The Navigation Economic Technologies Program

December 15, 2006

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

US Army Corps of Engineers®

IWR Report 06-NETS-R-12

Navigation Economic Technologies

The purpose of the Navigation Economic Technologies (NETS) research program is to develop a standardized and defensible suite of economic tools for navigation improvement evaluation. NETS addresses specific navigation economic evaluation and modeling issues that have been raised inside and outside the Corps and is responsive to our commitment to develop and use peer-reviewed tools, techniques and procedures as expressed in the Civil Works strategic plan. The new tools and techniques developed by the NETS research program are to be based on 1) reviews of economic theory, 2) current practices across the Corps (and elsewhere), 3) data needs and availability, and 4) peer recommendations.

The NETS research program has two focus points: expansion of the body of knowledge about the economics underlying uses of the waterways; and creation of a toolbox of practical planning models, methods and techniques that can be applied to a variety of situations.

Expanding the Body of Knowledge

NETS will strive to expand the available body of knowledge about core concepts underlying navigation economic models through the development of scientific papers and reports. For example, NETS will explore how the economic benefits of building new navigation projects are affected by market conditions and/or changes in shipper behaviors, particularly decisions to switch to non-water modes of transportation. The results of such studies will help Corps planners determine whether their economic models are based on realistic premises.

Creating a Planning Toolbox

The NETS research program will develop a series of practical tools and techniques that can be used by Corps navigation planners. The centerpiece of these efforts will be a suite of simulation models. The suite will include models for forecasting international and domestic traffic flows and how they may change with project improvements. It will also include a regional traffic routing model that identifies the annual quantities from each origin and the routes used to satisfy the forecasted demand at each destination. Finally, the suite will include a microscopic event model that generates and routes individual shipments through a system from commodity origin to destination to evaluate non-structural and reliability based measures.

This suite of economic models will enable Corps planners across the country to develop consistent, accurate, useful and comparable analyses regarding the likely impact of changes to navigation infrastructure or systems.

NETS research has been accomplished by a team of academicians, contractors and Corps employees in consultation with other Federal agencies, including the US DOT and USDA; and the Corps Planning Centers of Expertise for Inland and Deep Draft Navigation.

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LONGER-TERM FORECASTING OF COMMODITY FLOWS ON THE MISSISSIPPI RIVER: APPLICATION TO GRAINS AND WORLD TRADE

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Model results presented in this report reflect cases that have been considered to date for purposes of demonstrating replication of actual events or understanding the sensitivity of model outputs to changes in assumptions.

Scenarios that will be used in the reevaluation of the Recommended Plan from the UMR-IWW System Navigation Study will be formulated as part of the process for reevaluation.

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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. Relative costs of production, interior shipping, handling and ocean shipping costs all have an impact on trade and competitiveness of the interior logistical systems. Changes in the variable costs of any of these 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 were generated using a chance-constrained stochastic optimization model to derive explicit measures of risks.

To analyze these effects, a spatial optimization model of world grain trade was developed. Important parameters are forecasted and used to evaluate changes in flows. 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. 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.

2) Development of an analytical model to analyze world grain and oilseeds trade. Specifically,

[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.

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 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, soybeans and wheat. Costs included 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 in 10 year increments for 50 years were generated. The base case uses values for the 2000-2004 world crop marketing years 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 impacts of critical uncertain variables and to derive the distributions about the forecasts. Important uncertain variables are error terms in the consumption functions, production forecasts and modal rates. Distributions about these variables were derived and integrated into the stochastic simulations.

Development of the model confronted several major challenges. One was that in it was common for production to be less than demand on a worldwide basis. In practice, this is reflected in the draw-down in stocks in individual countries and/or worldwide. Since stocks were excluded in the model, it was potentially infeasible in selected years during the calibration period. Second were the peculiarities of the wheat market ultimately requiring restrictions on imports of selected classes from the United States. 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 between 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. Previous Studies and River System Issues[2]

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:

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[2] A separate Appendix to this report contains a detailed description of these and other studies.

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)

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.

Finally, legislative initiatives in late 2006 authorized lock projects on the river system. Specifically, the *Water Resources Development Act* authorized construction of seven new 1200 ft locks on the Mississippi River, modernizes others as well as on the Illinois river. The purpose would be to eliminate bottlenecks. However, funding was not appropriated (as reported by Ratka 2006, p. 1.)

2.2 Previous Studies: 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 and comparative statics about changes in logistical costs and infrastructure. 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 Xiaohua; Jack Faucett Associates (1997, 2000); and Tang. Others include Veenstra and Haralambides who focused on major seaborne trade flows. Babcock and Xiaohua 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.

Numerous studies have examined supply and demand elasticities for modes of transportation. Oum et al. reviewed more than 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 and wheat of -0.52 to -1.18 (3 studies), truck for corn and wheat of -.73 to -.99 (2 studies), inland waterways for grain of -.64 to -1.62 (2 studies), and ocean shipping for dry bulk shipments of -.06 to .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 (Minneapolis 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 an inaccurate forecast of future use without the project.

3. Background

While there are numerous structural changes occurring in the world grain trade, three are particularly apparent and are elaborated. These include developments in Brazil's soybean sector, China and ethanol. Each is discussed below.

3.1 Changes in Brazil Soybean Sector Soybean production and productivity in Brazil are changing and will impact world trade. Production has traditionally been concentrated in the Southern provinces and the Central West regions. These soybeans 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 infrastructures 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, changes are occurring in shipping economics within Brazil. 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 Northern ports. These include interior truck/water shipments to Itacoatiara and Santarem (a port facility was opened in April 2003) which has a new export grain handling facility. The BR163 is a highway to Santarem is in the process of being developed. The USDA AMS indicated that “environmental restrictions and lack of funds are inhibiting the initiation of this project.” (as reported by Howie, 2006a). But, in June 2006, the Brazilian government approved the building of BR163.[3]

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). In most cases the Northern shipments of soybeans from Brazil would be natural tributary to Rotterdam, the traditional market for Brazilian soybeans, or to Asia and China via the Panama Canal.[4]

Despite the prospect for expanding transport projects in Brazil, as well as its large amount of undeveloped land for agricultural production, further development is not presupposed. Since the higher-priced soybeans in 2004 have fallen in value, and the Brazilian currency has appreciated, the prospects for further development are less clear. In early 2006, as a result of these developments, there were strikes and blockades prompted by lower returns to growers. Specifically, farmers reportedly were staging blockades which were unprecedented and a result of their economic plight (Agriweek, May 8, 2006, p. 3). This was due to a 13% appreciation of the real which resulted in soybean prices in interior producing areas equivalent of 250c/b. Production costs in the lowest cost areas are 350-400c/b. The combination of these limited yields in 2006 and production was estimated at 54 mmt in 2006, down from early season estimates of 58-59 mmt. Looking to 2007, they were expecting a drop in area of 10-20% and reduced production to 45 mmt.

3.2 China Growth in Import Demand China is a large market with rapid growth in population and income which impacts growth in domestic demands. Despite this, traditionally China had large stocks of strategic commodities (corn, wheat, rice, and until recently, soybeans).

