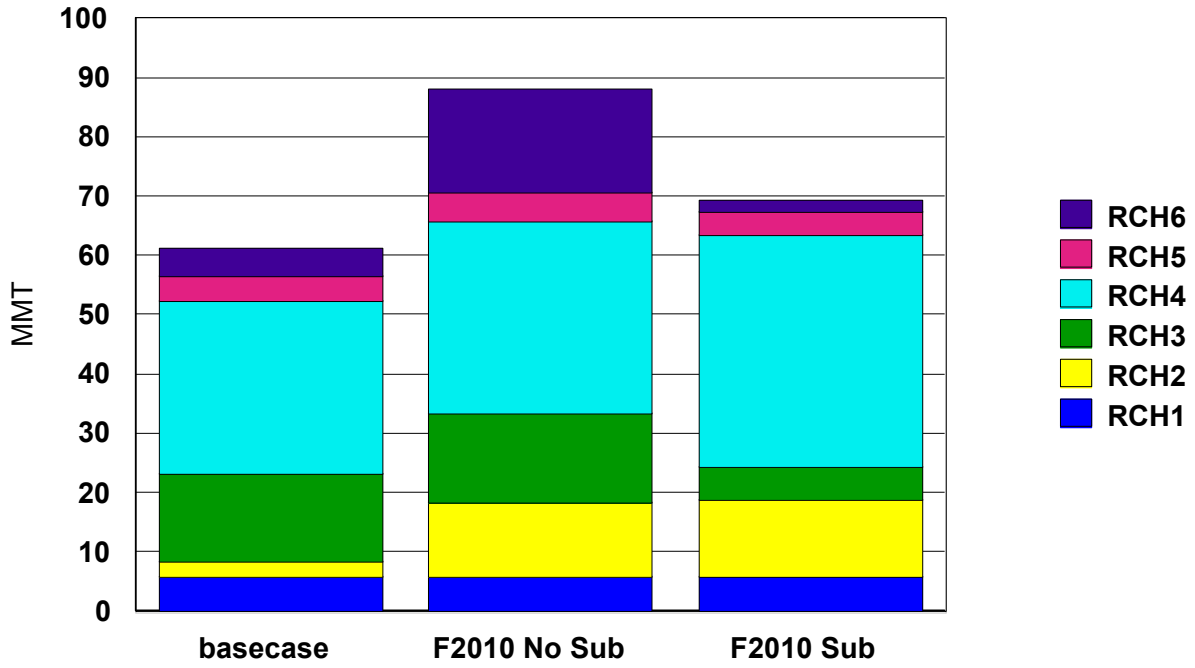


**Figure 6.16 Comparison of Reach Volumes for Basecase and Forecasts for 2010 with and without Subsidies.**

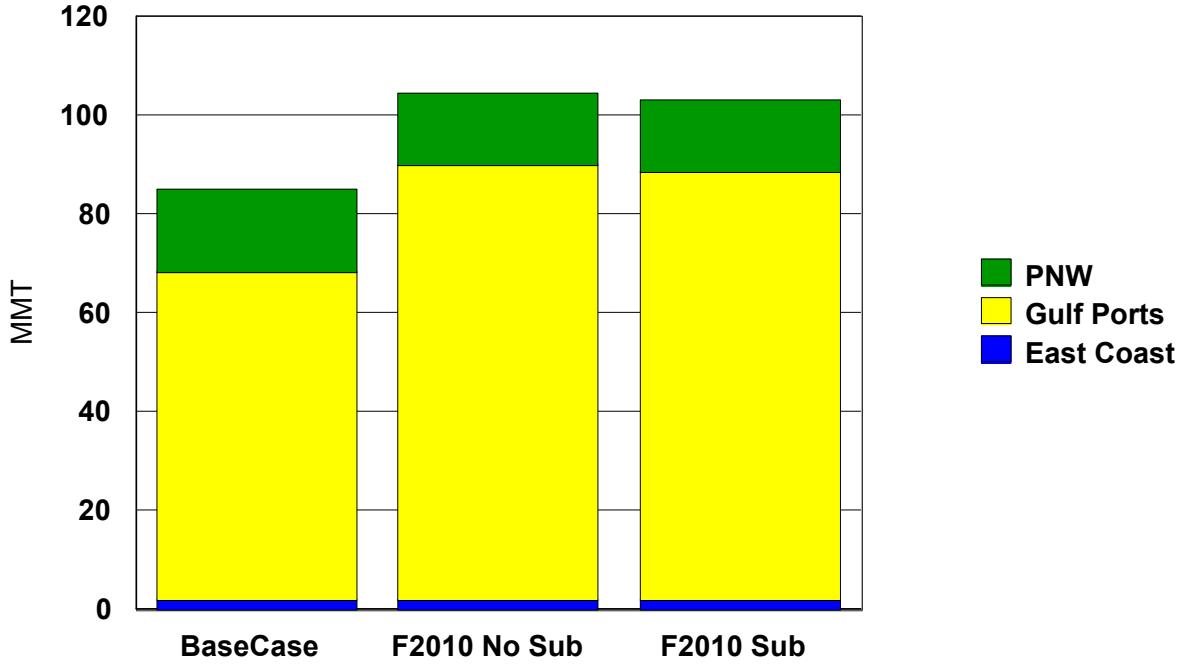


**Figure 6.17 Comparison of U.S. Export Shipments for Basecase and Forecasts for 2010 with and without Subsidies.**

Changes in EU Production One of the other critical trade policy issues relates to EU production levels. These are the result of a highly regulated regime in the Common Agricultural Policy. The base case allowed EU production at current values. To explore the significance of this, the model was revised to allow reduced or expanded production in the EU from current values. These were simulated at 96% and 106% of normal production respectively.

The results (See Figure 6.18) illustrate that reduced production in EU, results in an increase in barge shipments; and vice versa. Most significant is that reduced EU production results in an increase in shipments from each of Reaches 2-6, but, the largest gain is on Reach 3. No doubt this is the impact of increased wheat shipments from the United States.

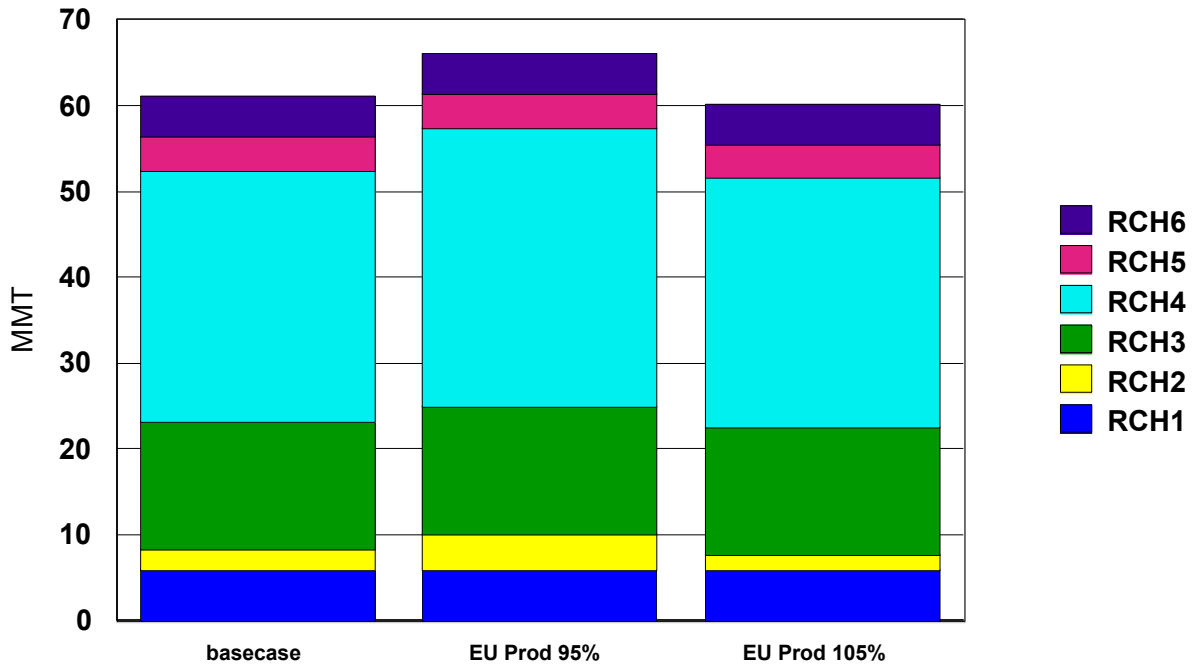


**Figure 6.18 Sensitivities: EU Production.**

Changes in Brazil Production: One of the other major structural changes occurring in the world grain market is related to Brazil. Most important here is the gradual expansion of production what is referred as Brazil North in the model. The base case assumes current area in Brazil. The model was revised to allow reduced and increased soybean production in Brazil. Simply, production was forced to increase and decrease by 10%. This contrasts with the base case where Brazil's production enters the solution based on cost estimates relative to competing regions.

The results (See Figure 6.19) indicate that reduced Brazil production increases barge demand; notably from Reach 2 and 3. Increased Brazil production reduces barge demand; mostly from Reach 4, as well as Reach 2.

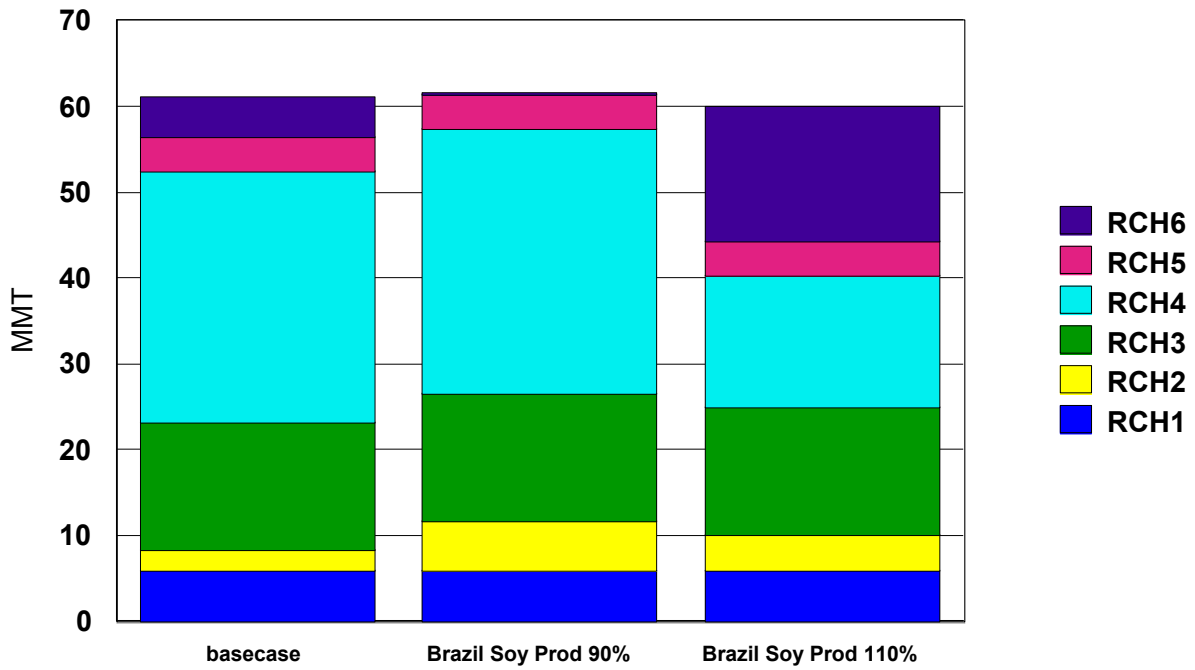


**Figure 6.19 Sensitivities: Brazil Soybean Production.**

## 7. Stochastic Analysis of World Grain Trade

***7.1 Model Specification*** The deterministic model described above was converted to a stochastic optimization model for two reasons. One was to capture the relevant sources of uncertainty in the model and derive the impacts of these on the distribution of barges shipments. The second was to evaluate how far forward the model could be projected prior to the uncertainty overwhelming the results.

The model was specified as a chance-constrained specification which accounts for right-hand side uncertainty (Charnes and Cooper 1959).[5, 6] In this model, the forecast variance is an input to the modeling specification. The specification assumes the decision maker is willing to allow constraint violations with some specified probability, $\alpha$. The model constraints are written as, for example, Prob(total shipments $\geq$import demand) $\geq \alpha$. Treating the stochastic elements as a

[5]The appendix (Section 11) describes this model in detail.

[6]It should be clear that this is an analytical model of a stochastic problem. Thus, the model was specified and solved numerically. This contrasts with a simulation solution. Early experimentation led to the conclusion that the size and detail of the model made such a stochastic optimization nearly infeasible. For that reason, the anlytical specification was pursued.

chance constrained has the effect of converting this to a deterministic model. Thus, the extent of variability in the stochastic elements of the problem can be interpreted by examining the impacts of $\alpha$ on barge demand.

If the distribution of import demand is known and integratable, it is possible to write the chance constraint. With multiple constraints, the joint probability of satisfying all constraints simultaneously must be computed. The challenge is that few distributions allow for analytical computation of the joint cumulative density. In total there were 30 chance constraints with a probability of satisfying demand.

The model objective function is specified as the sum of expected production costs, transportation costs, and delay costs. Model constraints include satisfaction of demands, acreage limits and exports limited to production. Chance constraints are adopted for demand satisfaction and exports limited by production. Each of these constraints must incorporate stochastic variables on the right-hand side. It is important that shipping by barge is a cost and a cost element in the model. As volumes increase, barge rates increase and as delay costs are incurred, shipments are diverted to other modes and/or crops in the United States and/or other countries. It was decided early in the model development stage that the appropriate way to model barge delays was through a cost rather than as a constraint. Thus, barges were not interpreted as a constraint, but, rather a cost. Of course, expansion results in a reduced delay cost.

There are three groups of random variables. One is consumption for each country/region which are impacted by stochastic nature of consumption function. The second is crop yield which impacts production costs. Third are modal rates for which a function was estimated for each of rail (domestic and export), barge and ocean shipping. The distributions for some of these were characterized by their respective variance/covariance matrixes. This was the approach for consumption and yields.

Modal rates were specified as a group of econometrically specified functions. Generally, this was a system including:

- Ocean rates which were related to distance, origin and destination dummies, fuel costs and trend;

- Barge rates which were related to export levels, shipments on individual reaches, and ocean spreads;

- Domestic rail rates, estimated separately for each crop, where rail rates were related to distance, distance to barges, trend and the interaction with barge rates from Reach 1.

- Export rail rates, estimated for each crop, which were related to distance, distance to barge, reach origins and the barge rate at each of the reach origins and the ocean rate spreads.

Each of these was estimated separately to accommodate the data and other restrictions. In particular, the rate functions for each mode were estimated from pooled data, but the dimensions varied. Joint estimation would require some type of a priori restrictions on the pooling which was thought to be more onerous than the efficiency gains from joint estimation. The results were a set of equations that were selectively related to each other.

The model was estimated and calibrated relative to the base case deterministic model described above (assuming $\alpha$=.5). A number of restrictions were made in the deterministic model to help depict a solution reflective of past movements. In part, these were imposed due to the deterministic nature of that model. In the stochastic model, these were largely dropped. The exception was the restriction on wheat marketing to reflect quality demands. Otherwise, these were dropped including the St Louis and New Orleans transfer restriction. Finally, in contrast to the deterministic model, the results presented below allowed for a 20% change in area planted to each crop versus a 10% change in the deterministic model, and most of the results assume a $\alpha$=.9 versus the implied $\alpha$ of .5 in the deterministic model. Of course, the effects of some of these are evaluated using sensitivities, and since these are assumptions they can be easily changed.

The model was used to evaluate the base case, and make projections with and without expanded barge capacity. Finally, the model was used to determine how far forward it could reliably make projections about the effects of barge expansions.

***7.2 Base Case and Projections with Existing Capacity*** The base case was evaluated assuming existing barge system capacity as represented by the delay costs and restrictions. It was also used to make projections assuming existing capacity. To do so, incomes and population projections were taken from *Global Insights (*2004a), yields and modal rates were projected. The results are summarized in Figures 7.1-7.5.

These results are more conservative than deterministic model. The deterministic model is roughly the equivalent of the stochastic model with alpha = 0.5. In other words, the in the deterministic model, regional demands are satisfied with confidence 50%. The stochastic model considered confidence levels of 0.6 up to 1.0 in increments of 0.1 and illustrates the differences. The base case results presented below assumes $\alpha$= 0.9, or 90% confidence level, which can be thought of as a one-sided confidence interval. With 90% confidence, individual demands are satisfied and the joint probability is much, much lower (about 7.617735E-5 = $0.9^{30}$).

The results show that for the base year exports are about 77 mmt with barge traffic of 48 mmt. Exports climb to 155 mmt in 2010 with barge traffic of just under 55 mmt. From the base year, exports increase by about 50% in five years. Another increase of 50% would put exports at 172 mmt (as compared to the model result of 155 mmt). Barge traffic increases by about 10 mmt over the next five years.