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[3]President Lula authorized the paving of a 975 mile road through the Amazon rainforest in June 2006. The highway will connect Brazil's center-west soybean belt to a major port and export markets in Europe and Asia. Currently the dirt road frequently washes out. Lula made the announcement during a ceremony marking World Environment Day but his decision was criticized by environmental activists (Red River Farm Network 2006a).

[4]Recently the USDA AMS created a guide to Brazil’s transportation system. See www.ams.usda./tmdtsb/grain as reported by Howie (2006a).

Sparks (2003) expected 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.

Chinese trade policies are changing rapidly, both during our base period and expected during the projection period. Most important are that China intervenes routinely in policies that impact its imports and exports of these grains, notably corn. This has been done in the past using import/export quotas, and/or tariffs or subsidies in the case of corn. In 2001 China joined the WTO and initiated trade policies to facilitate this change. In particular, it adopted a trade regime of tariff rate quotas. For imports within the quota an import tariff and value-added tax (VAT) were applied. In 2006, these are at 1% and 13% VAT for corn for imports less than the quota of 7.2 mmt; the same values applied to wheat; and for soybeans, the import tariff was 3% and 13% for the duty and VAT respectively. For imports above the TRQ value, the tariff was far greater at about 60%.

In addition, until recently it retained a policy of subsidizing corn exports, primarily from northern China to Korea and Malaysia. Export quotas were provided by the National Government to the State Governments who choose how to allocate them amongst exporting companies. Subsidies, when offered, were determined annually approximately reflecting the C&F differential to US corn at Korea. As recently as mid-2006 it was anticipated these would be eliminated in response to the growth of the domestic market, and rising prices.[5] These policies facilitated exporting about eight mmt/year during the period 2000-2004, reaching a peak of about 15 mmt in 2002.

China has also retained a large stockholding strategy for each of these grains. While this is in a state of transition, stock levels have been reduced. Use of stocks relieves pressures on supplies when and if supplies are reduced. During 2004, China drew down its stocks for corn by 8.3 mmt, and for wheat by 4.5 mmt.

Finally, the pace of urbanization is impacting lands available for agricultural production. Recently, the shortage of land was viewed as a significant challenge confronting agricultural development (International Grains Council, 2006). In particular,

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[5] See www.jcichina.com, a Chinese grain marketing consulting firm who frequently and recently reported on these issues (Shainghai JC Intelligence Co., Ltd).

...China's cultivated land areas fell from 130 m. ha in 1996 to 122m. ha. in 2005 and with accelerating industrialization and urbanization the trend seems likely to continue. Local governments apply annually for 800,000 ha. of land for their construction projects, although the central government only allows a third of that total to be used... (International Grains Council 2006, p. 16).

3.3 Development of the US Ethanol Industry: 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. This will impact demand for domestic consumption of corn in future and reduce exportable supplies.

For perspective on growth and changes in this sector, in 2003, the indications were that the demand for 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, "more than 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 expanded the future role of ethanol and biodiesel. The Energy Policy Act of 2005 established the RFS (Renewable Fuel Standards) at 4 billion gallons in 2006, increasing to 7.5 by 2012.

There are numerous aspects of the growth in demand for ethanol production. One is the location of new ethanol plants. In the analysis, corn demand was split into that for ethanol and that for all other domestic consumption. Then, assumptions and transformations were used to derive ethanol demand by region. A map of current ethanol plants (including planned plants) is shown in Figures 3.1 and 3.2 and the results of this transformation are shown in Table 3.1.[6]

Though ethanol production was earlier concentrated in the Eastern Corn Belt, the recent expansions have concentrated in the Western Corn Belt which now has about 42% of the capacity. The Central Plains is the third largest region. Earlier plants located away from the Mississippi River system, but a number of the more recent plants are located more near the Mississippi River.

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[6] These plants and planned projects were taken from Renewable Fuels Association (April 2006).

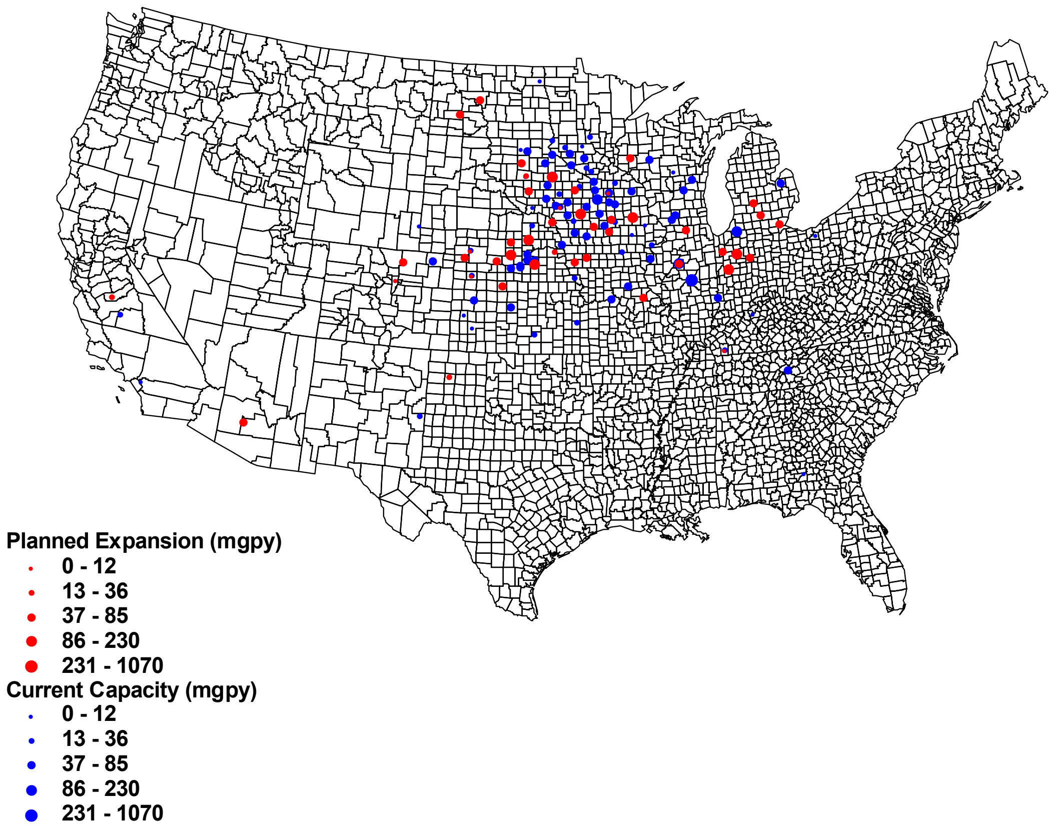

Figure 3.1. Location of Current and Planned Ethanol Capacity, 2006.

Existing plants comprise 4,490 million gallons of capacity and when taken together with planned plants, total capacity would be 6,715 million gallons.