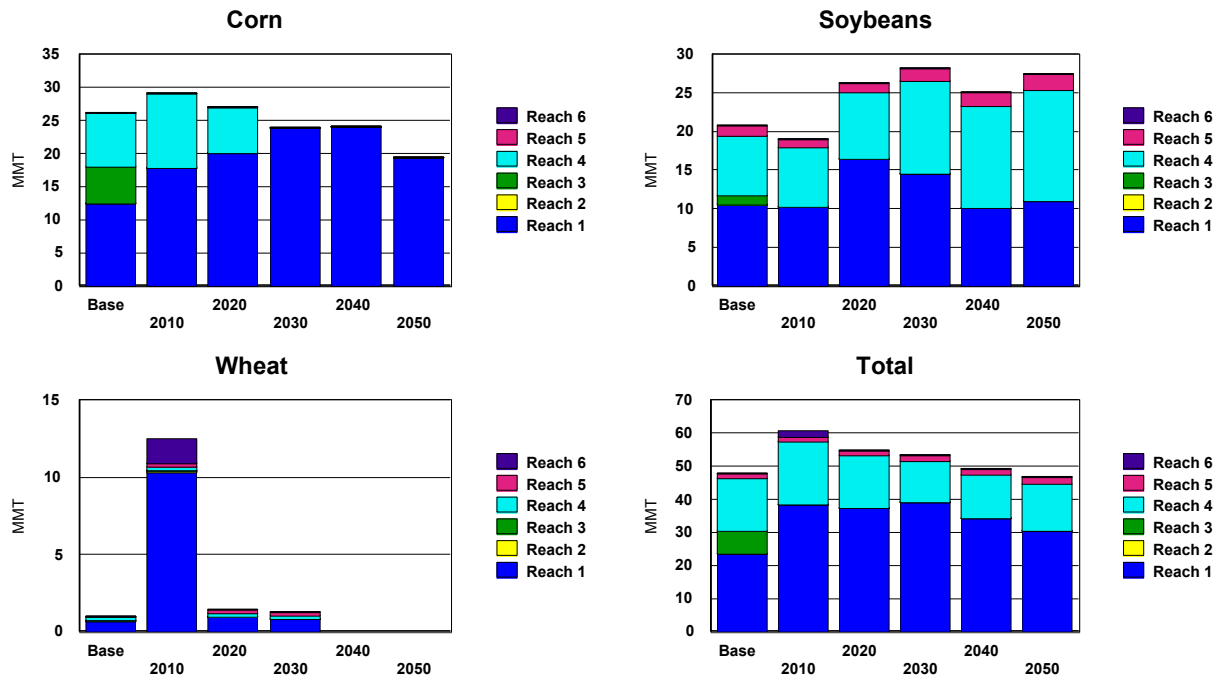


**Figure 7.1 Reach Volume by Crop and Total, Current Capacity, Alpha=.9.**

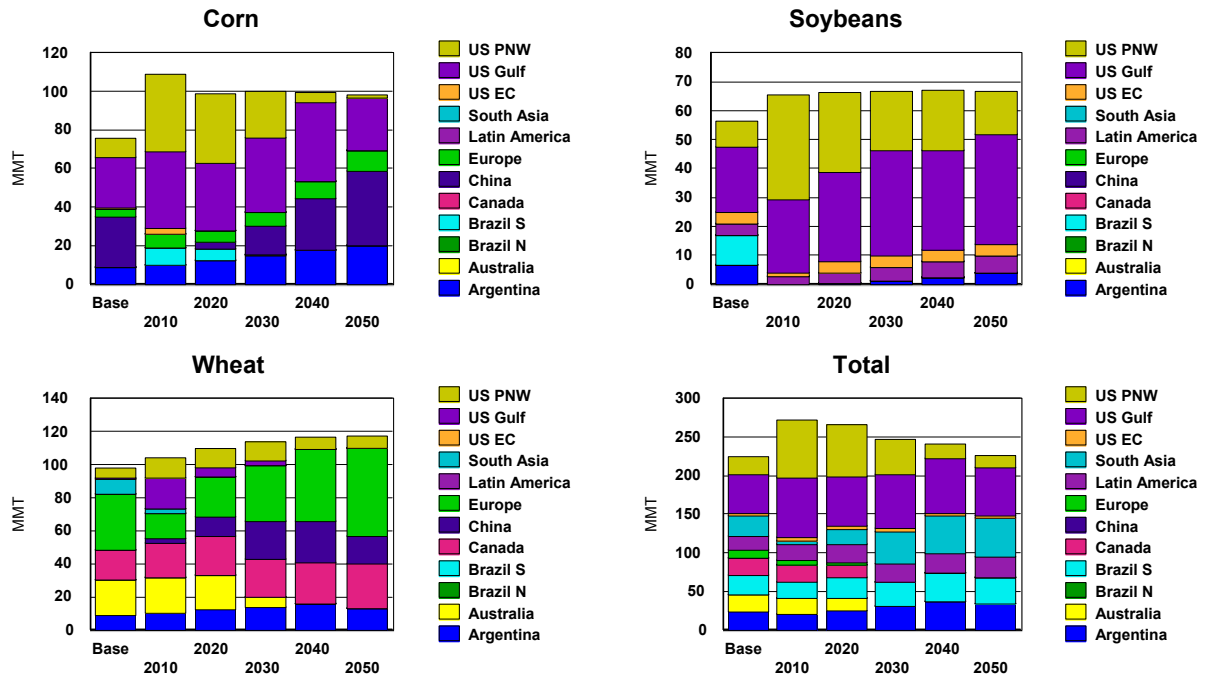


**Figure 7.2 Export Volumes by Crop and Total, Current Capacity, Alpha=.9.**

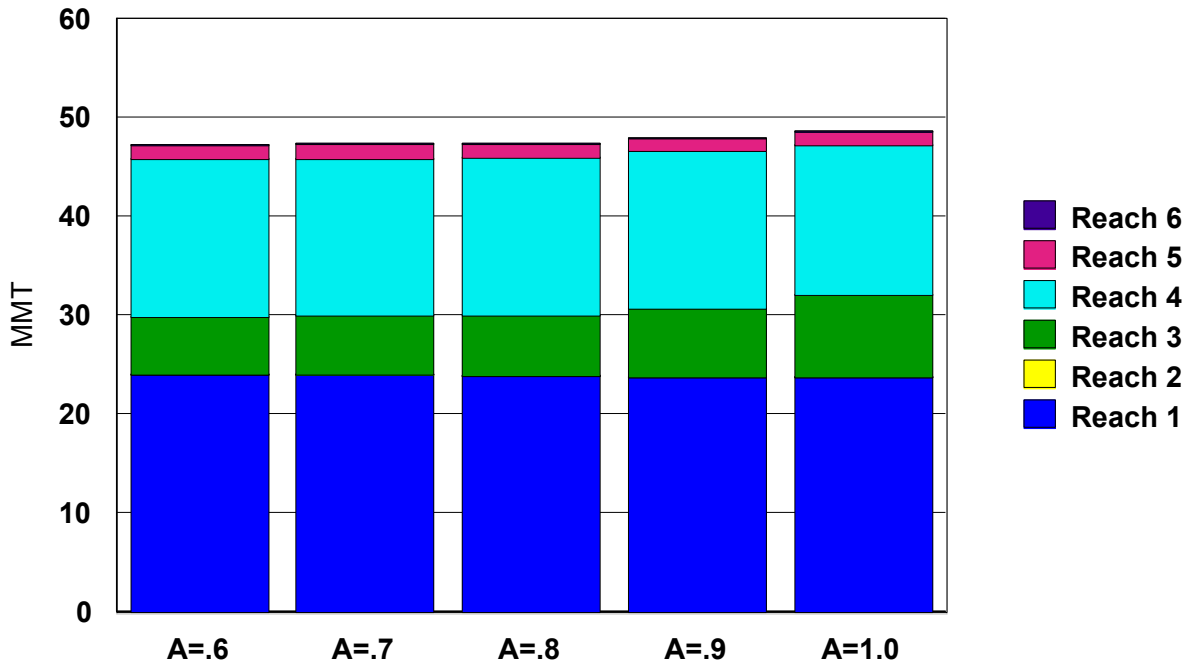


**Figure 7.3 Effect of Alpha on Total Barge Volume for Base Year, Current Capacity.**

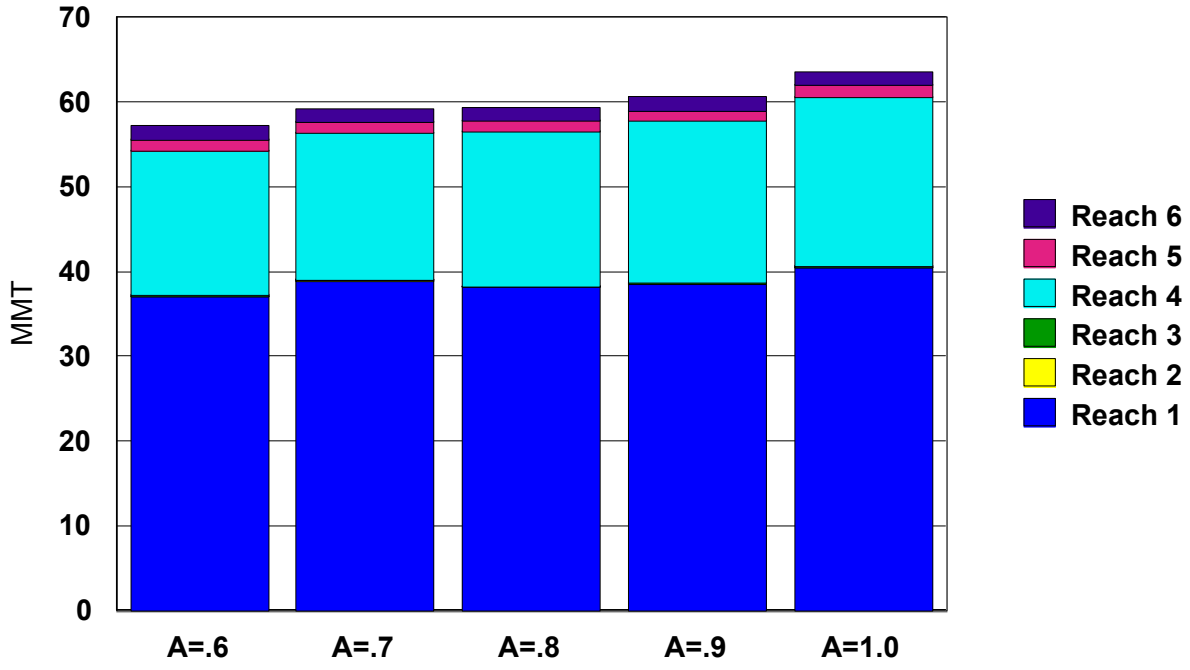


**Figure 7.4 Effect of Alpha on Total Barge Volume for 2010, Current Capacity.**

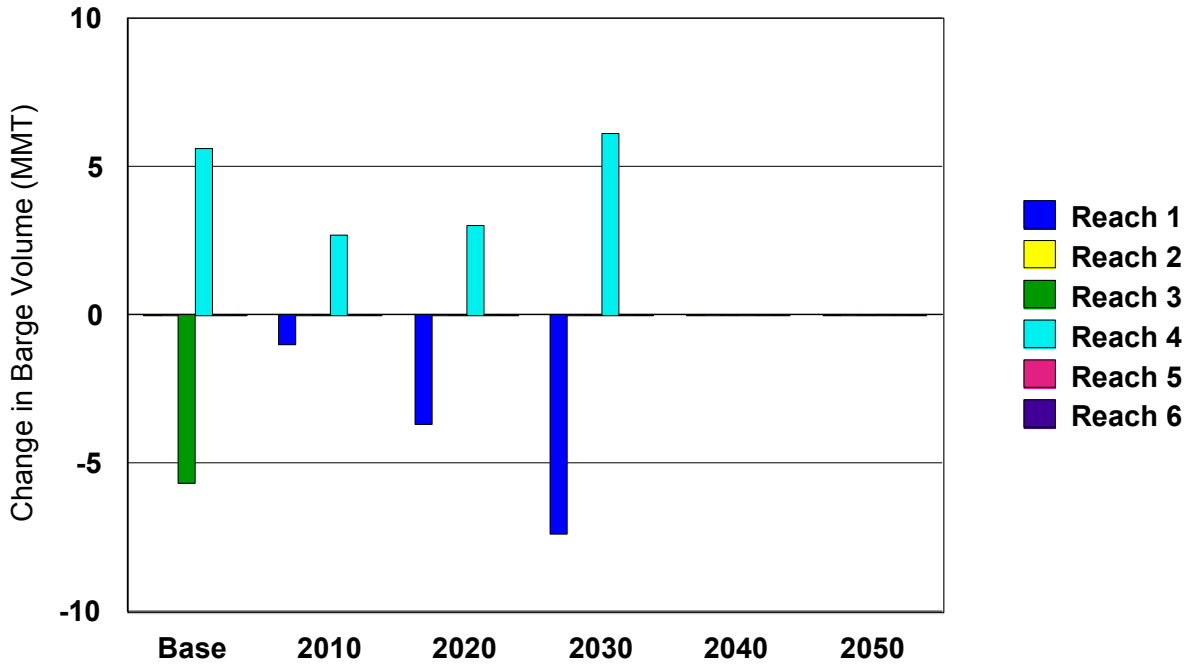


**Figure 7.5 Change in Barge Volume Current Capacity vs No Delay Cost, Alpha=.9.**

It is noteworthy that barge shipments are concentrated in Reach 1, followed by Reach 3 and 4. In contrast to the deterministic model this is due in part to not imposing the restriction on St. Louis and New Orleans rail transfer. As a result, a significant amount is shipped by rail to Reach 1 and/or directly to New Orleans by rail. The impact is to increase the originations at Reach 1. Also, shipments from Reach 2 are diverted to Reach 1 and/or used domestically.

The model forecasts US exports and barge traffic to decline after 2010. This is in part due to the conservative specification of the model regarding satisfaction of demand. An increasing percent of US grain production is consumed domestically, leaving less available for export. Recall that demand must be satisfied with some specified confidence level that exceeds 90% confidence. Also, forecast variability increases over time (see below). Thus, in order to satisfy the chance constraint, over time an increasing amount of US-produced grain is consumed domestically.

A sensitivity of the model results with respect to $\alpha$ was conducted (Figures 7.3-7.4). Results suggest that changes in $\alpha$ do not have an important impact on barges traffic. An increase in $\alpha$ results in a very slight increase in Reach 3. By 2010, increases in $\alpha$ have a greater impact on Reach 1 and Reach 4 shipments. These results in part suggest that barge shipments do not vary too much with respect to the choice of $\alpha$ which implies that increases in certainty of meeting demands to not have a drastic impact on barge shipments. Given that exports vary little with $\alpha$, it follows that barge traffic is also relatively stable.

The model was also run with existing capacity and assuming delay costs are nil. The

reason for this is to evaluate the impact of these delay costs on the solution. The results show that expansion has minimal impacts on flows and total costs. As noted above rail has become increasingly cost effective on particular movements that compete with barges which are the primary reason for this effect.

Finally, the results are highly sensitive to a number of variables. Though their impacts are not illustrated here as sensitivities, they are mentioned as important. One is the amount of area planted that is allowed to shift between crops. In the stochastic model this was allowed at 20%. In other words, area planted could shift between crops in all countries by 20% per year, which by empirical comparison is quite large. This assumption is fairly critical. As example, it has the impact of shifting more area in the United States into soybean since in part it is a lower cost producer. The other two effects that have an important impact on the results are the demand projections and yield forecasts.

***7.3 Projections with Expanded Capacity***: The model was also simulated assuming each of the proposed expansions were adopted. These results are shown in Figures 7.6-7.8.

Results are comparable to the current capacity scenarios discussed above with a few exceptions. Most important is that there is an increase in shipments from Reach 4, notably by nearly 6 mmt in the base period, and about 2 mmt in subsequent years. This however, is offset by shipments declining in Reach 3 and Reach 6. In total, the expansion results in only a modest increase in shipments. It is important that Reach 4 currently experiences delay costs due to its capacity. Expanding the system to essentially eliminate these costs has fairly drastic impacts on inter regional competition. In particular, grain shipments are shifted from Reach 4 to the barges, and Reach 3 and Reach 6 shipments are diverted to either domestic use or other channels.

Total delay costs are higher with the expansion in each of the Reaches simultaneously. With the expanded capacity, per unit delay costs are reduced more for Reach 4 in comparison with Reach 3. The model minimizes the total cost of satisfying demand, and production cost + shipping cost + delay cost is minimized. Consequently, when the locks are expanded, the per unit delay cost for Reach 4 is reduced. Given similar production cost and lower shipping cost for corn shipped from Reach 4 (versus 3), it is now cost minimizing to move more grain through Reach 4 even though some delay costs are accrued.

These results differ somewhat from the deterministic model, but these can be explained. In the deterministic model, changes in capacity were the only adjustments introduced, and, as illustrated there are measurable increases in barge demand. In contrast here, the extent of increases in demand are much less. The reason for that is because the simulation allows for numerous other simultaneous changes. As a result of expanding barges, delay costs decline some, barge movements increase on some flows, rail rates adjust, and concurrently there are some changes in production in the United States and elsewhere. As a result of these longer-run