Projections have changed recently on ethanol targets and mandates. Both the EIA 2005 and 2006 report projections to 2015 in ProExporter(2006d). The EIA 2005 more consistently coincides with our base case parameters and generally has ethanol from corn production at just less than four billion gallons. The EIA 2006 estimates reflect current notions of ethanol production as reflected in the EIA projections and reflective of the President's policy goals. In this case, corn used in ethanol production increases from four billion gallons to nearly 10 billion gallons in 2015, and then converge to about 11 billion gallons in 2020 forward. In the period after 2015 a minor portion of this will be met by ethanol from cellulose (EIA 2005). These are fairly drastic changes. Demand growth should taper off beginning in about 2020. These levels of ethanol consumption suggest the growth in demand for corn for ethanol to increase from about 1.4 billion bushels in 2005/06 to about four billion bushels by 2020.

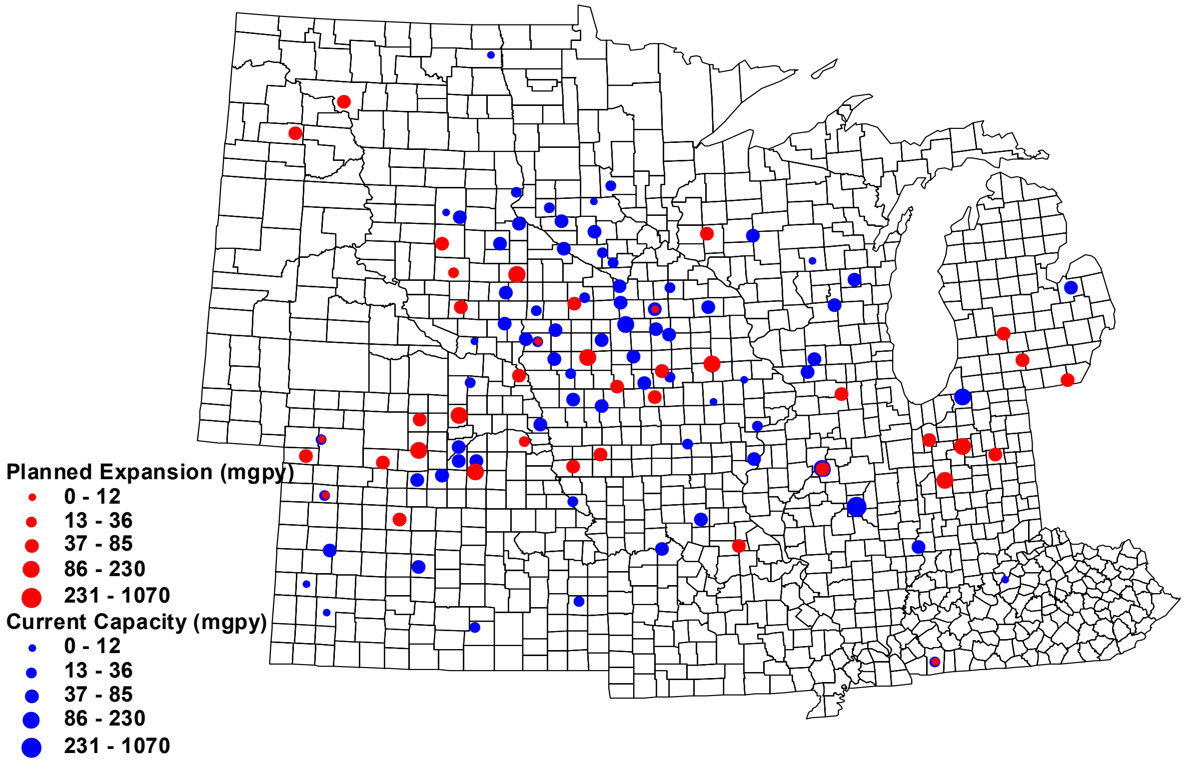

Figure 3.2 Expanded View of Ethanol Plant Locations and Planned Expansions in Upper Mississippi-Illinois River Area.

Table 3.1 Percent of U.S. Consumption by Crop and Region, 2003-2005.

Region	Total Corn Demand	Corn Demand for Ethanol Use	All Other Demand
US Central Plains	14%	17%	13%
US Delta	4%	0%	5%
US Eastern Corn Belt	21%	26%	21%
US North East	5%	0%	6%
US Northern Plains	4%	12%	2%
US Pacific North West	2%	0%	2%
US South East	15%	2%	17%
US Southern Plains	8%	0%	9%
US Western Corn Belt	24%	42%	20%
US West	4%	0%	5%

The principal byproduct from ethanol production is referred as distillers dry grains (DDGs). Wide-scale use of the byproduct is just evolving and there is much to be known about its feeding value and shipping characteristics. Only a small amount is expected to be exported due in part to its lower value and higher cost of shipping. For our purposes, the impact of using corn for ethanol is to reduce the feed supply of corn displaced by the amount displaced by DDGs.[7]

There are numerous issues and views on the prospects of there being enough corn to meet demands for both the growing world market and the US ethanol market. For discussion here these include the ethanol processing projections and impacts on demand, yields and the ability to increase production, impacts on longer-term equilibrium and impacts on grain flows. Each is discussed below.

<u>Ethanol processing projections and impacts on demand:</u> Development of the ethanol industry is one of the most dynamic changes in U.S. agriculture in numerous decades. Most important is the very rapid increase in ethanol processing, and the concurrent impacts on demand. Using the above geographical depiction of the industry as of mid-2006, there are numerous changes

[7]The maximum amount that can be used in rations varies by animal type and composition of herds. The value used is similar to that used by ProExporter (2006) averaged over the period 2000-2004. The rate of adoption of DDG for corn is less than the rate of substitution in corn rations (i.e., a lot more corn could be displaced with wider adoption of DDG for livestock ratios). The substitition rate of DDG for corn in livestock is 40 lbs. of corn is displaced by 400 lbs. of DDG and for swine and poultry, 177 lbs. of corn is displaced by 200 lbs. of DDG (Urbanchuk). An article covering the effect of ethanol on Iowa indicated DDG are largely fed to cattle and that Swine and Poultry are largely untapped markets (Otto and Gallagher, 2003).

occurring. These are highlighted below and taken from varying sources:

- » Plans for new plants and expansions continue to change. Current expansion plans suggest that south central Minnesota and Central Nebraska will soon be corn deficit (Proexporter 2006e). Recently, the state of Illinois indicated that there are seven operating plants, and 30 plants in various planning stages, and 24 operating units in Iowa (as reported by Associated Press June 19, 2006, and citing statistics from Renewable Fuels Association, Iowa Renewable Fuels Association and Illinois Corn Growers Association). The State of Nebraska has 12 plants running and about 22 ethanol plants in the planning stages and four projects were under way in North Dakota including plants in Hankinson, Red Tail Energy, Spiritwood ND and Underwood (*AgWeek*, 2006b) and an additional one was to be announced in Williston on July 7, 2006.

- » The state of Iowa exported 803 million bushels in 2003, but by 2008 would be deficit 400-500 million bushels with existing plants running at rated capacity (Wisner);

- » The most recent ProExporter estimates were for 5.3 billion gallons of capacity currently operating, and another 6 billion under construction. In addition, they indicated there were an additional 369 projects on the drawing boards representing an additional 24.7 bill gallons of ethanol capacity (as reported in Mann Global Research, 2006c). They indicated the ethanol margin in 2005 was 152 c/bu of corn processed and this has declined to 44 c/bu this year, and this was more than attractive to justify additional investment.