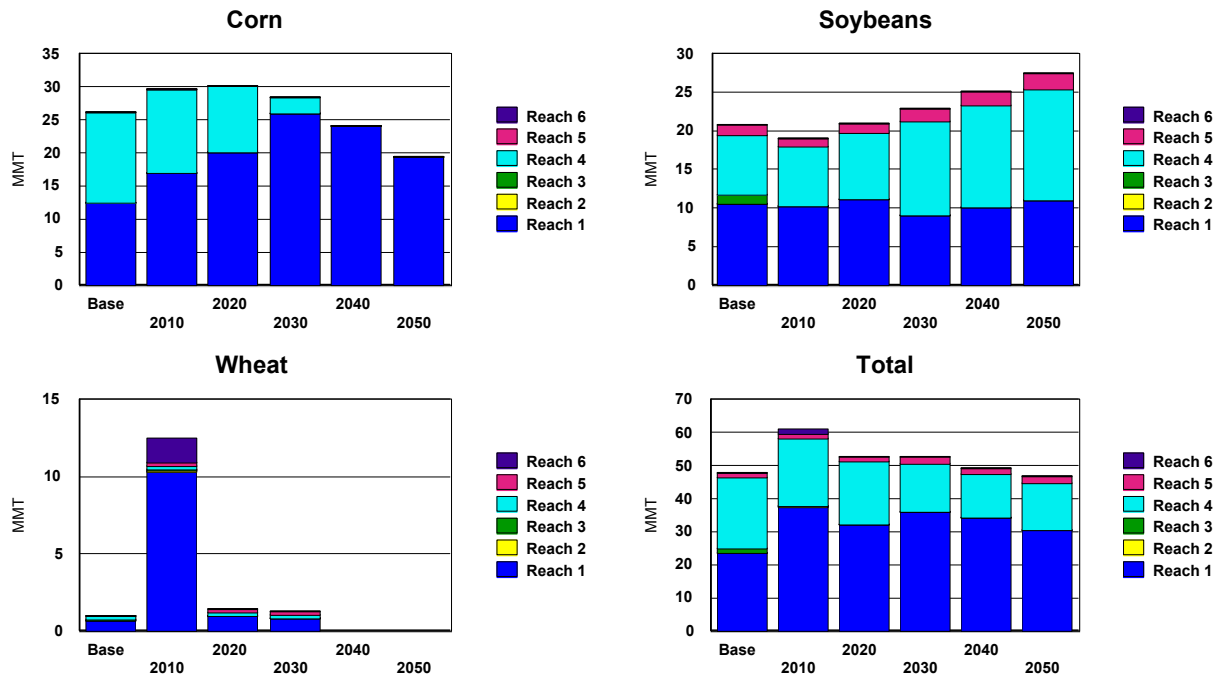


**Figure 7.6 Reach Volume by Crop and Total, Expanded Capacity, Alpha=.9.**

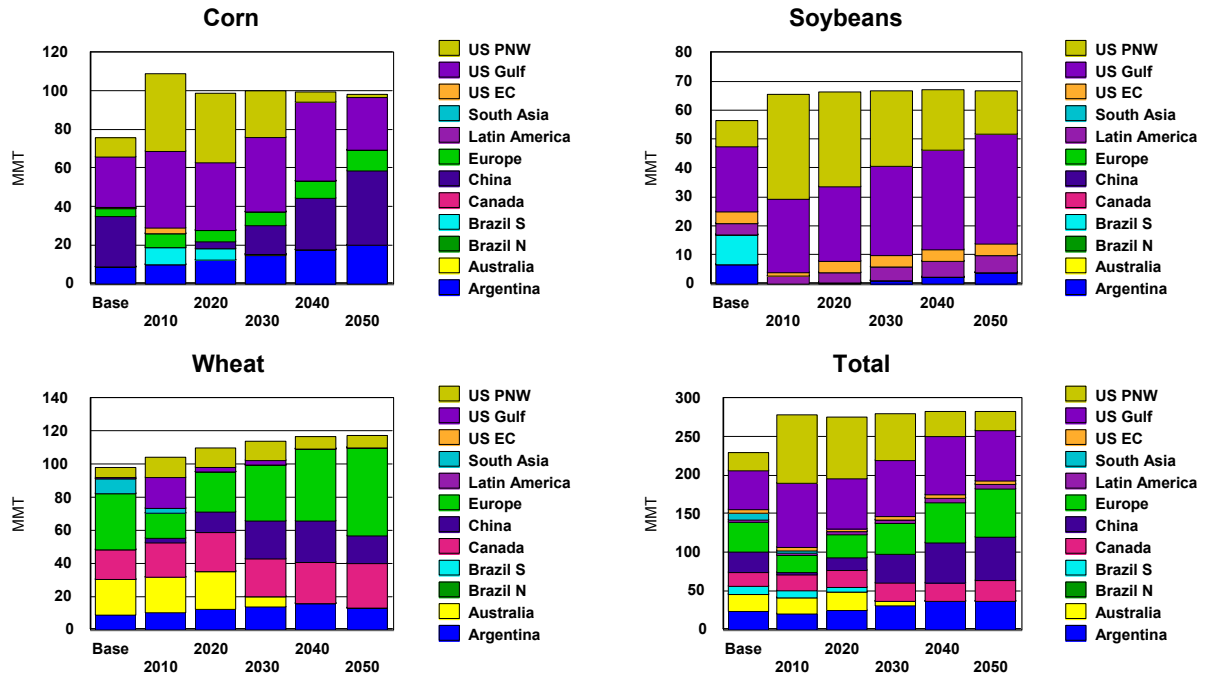


**Figure 7.7 Export Volume by Crop and Total, Expanded Capacity, Alpha=.9.**

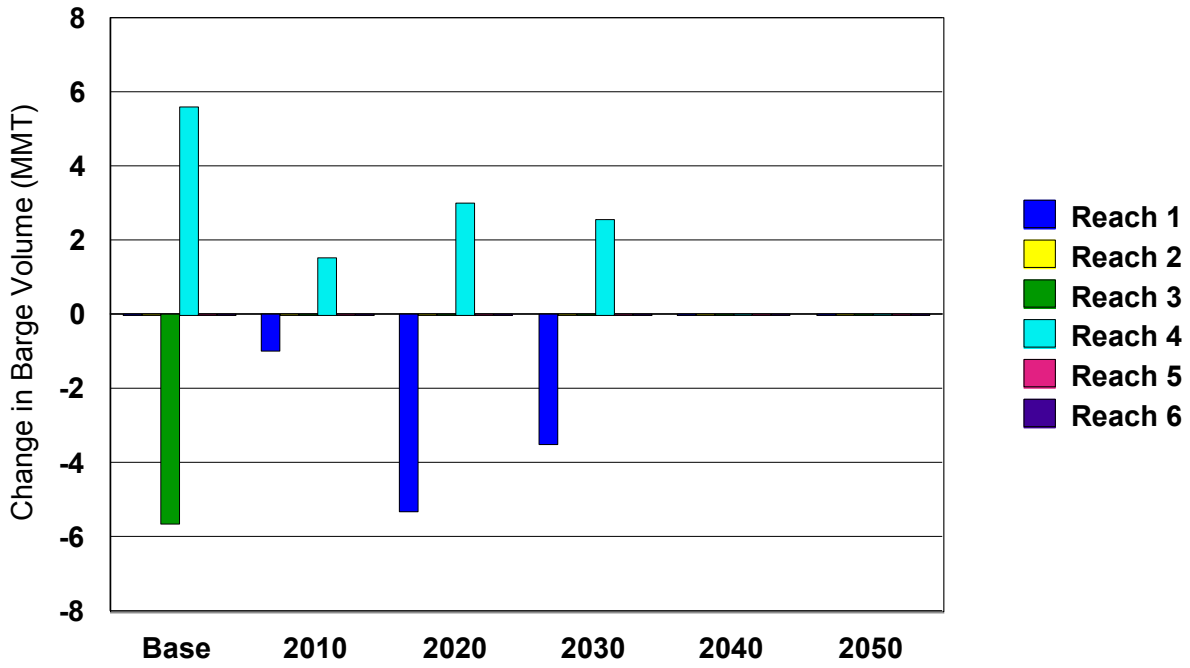


**Figure 7.8 Change in Barge Volume, Expanded - Current Capacity, Alpha=.9.**

adjustments, the impact of expansions is much less than that shown in the deterministic model.

Sensitivities were conducted with respect to the value of α. See Figure 7.9-7.10. The results illustrate that at lower values of α the difference in cost savings declines substantially and by 2030 is near nil. At higher values of α differences are also substantially lesser as the projection period increases.

Finally, as a global measure of the value of increased locks one could interpret the differences in total costs (i.e., the model objective function). See Figure 7.10. The differences (at the 90% confidence level) are $1.6 million in the base year, $1.9 million (2010), $1.1 million (2020), $100k (2030) and zero thereafter. Beyond year 2020, the forecast variance essentially "swamps" the model (see below). The reasons for this are the large number of changes that are allowed in the longer-run in response to these changes.