- » In contrast, Goldman Sach (as reported by Red River Farm Network, 2006c) expressed worry about high corn prices indicating that rising corn prices threaten profitability of ethanol. Biomargins have been hurt by 55% increase in corn price and price of ethanol has risen by 8%. Without producer incentives and tax credits Goldman believes many biofuel plants would be unprofitable.

- » By 2012, using data from Renewable Fuel Association, corn demand for ethanol would be 2.7 billion bushels. But, Wisner notes that if you consider in addition other possible plants, this could be as high as 4.0 billion bushels. ProExporter (2006e) indicated by this period, ethanol production would be 13.8 billion gallons and require nearly 5 billion bushels of corn.

<u>Yields, CRP and the ability to increase production:</u> There is much debate and discussion about the ability and how U.S. agriculture will respond to this change in demand. There are two areas of importance. One is the growth rate in yields, and the other is the source of additional acres that could be shifted to corn. View on these are summarized below:

- » Schlicher indicated "Improvements in corn yields and the ethanol process will allow the number of gallons of ethanol produced per acre to increase from 385 gal in 2004 to 618 gal by 2015. The historical average annual corn yield increase was 1.87 b/a; and is now averaged at 3.14 b/ac over the past 10 years...which shows the impact of ag biotech." ...with such improvements, she said, 10% of the country's gasoline can come from corn ethanol within a decade without sacrificing corn use elsewhere.

» Meyer indicated that corn yields in past 10 years have increased from 126 b/a in 1996 to a projected 153 b/a in 2006. The gains substantially over trend line per year are possible due to genetic modification as these adopted by growers. Stacking of traits in the next 3-5 years could result in corn production in 14-15 bill bu per year on the same acres as 1996.

» Analysis conducted by Wisner and Hurd as summarized by Smith (2006) are most recent. They expressed caution on the potential to shift enough acres to corn to accommodate growth in ethanol, the prospects of a drought and concerns for the draw-down in stocks. In particular, Wisner analysis indicated: the increase in corn acres to meet these demands would be in the area of 11-12 million acres of corn by 2012, and, if China were an importer this would be 14 million acres. The added planted area could be taken from soybeans, other small grains or from the Conservation Reserve Program (but, with a majority coming from soybeans). Both he and Hurt emphasized that a corn supply crunch was on and the impacts of these will be reduced stocks after which each marketing year will be fraught with uncertainties about supplies.

» In response, the National Corn Growers Association indicated

...We can easily foresee a 15 billion corn crop by 2015...That's enough to support production of 15 to 18 billion gallons of ethanol per year and still supply the feed industry and exports, with some room for growth. (as reported by Zdrojewski, 2006).

This view is largely attributed to prospective advances in corn genetics and some acreage increase. Further, the NCGA indicated that corn use for fuel will not take away from food. This is "patently false, as US producers will continue to adequately supply all markets with high quality corn." Instead, their view is:

» The United States could produce 15 billion bushels to produce 15 billion gallons of ethanol by 2015. They indicated historic yield trends by 2010 would be 162 b/a and 173 by 2015. Planted area would need to be about 90 million acres, up from 71 this year, which would be the highest plantings on record (the previous high was 75 million acres in 1986). The difference would come from CRP.

» And Rob Fraley (Chief Technology Officer at Monsanto), indicated corn yields double in 25 years, reaching 300b/a in 25 years which was a reasonable goal (Sosland Publishing, 2006). New technology includes traits influencing yields, drought tolerance, fertilizer use and pest resistance. Yields on dryland conditions could increase 8-10%. GM technology would also allow the redesign of corn to increase starch content. With this, he indicated it would be possible to increase ethanol production to 50 bill gallons, based on a corn crop of 25 bill bushels from 90 million acres in 2030.

Corn production could also be increased by changes in rotations. Fatka (2006b) reporting on a study by Hart (2006b) indicated that if Iowa and Illinois shifted to a 2:1 rotations for corn for soybeans, they could each add 3 million acres which would move the national total to 90 million acres. And, if all states shifted similarly, the acres available for corn planting would be 97 million.

A major policy concern is the role of CRP in expanding area available for planting. For perspective, there are 37 million acres in CRP. In 2007 there were 16 million acres scheduled to come out. USDA had earlier offered reenrollments of these acres. By mid-November, higher prices were not enticing landowners to move land back into production and USDA was expecting an 81% retention rate. There are 3 million acres in CRP that would be available for 2008 and USDA has made offers for CRP contracts expiring in 2008-2010 totaling 12 million acres. Preliminary estimates are that only 15% would be accepted (Kovers, 2006).

The ability to release area from CRP for this purpose is not as easy as posed.

» Fatka (2006a) indicated the industry was looking for 4-8 million acres of corn for next growing season. However, releasing these acres may end up costing the government money. Secretary of Agriculture Johannes has made no decision about paring down CRP to allow more planting for biofuels, and said plans to kick out acreage are baseless. Further, land in CRP would face steep penalties if ended before the contracts expire and there are substantial costs to getting land prepared and ready for cropping.

» Mann Global Research 2006c reported that the trade is fully aware that up to 3 million CRP acres could be available in 2007. However, they noted that this CRP land is of questionable agricultural value, with the biggest chunk in Texas, Kansas and North Dakota. Some of this could be switched into wheat, but corn would be unlikely. The crop land coming out of production in the Corn Belt is limited, with Minnesota and Iowa at about 300,000-500,000 acres. Though USDA had hinted that a plan has been formulated to increase the amount of acres from the CPR, any further details were merely speculation.

» While farmers with CRP could opt out of the contracts, they would incur penalties to do so (Pates, 2006). Specifically, though there are ideas of early opt-outs, this is unlikely without a change in the rules. Under exiting rules, anyone wanting to opt out of a CRP contract would have to pay back all the money they had received in that contract, plus liquidated damages, a penalty equal to 25% of one annual payment, amongst other costs. Taken together, this is the reason that it is unlikely than much CRP area would be returned to production without a change in the rules.

<u>Impact on longer-term equilibrium</u>: These changes are resulting a concern about the changes in longer-term equilibrium in the U.S. grains sector. In mid-2006, analysts have begun to caution

on the potential impacts of ethanol on corn supply and demand.[8] At the heart of this issue is the resulting change in supply and demand, and issues related to food vs. fuel. As Dr. Thompson suggested, the US ethanol policy may work for the next decade but continued rapid growth in corn used for ethanol will set the stage for a collision of "food vs. fuel" when US agriculture productivity growth is no longer able to meet needs of fuel, export and domestic food sectors.