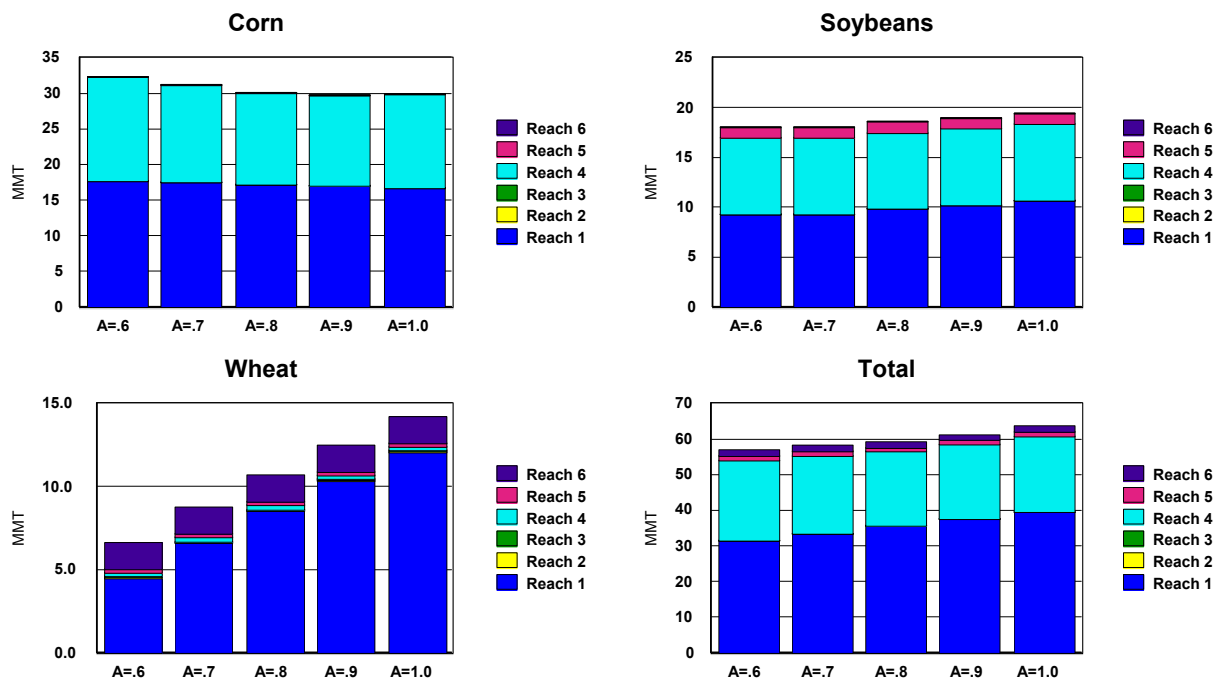


**Figure 7.9 Barge Volume by Reach, Expanded Capacity for 2010, by Crop and Total and Alpha.**

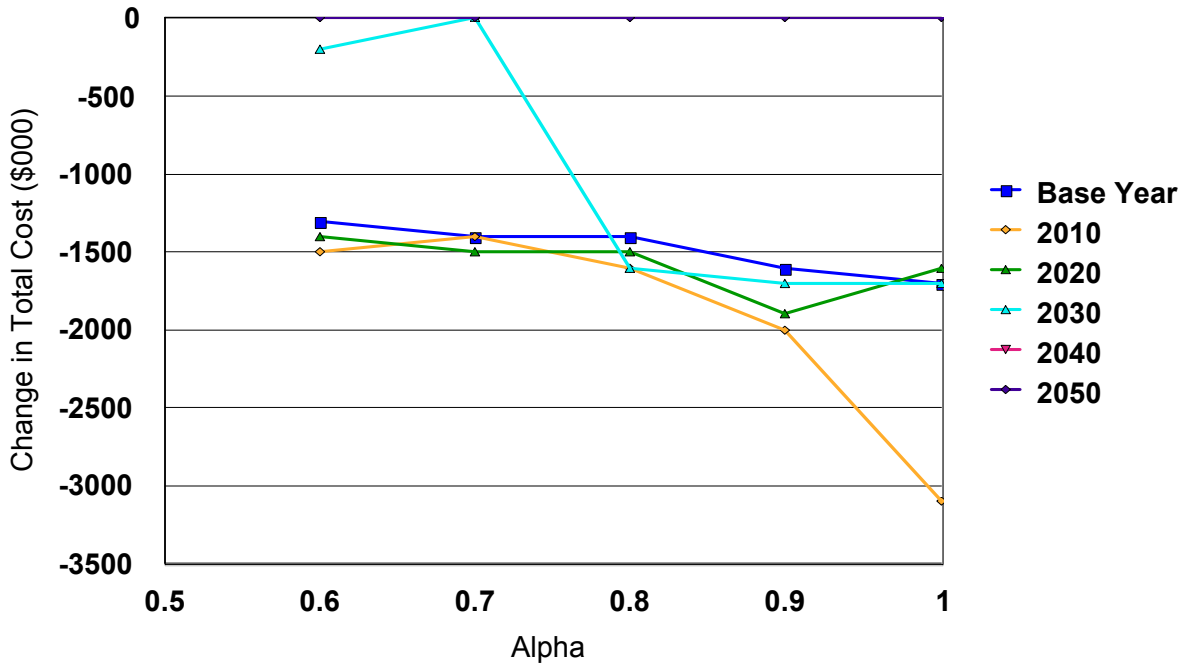


**Figure 7.10 Difference in Total Costs by Alpha and Year (Expanded - Current Capacity).**

***7.4 How Far Forward are Projections Valid?*** The model was used to determine how far forward it would be reasonable to make projections about the impacts of lock expansions.

The approach used was to forecast future demands and characterize demand uncertainty are statistically valid. The estimation procedures employ a finite number of historical observations. The demand equations and estimation residuals are then used to extrapolate demand and demand uncertainty for up to 50 years into the future.[7] With any extrapolation procedure, the forecasting error variance increases with the distance from the mean of the estimation data.

The forecast variance is shown in Figure 7.11 and 7.12. Strictly, this is the variance of total consumption across all markets and is in 000 mt. As noted, this increases from about 40 to 80 billion units looking forward from 2000. Though not radically apparent, it increases at an increasing rate by about year 2030. This variance impacts the variance of barge demand though the latter could not be derived.

The value of the objective function can also be used to interpret the results. See Figure 7.13 which shows the difference in the objective function value with and without the expansion. As illustrated, the objective function results in a lower long term cost in the early years. However, by 2020 there is not much difference in the cost savings; and by 2030 it is negligible, and by 2040-2050 the difference is virtually meaningless. This implies that the projections of the impact of the expansion are reliable through about 2020, but, beyond that the advantages diminish to near nil. This is more apparent with lower values of $\alpha$.

The potential for large errors cannot be overemphasized. At some point, the variance of the forecast error overwhelms the model results. Although our model accounts for demand uncertainty through chance constraints and other sources of variability in the objective function, our confidence in the model results are negligible beyond 20 years out.

[7] An appropriate analogy is to use ten points lying in straight line, each one mile apart. Using the elevation of those points, fit a line through the points to project elevation out past the points–in a direction that you have never traveled. Using the fitted line, predict the elevation of a point 50 miles past the last point of the sample. Since you have never traveled in the direction of the line, it is impossible to know if there is a mountain or an ocean lying 50 miles out. Since we cannot travel 50 years forward in time, or even one year, our model forecast suffers from similar uncertainties.