» More recently, at a National Grain and Feed Association conference (as reported by Mann Global Research 2006c), Tierney indicated that considering growth in international oilseeds (growth=8-12 mmt/year), the decline in U.S. soybeans, and increasing Chinese corn demand, the area planted in Brazil would have to increase by 50% in coming years. This would be an increase to 27 mill acres to offset U.S. lost acres and growth in soybean demand

» One study modeled the U.S. corn industry with emphasis on the industrial uses of corn, especially ethanol (Taylor, et.al. 2006). The model is a partial equilibrium econometric simulation model and contained behavioral equations for production, domestic consumption, import demand and U.S. carry-over stocks. The world is divided into two regions, the United States and a rest of the world. The model increases (decreases) price until production increases (decreases) equals the decreasing (increasing) levels of consumption. The results showed that with expanded ethanol, production increases about 100 million bushels, feed use falls about 500 million bushels, exports fall about 80 million bushels and other industrial uses fall 20 million bushels. Price increases from $2.32 in 2014 under the base case to $2.46 under scenario 1 which has the effects of increasing production, reducing exports, other industrial uses, and feed uses.

» FAPRI indicated that by 2010, 32% of the U.S. corn would be used in ethanol production (Schuff, 2006 (a,b or c) and that due to the price increase, by 2010, corn acres would increase by seven million. Some of this (three million acres) would come from soybeans and the remainder from the CRP or other crops.

» USDA's most recent statement (Collins, 2006) indicated that ethanol plants will be able to bid corn away from a variety of other uses and that the United States will need substantial increases in corn acreage to prevent reductions in exports. He indicated corn acres would have to increase by 10 million acres more than during 2005 and 2006 (assuming ethanol increases to 10 billion gallons). Finally, he suggested the CRP will likely be examined during the 2007 Farm Bill process and that 4.3 to 7.2 million acres

[8] Issues related to ethanol have also become topics in some of the more popular business press. *Business Week* (August 14, 2006, p. 56) noted "Facilities that can turn kernels into clean fuel seem to be sprouting up faster than the corn itself. There are 101 ethanol plants in existence, more than 42 new facilities and expansions in the works, and another 100 in the planning stages....Investors are wowed by the combination of short supply, surging demand,and government subsidies that top $2 billion annually (Green). And, in a recent *Fortune* article (Brown, 2006), indicated that Iowa had 25 ethanol plants operating, four are under construction and another 26 are planned, and Wisener indicated "if all those plants are built, distilleries would use the entire Iowa corn harvest. Finally, Hurt indicated "There is a 'gold rush' occurring now in building ethanol plants" (as reported by Wulf, 2006).

currently enrolled in the CRP "could be used to grow corn or soybeans in a sustainable way." (as reported by Schuff, 2006b).

In recent Congressional testimony the point was made that "there could come a time in years ahead when U.S. agriculture may not be able to meet the increased needs of ethanol and biodiesel while continuing to supply feed needs of the poultry and livestock sectors"(Schuff 2006c referring to testimony of processors to the House Agriculture Committee).

» A recent CARD study modeled the potential impacts of ethanol on corn and international trade (Elobeid, Tokgoz, Hayes, Babcock and Hart, 2006). That analysis modeled returns in ethanol, and determined the corn price at which it would no longer induce investment in new ethanol capacity. It then introduced this price and demand in a multi-commodity international equilibrium trade model. The results indicated the break-even corn price is 405c/b. At this price, corn based ethanol would increase to 31.5 bill gal by 2015. To support this industry, the U.S. would have to plant 95.6 million acres of corn (vs. 79 million in 2006) and produce 15.6 bill bush (vs. 11 billion today). Most of the acres would come from reduced soybean acreage. Corn exports would be reduced substantially and the study even suggested the U.S. could become a corn importer. There would be a 9 million-acre reduction in soybean area and a change in rotation from corn-soybean to corn-corn-soybean. Finally, wheat prices would increase 20%, and there would be a 3% reduction in wheat area with wheat feed use increasing. Wheat exports decline 16 percent.

» ProExporter (2006e), in their *Blue Sky* model indicated a permanent shift in corn prices to the 350-400c/b area into at least 2015. Based on ongoing expansion in ethanol demand and usage would have to be cut. He suggested there would be origination wars in Minnesota, Iowa and Nebraska as shuttle shippers for feed to California and the Southwest, and the PNW have to compete with ethanol. However, due to superior margins in ethanol, the latter would set the price and force others to pay more. Stocks would be drawn down, reduced exports and there would be greater volatility in prices and supplies.

Much of these issues revolve around assumptions on future supply and demand (e.g., as done by one of the more respected analysts in this area, (ProExporter 2006d)). In many of these cases, the analysis makes assumptions about critical variables, namely about increased yields, increased conversions from corn to ethanol, and increased area planted to corn. With adjustments in these values, by drawing down stocks, and assuming no risk or crop shortfalls, one can demonstrate there would be adequate supplies to meet the increased demand for ethanol, though, typically, exports would decline.

A critical issue is that related to the CRP. Production can increase through acreage expansions (from other crops, and/or from the CRP) and/or from yield increases and crop rotations (Hart 2006a). Other crops in our model include soybeans and wheat and have to compete for area. In addition, land may be taken from crops other than those included in our anlaysis. On the issue of yields, Dr. Schlicher indicated that the amount of ethanol that can be produced per acre of corn will increase from 385 gallons in 2004 to 618 in 2015. This will come from greater corn yields and a larger ethanol yield per bushel of that corn (as reported by Howie, 2006b). And, the National Corn Growers Association has indicated that yields of 178-187 bushels per acre can be a reality by 2015 (Howie, 2006b).

Impacts on grain flows: Ethanol is already having an impact on grain flows and barge demand in particular. Informa Economics indicated that

> *... ethanol expansion is changing the grain flow landscape. In Illinois, the representatives share of its corn production that would have gone to ethanol production in 2004 totaled 13%. For the 2005/06 crop year, it is anticipated that ethanol's share of the Illinois' production harvest will be 18% increasing to more than 25% of this coming fall harvest. In South Dakota, ethanol's share is teetering on nearly half of the state's corn harvest expected for 2006, up from 30% two years ago. This is a similar situation for many corn belt states, especially those in the western Corn Belt where there is a surplus supply of corn. As more ethanol plants are built, this will have implications on the availability of surplus grain for various markets whether for export moves to the PNW or feed markets into the Southeast and Southwest.*

4. Deterministic Model of World Grain Trade and Barge Demands

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 domestic and import demands are determined and from this flows and production are determined. Grains included are corn, soybeans and wheat.

The longer-run focus of the model and analysis 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.

Below are the major components of the model:

Consumption and import demand: For each country, consumption functions are estimated from historical values. For the projection 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. For the United States, ethanol demand for corn was treated separately from other sources of demand.

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 in the United States approximated USDA crop regions with additional segments in river cachement areas. Five regions were included for Canada and Brazil included Brazil South and Brazil North.

Model dimensions: The model was defined in GAMS and has 21,301 variables and 761 restrictions.

4.2 Destinations and Port Areas: Each importing and exporting country was defined by one port area which was the dominant port. 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.

4.3 Costs Included: Elements of costs 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 ocean shipping for international trade. Barge rate functions were estimated for shipping by barge. In addition, delay costs were included and derived for barge shipments exceeding certain levels.

Handling costs for exporting: Handling costs were defined throughout the system for each exporting country. These included country handling costs, barge transfer costs, extra costs for handling soybeans, and for double handling associated with shipping on the Great Lakes and US Gulf.

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, production subsidies and import tariffs were included.

4.4 Modal Shipping Costs and Restrictions: Shipping costs were defined for each mode.

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.

Truck: Rates were defined from Dager 2007 for shipments to the river, and from data reported by the USDA AMS for domestic shipments. 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. For shipments exceeding 350 miles, were forced to be shipped by rail.

Rail: Rail rates derived for periods 1995-2004 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. Shipments to Reaches and export ports were not allowed for those movements in which rail rates were not observed (which would be due to rail being noncompetitive on that route) and/or where observed rail shipments were nil.

A rail capacity restriction was applied to reflect that there is the prospect of a capacity constraint to rail. Finally, a set of restrictions was applied to rail movements that for varying reasons are virtually nil. These were discovered through the calibration process by comparing model results with observed flows and then verifying reasons for differences.

Barge: Barge shipping costs are shown below (Section 5.5). Six origins were defined on the Mississippi river system. These were defined as Reaches and encompassed all origins within that geographic region. These are defined below and illustrated in Figures 4.1 and 4.2:

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).

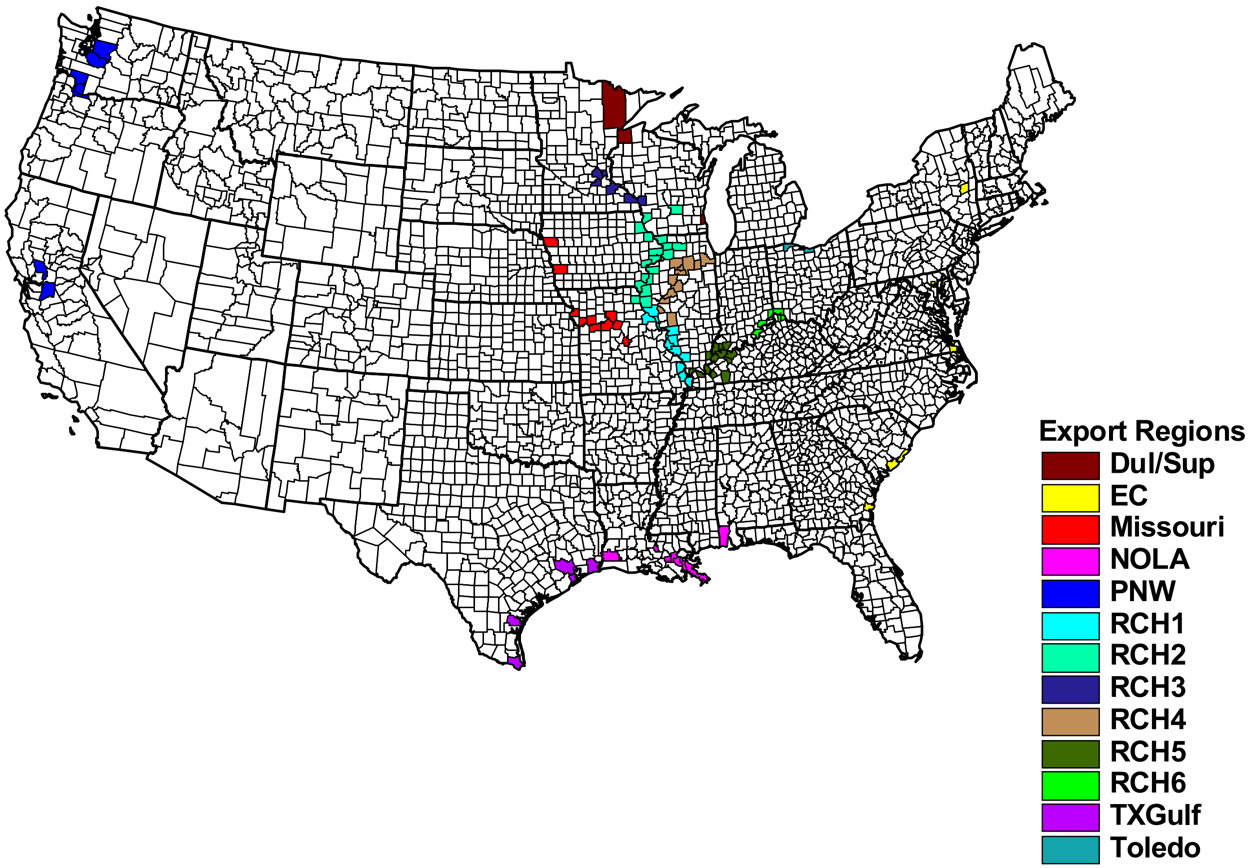

Figure 4.1 Location of Export Reaches.

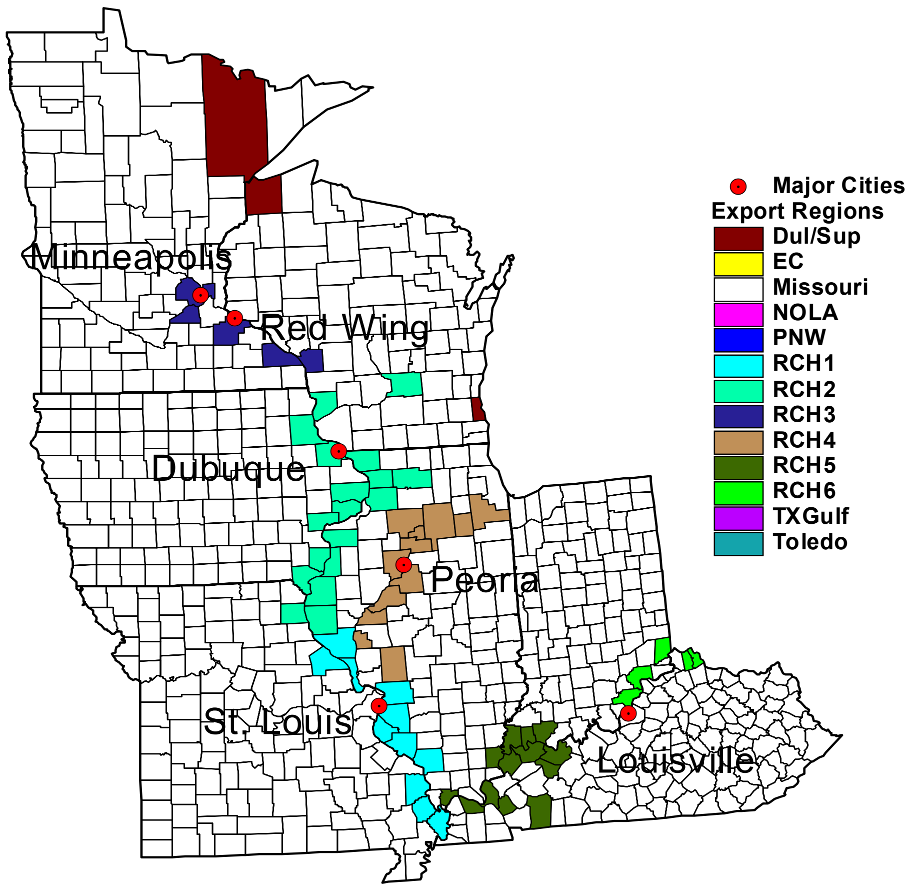

Figure 4.2. Expanded View of River Reach Definitions.