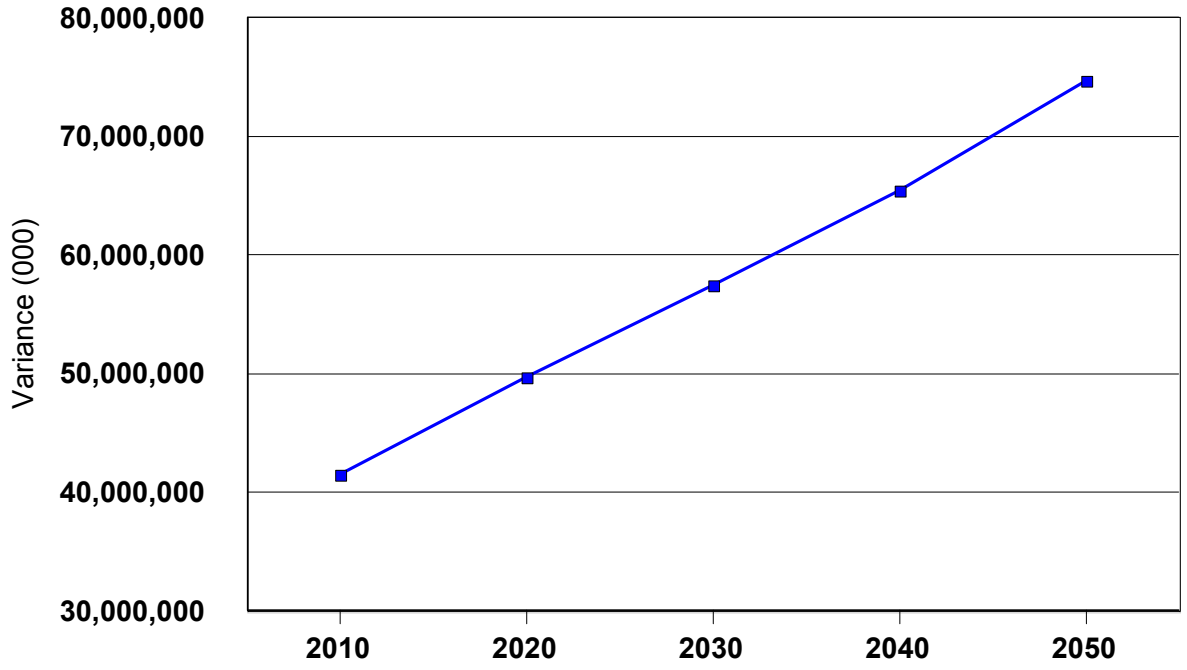


**Figure 7.11 Total Variance over Time.**

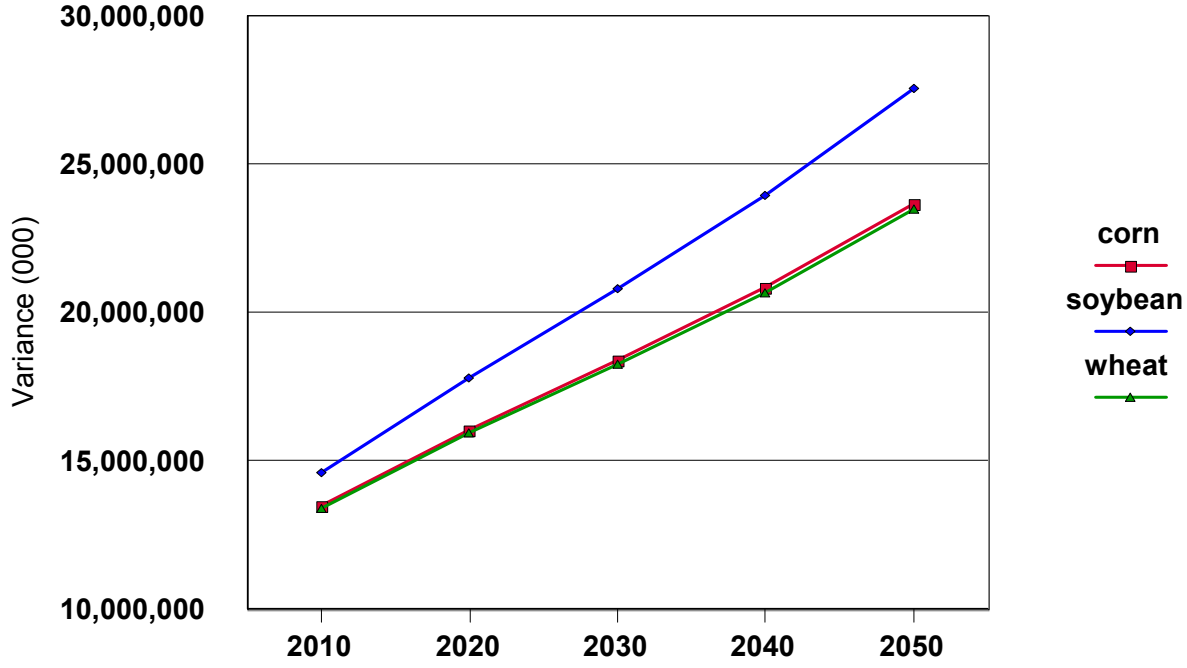


**Figure 7.12 Model Variance by Crop over Time.**

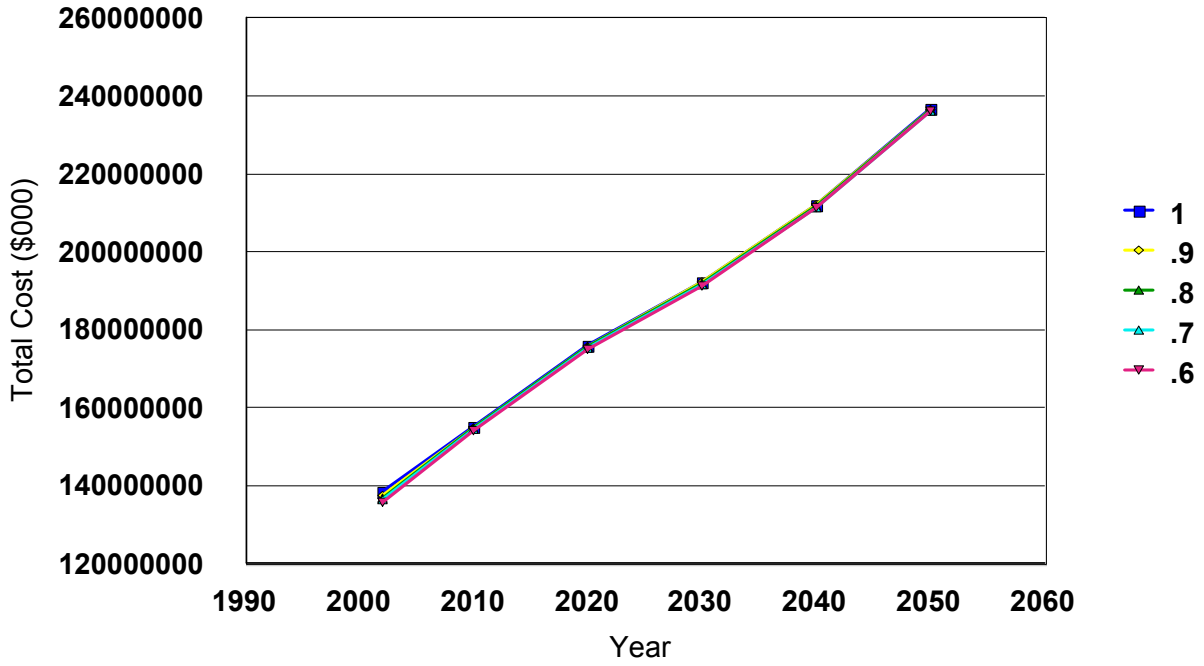


**Figure 7.13 Total Cost by Alpha over Time.**

## 8. Summary and Implications

***8.1 Purpose and Model*** The purpose of this study was to develop a methodology and analytical model to forecast grain and oilseed shipments through the Mississippi River system. The focus is on the world grain trade and expected changes in response to a multitude of evolving competitive pressures and structural changes. Emphasis is on the competitiveness of the US agriculture sector that is tributary to the Mississippi River system, and to assess impacts of critical variables on its competitiveness, and to project changes in flows for 50 years. Finally, the forecasts were caste using stochastic optimization methods to measure distributions of future flows and considers forecast variability.

The model is a spatial optimization model of the world grain trade. Important parameters are forecasted for relevant periods forward and used to evaluate changes in flows through the targeted logistical channels. Projected import demands are based on consumption functions estimated using income and population and accounting for intercountry differences in consumption dependent on economic development. Each of the competing supply regions and countries were represented by yields, area potential that could be used in production of each grain, costs of production and interior shipping costs where relevant. Crucial in this model is the interior spatial competition between the US Pacific Northwest and shipments through the US Gulf as well as inter-reach competition. This differs from other analysis based on econometric projections which do not address inter-port and inter-reach competition.

The model has the objective of minimizing costs of world grain trade, subject to meeting

demands at 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 model was solved jointly for corn, soybean and wheat. Costs included in the model are production costs for each grain in each exporting region and country, interior shipping and handling costs and ocean shipping costs. First a base case is evaluated and interpreted relative to current grain trade. Forecasts of varying periods forward, up to 50 years, were generated. The base case uses values for the 2002 world crops marketing year for calibrating domestic consumption and production, as well as for interior and international shipping costs.

***8.2 Summary of Results*** The results indicate the most important and fastest growth markets, in terms of consumption are for corn and soybeans are China, North Africa, South Africa and the FSU and Middle East. Growth in wheat is lesser and is dominated by South Asia, Southern Africa, China and Latin America. The larger traditional wheat markets of Japan and the EU have near nil growth rates.

The model included grain production costs across regions and countries. These results indicated there is substantial difference in production costs. Items of interest are that 1) the US is by far the lowest cost producer of corn and soybeans; 2) most regions' production cost for soybeans is less than those in Brazil, and those in Brazil South are less than those in Brazil North; and 3) other countries have lower costs for producing wheat than those in the United States. However, the United States, and Canada have quality advantages which are not shared by some of these other wheat producing countries. These notwithstanding, as illustrated the world supply/demand balance is relatively tight for most grains in most years and as such production from most regions is necessary to satisfy demand requirements.

There are two important features of this model in contrast to others. It is a longer-run model. Consequently, when impacts are evaluated, the model allows for numerous longer-run adjustments. For example, changes in barge rates or capacities have the impact of simultaneously affecting barge shipping costs including delay costs, as well as barge movements on particular reaches, rail rates, as well as marginal changes in production and exports from the United States and other countries. Thus, the comparative statics capture the impact of longer-run adjustments.

The second feature of the model is the detail of intermodal competition within the United States, as well as between ports. Most important is the close relationship between rail and barge shipments, particularly from the Upper Mississippi River. During the base period, it is critically important that rail rates are less than the summation of barge shipping costs for some larger origin areas. In addition, in some cases the direct rail cost to the US Gulf is less than the summation of barge shipping costs. The impact of each of these suggests the potential for a radical large scale shift from barge movements to rail shipments to St. Louis, and then barge beyond, or for direct rail shipments to the U.S. Gulf. If these were to evolve, the demand for barge shipping on the Upper Mississippi River system would be less than in our base case which imposed restrictions in order to conform to historical movements. Nevertheless, these results clearly point to barge shipping as being more of a residual supplier of relative to rail than was the case many years ago.

The results suggest that some of the more important factors impacting barge demand are area planted in competitor countries, U.S. domestic demand and growth in yield potential in all producing regions. The results indicated a number of important factors that will be impacting barge shipments. These include:

Demand. These results are driven by changes in demand. In particular, consumption is driven by income and population, as well as changes in income elasticities as countries mature. The impact of this is for fairly strong demand for corn, and soybeans. The effect of this encourages as much as possible a shift in production in those regions that are lower cost producers of corn and soybeans. In most cases, this is the United States. In fact, the results suggest fairly sharp shifts in production, primarily from wheat into corn and soybeans in the United States. Ultimately, this impacts barge demand since these commodities are more barge oriented than the wheat sector. Whether and how long this transformation will take in practice is not so clear, but, the results are suggestive of the nature of this change.

St Louis and New Orleans transfer restrictions. The railroads in the United States, as least during our base period, have become very competitive relative to barges in selected movements. This is a significant result as these appear to be targeted origins and for shipments specifically to St. Louis for barge beyond, or, direct to the US Gulf. Nevertheless, they are real and given these appear to be targeted to the larger volume origin regions has important implications. In particular, if the model is run unrestricted, there are large shifts from barges to rail for some of these movements suggesting that in these regions the barges are the residual mode.

PNW ocean spreads One of the most important impacts affecting barge demand is the spread in ocean shipping costs to Asia from the PNW vs. the US Gulf. During our base period, and much of the 1990s, this value was about $5/mt. However, since then, this spread has increased to as high as $27/mt, and has since moderated down to the $16-20/mt range.

Greater spreads has a dramatic shift if U.S. grain flows. In particular, barge shipping demand falls drastically, and that through the PNW increase sharply. If a restriction is imposed on PNW shipping capacity, more shipments are retained by barges. However, longer term these should be concern because no doubt there will be effort to expand PNW capacity which would have an irreversible impact on barge demand.

Delay costs These results suggest that during our base and projected period, the delay costs are particularly important. Most important are those in Reach 2 and 4. However, these are subject to the rail transfer restriction noted above. The impact of these delay costs is to shift movements to rail, and/or to other origins or ports. Relaxing this restriction has a positive impact on barge demand. However, part of that is a subtle shift from Reach 5 and 6.

Free Trade: The model assumed the trade regimes that existed in 2002 would be retained. These include both production and export subsidies as well as import tariffs all of which vary drastically across countries. The current WTO negotiations are seeking to reduce or eliminate these interventions.

The model was run for 2010 with and without these subsidies. The results suggest that under free trade there would be a quite sharp increase in shipments through Reaches 3, 4 and 6. Much of this comes from reduced production in the EU, which would have a notable increase in barge demand as well as exports from some other countries.

Increase in domestic use of some grains. Finally, export demand is impacted by the amount of grain used for domestic processing. One of the fastest growing sectors is ethanol, which has the impact of reducing exportable supplies, to some extent. These results illustrate the impact of the planned expansions through 2010. Since then, there has been an invigorated interest in further expansion in this sector resulting from the recently announced Energy Bill. Where these new plants will be built is not clear and thus, it is not clear how these will impact barge demand. Nevertheless, there is nearly a 1 to 1 tradeoff between increased ethanol demand and exports. It is not quite 1 to 1 since there would be a shift to expanded corn production, to the extent possible.

Besides these effects, a number of others were explored, but each individually does not have a major impact of barge demand. These include expansion of the Panama Canal, production costs, and further expansion possibilities in Brazil.

Stochastic Results The deterministic model was used for purposes of development, calibration and conducting sensitivities. A stochastic model was derived from the deterministic model and used to evaluate risks associated with barge shipments. In this model, the uncertainty comes from a number of variables including consumption, production costs and yields, as well as the error term in the estimated modal shipping costs. In particular a chance constrained model was developed whereby uncertain demands had to be satisfied with a prescribed probability referred as $\alpha$. In the deterministic model, the implicit prescribed probability is $\alpha$=.5. Thus, there is a 50/50 chance of meeting demands. In the stochastic model, we evaluate the impacts of $\alpha$ on the results, and interpret and make projections using a base case $\alpha$=.9.

Results indicated exports climb to 155 mmt in 2010 with barge traffic of just under 55 mmt. Barge traffic increases by about 10 mmt over the next five years. The model forecasts US exports and barge traffic to decline after 2010. This is in part due to the conservative specification of the model regarding satisfaction of demand. An increasing percent of US grain production is consumed domestically, leaving less available for export. This results is also due in part to the increase in yield forecasts in other producing regions.

With expanded barge capacity, the results are comparable to the current capacity scenarios with a few exceptions. Most important is that there is a increase in shipments from Reach 4, notably by nearly 6 mmt in the base period, and about 2 mmt in subsequent years. This however, is offset by shipments declining in Reach 3 and Reach 6. In total, the expansion results in only a

modest increase in shipments. It is important that Reach 4 currently experiences delay costs due to its capacity. Expanding the system to reduce these costs has fairly drastic impacts on inter regional competition. In particular, grain shipments are shifted from Reach 4 to the barges, and Reach 3 and Reach 6 shipments are diverted to either domestic use or other channels.

As a global measure of the value of increased locks one could interpreted as the differences in total costs (i.e., the model objective function). The differences (at the 90% confidence level) are $1.6 million in the base year, $1.9 million (2010), $1.1 million (2020), $100k (2030) and zero thereafter. Beyond year 2020, the forecast variance essentially "swamps" the model. The reasons for this are the large number of changes that are allowed in the longer-run in response to these changes.

The stochastic model was used to evaluate how far forward projections would be reliable. It is expected that the further forward projections are made, the greater uncertainty they would have. The cumulation of the variances impact the certainty of the projection. In particular, the further from the mean projection the greater is the projection error. Thus, the further forward the projection is made, the more likely it would deviate from the mean during the calibration period, and hence the greater the error.

These results suggest that projections of the impact of expanding the barge system beyond about year 20 are virtually meaningless. At that point the error terms overwhelm the results and make the model and projection highly unreliable. Thus, discounting of projections beyond this period forward is important.

***8.3 Extensions*** Development of this model allows both an evaluation of an initial set of results, as well as the possibility of using it for further projections. That has been accomplished as summarized in this report and illustrate the results from each of the two models. As expected, any set of results are partly dependent on the inputs, and the model. While it is expected that the models will be used for analyzing different scenarios in the future (as prescribed by the ACE), the results presented were shown in part to illustrate the models.

The base case period for our model was 2002. This was driven by the availability of rail rates notably, as well as some of the other data. Since then the world has experienced several dramatic changes, which impact these results. Most important are the explosive impacts of fuel costs, and their impacts on both domestic and international shipping. It is notable that oil costs were not significant in any way in our modal shipping costs with exception of ocean rates. This notwithstanding, since then, fuel surcharges have become routine business in both rail and barge shipping as well as in trucking. Second has been the planned expansion of ethanol in the United States, as well as other countries (e.g., China). Finally, these results suggest the expansion of Brazilian soybean production does not have a dramatic impact on barge demand. Part of the reason for this is the shift to corn production in the United States and that the United States is a lower-cost producer and marketer than in Brazil. Nevertheless, these relationships may be changing.

A number of items should be considered for either updating or further refinement. These are mentioned here briefly in case there is a desire for further development, and are listed in terms of priority regarding their potential impact on the results.

Update and refine modal rates used in the model: rail, barge and ocean Most important would be to update the modal rates and functions used in the model. These results used 2002 as the base case. By now, rail rates for 2004 should be available in November 2005. These should be updated, along with barge and along with ocean shipping costs. Since 2002, rail, barge and ocean shipping rates have experienced some of the most dramatic impacts in recent history. In doing this, the rate functions should be examined very carefully to evaluate the impact of increased oil prices on modal rates, and the interrelationships.

St. Louis area and US Gulf Restrictions The base case treated restrictions on rail transfer at St. Louis and U.S. Center Gulf as maintained assumptions. If these were relaxed, as in the stochastic model, it would result in a sharp reduction in barge demand for the reasons noted above. The logic and validity of these restrictions, along with their sustainability should be reviewed carefully. Any revised knowledge about these restrictions could be entered into the model in the form of refined restrictions and then used to evaluate changes in projected barge demand.

Alternative Stochastic Specifications: There are numerous ways to introduce stochastic factors into a deterministic model. Early on we experimented using a stochastic optimization but the proposed scope of the model had so much detail, resulting in a large number of variables, that is was not possible to use stochastic optimization methods.

Looking forward, there are two alternatives. One would be to respecify the model to include barge capacity as a constraint. As noted above, and in the planning stages of the problem, it was decided to treat barge delays as a cost, rather than a constraint which dictated the model specification. An alternative would be to respecify it so that barge capacity were a constraint, in addition to the implied delay costs. To do so would require information on means, variances and covariance about capacities. It is expected these could be inferred from the simulation procedures used to simulate the delay costs.

The second would be to reduce the scope of the problem so that it could be solved through simulation. However, given the complexity it is not clear where or how this could be reduced. One would be to eliminate production costs, but in so doing one could not capture changes inter-crop competition. Retaining the inter-Reach competition is fairly important and impacts the results substantially. Maybe this impact is too great. For example as shown in these results, the simultaneous changes in capacities has the impact of shifting movements among Reaches which is likely not an anticipated consequence. Further, it is not clear how one could create further aggregations domestically given the geographic scope of the problem. Nevertheless, with some effort one could reduce the problem somehow to capture the salient features.

Econometrics of Modal Rate Relationships A critical feature of the stochastic model is the modal rate relationships. These were used as inputs into the model and were used to capture impacts of

exogenous shifts on modal rate levels, etc. These were estimated using available data and procedures. There were limits on this as noted above. Most important is that the data needs updating, however, the data is unbalanced, non-synchronous across modes and some type of simultaneous estimators should be pursued. These are not without challenges both from a data view, as well as an econometric perspective.

This should be pursued as these have an extremely important impact on the results. As example, in the stochastic model, the expansion in barge capacity has the impact of reducing barge shipping costs which has the impact of changing rail rates in such a way as to encourage shipments to the PNW ports. Rail rates throughout the United States are impacted by barge rate levels, as well as the distance from barge locations. Whether and the extent this is irreversible is not clear but certainly warranting of further investigation.

Impacts of the Energy Bill on Ethanol Demands and Barge Shipments Since these simulations were conducted a new Energy Bill was signed. The full impacts of this were unknown but should be reevaluated. To do so would require updating likely locations for the expanded industry, and then evaluating how the increased ethanol demand for corn would impact barge demand.

Review and consider using ProExporters' state level domestic demand projections One concern is how the model developed domestic demand at the individual state level. Since this data is not readily available, domestic demand was approximated using a combination of rail shipments and production. ProExporter now provides estimates of demands for individual grains at the state level. In addition, meetings and collaboration between USDA and ACE could be explored for these projections. In either case, these results would be a substantial improvement.

Reach Definitions and Tweaking of Delay Cost Functions At the time the model was specified, reaches were defined and delay costs for each was derived. The reaches were defined based on previous studies and in consultation with the IWR. However, since then, it became apparent that these may not necessarily be the best definitions of reaches from a decision making perspective. This is particularly in the areas in and around the north-south boundary of Reach 1 vs. Reaches 2 and 4.

These should be re-evaluated to assess if a better definition could be used. If so, it would result in a change in the delay functions, a change in the truck rate functions, amongst others. These would be consequential.

Scenarios Finally, as currently specified the models are operable and generate results as suggested in this report. One can change assumptions and alternative scenarios to generate results that should be useful in infrastructure planning. The above suggestions are based in part on the experience of building and using the model, and are suggested as ways to improve upon the projections that are generated.

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