***4.5 Trade Restrictions*: **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.

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; and 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

To capture the impacts of China's trade restrictions, we retained import tariffs but forced eight mmt of corn exports. This reflects the impact of the export subsidy that is difficult to observe. During the projection period China exports were restricted to nil, and then relaxed in a sensitivity to illustrate the impacts.

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

5. Critical Relationships Impacting Results

Numerous factors impact the future demand for shipments through the Mississippi River barge system. Some of these that are particularly important in the case of grain shipments are discussed below.

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 Figures 5.1-5.3.

Market growth rates were derived based on projections of population and income, as well as the changing impact of income on consumption as countries' go through different stages of development. The fastest growing markets include China, South Asia and North Africa. Generally, these are the same for each of the commodities. The slowest growing markets are Europe, Japan and North America.

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

	Wheat	Corn	Soybean
		Percent Change	
United States	19%	22%	20%
Canada	20%	27%	21%
Europe	8%	16%	9%
Australia	19%	28%	20%
China	82%	154%	89%
Japan	0%	6%	1%
Argentina	35%	58%	38%
Brazil	56%	82%	58%
Mexico	53%	81%	56%
South Korea	17%	46%	22%
Latin	67%	95%	70%
N Africa	82%	117%	85%
FSU-ME	52%	78%	54%
S Africa	87%	106%	88%
S Asia	100%	152%	104%
SEA	47%	73%	50%
World	55%	71%	46%

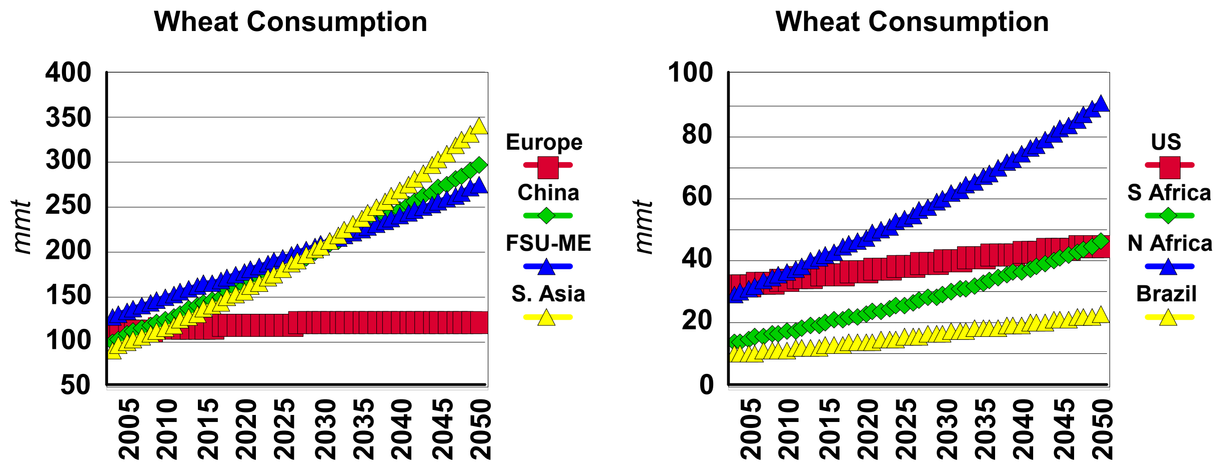

Figure 5.1 Forecast Wheat Consumption for Selected Importing Countries/Regions.

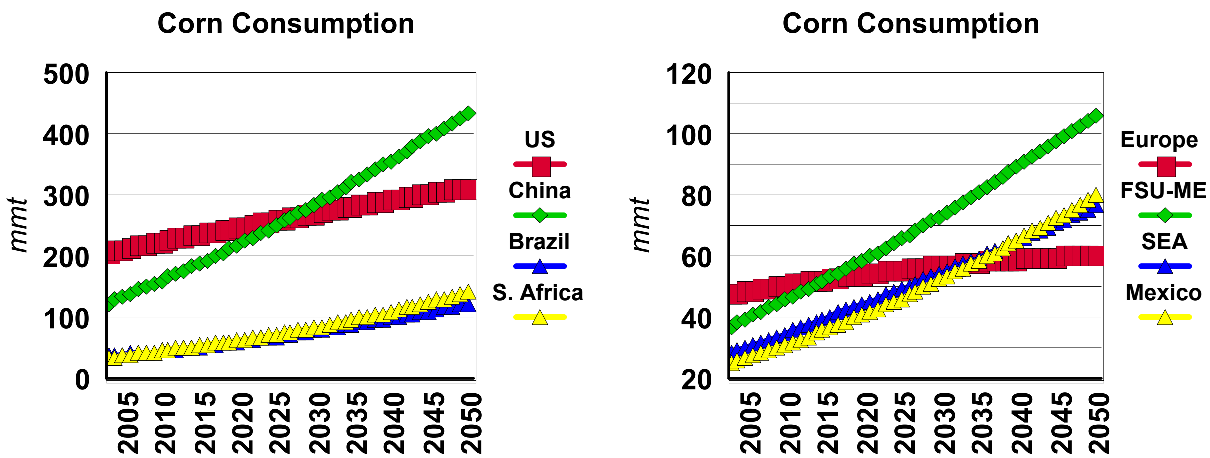

Figure 5.2 Forecast Corn Consumption for Selecting Importing Countries/Regions.

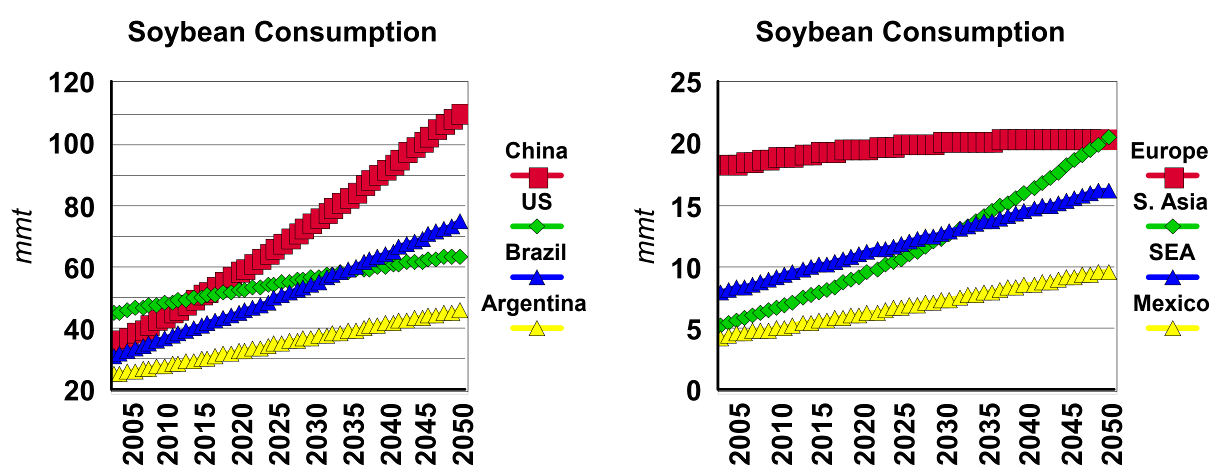

Figure 5.3 Forecast Soybean Consumption for Selected Importing Countries/Regions.

5.2 Production Costs Productions costs (Figures 5.4-5.6) illustrate that the United States is the lowest cost producer of corn and soybeans, but, other countries are lower cost in wheat production.

For corn, low-cost producers from 1995-2002 were U.S. producing regions, Argentina and Brazil. U.S. production regions have costs in the $35-$55/MT range, while China and Europe (EU-25 and Eastern Europe) are $86 and $152/MT, respectively. Low-cost producers for soybeans are the U.S. producing regions, Europe and Argentina. Brazil's costs are higher though declining. For wheat, low-cost producers from the period 1995 to 2002 were Australia, Saskatchewan and several production regions within the U.S. (Central Plains, Northern Plains, Southern Plains).[9]

The cost advantage for U.S. producing regions diminishes over time. Increases in production costs for U.S. regions rise at similar rates to that for major competing exporters. However, the rate of the increase in yields is less than competing exporters. In competing countries, the rate of the increase in yields is comparable to that of production costs. But in the United States, yield increases are less than competing exporters'; and, are less than production cost increases. The impact of these is very subtle, but, when extrapolated forward, results in a

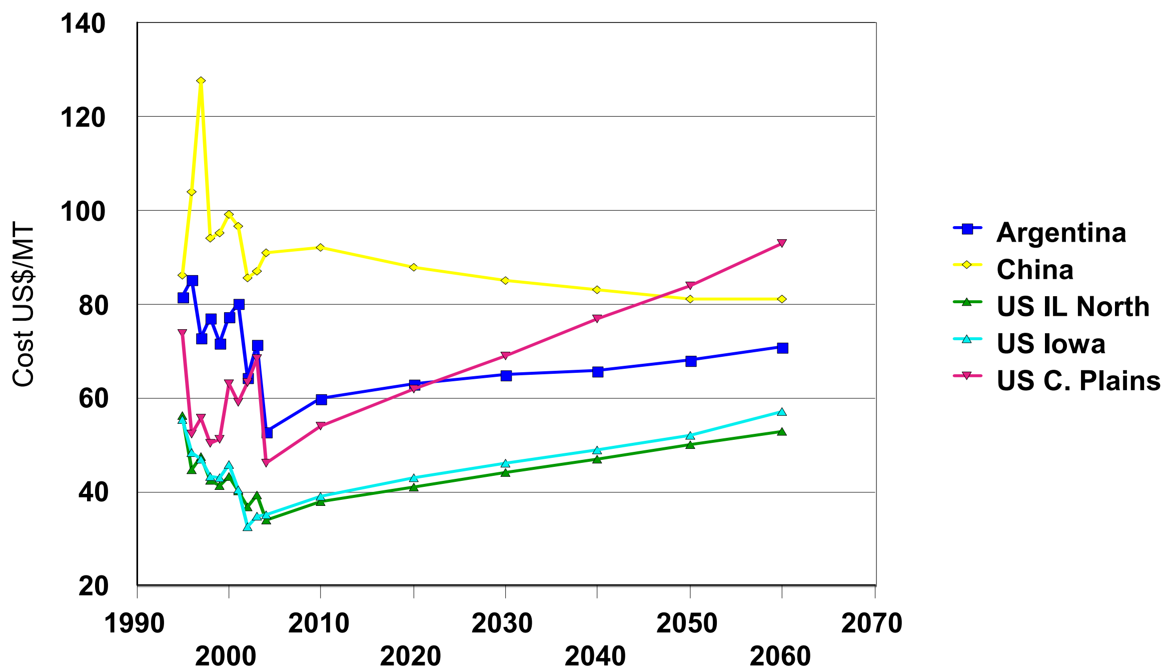

Figure 5.4 Corn Cost of Production.

[9]A coalition of wheat industry organizations is seeking ways to improve the competitiveness of America's wheat sector. A recent paper outlined elements of the core problems, including flat export growth and domestic consumption, the loss of acreage to other crops, wheat disease, and a lag in genetic improvements (Red River Farm Network, June 12 2006b).

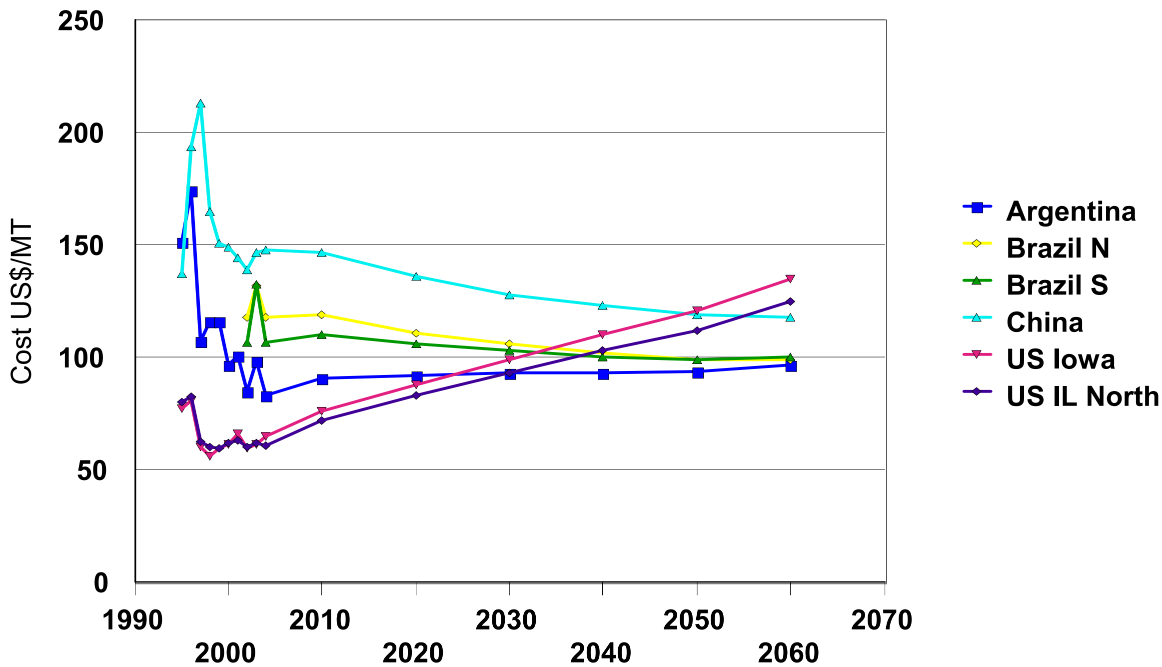

Figure 5.5 Soybean Cost of Production.

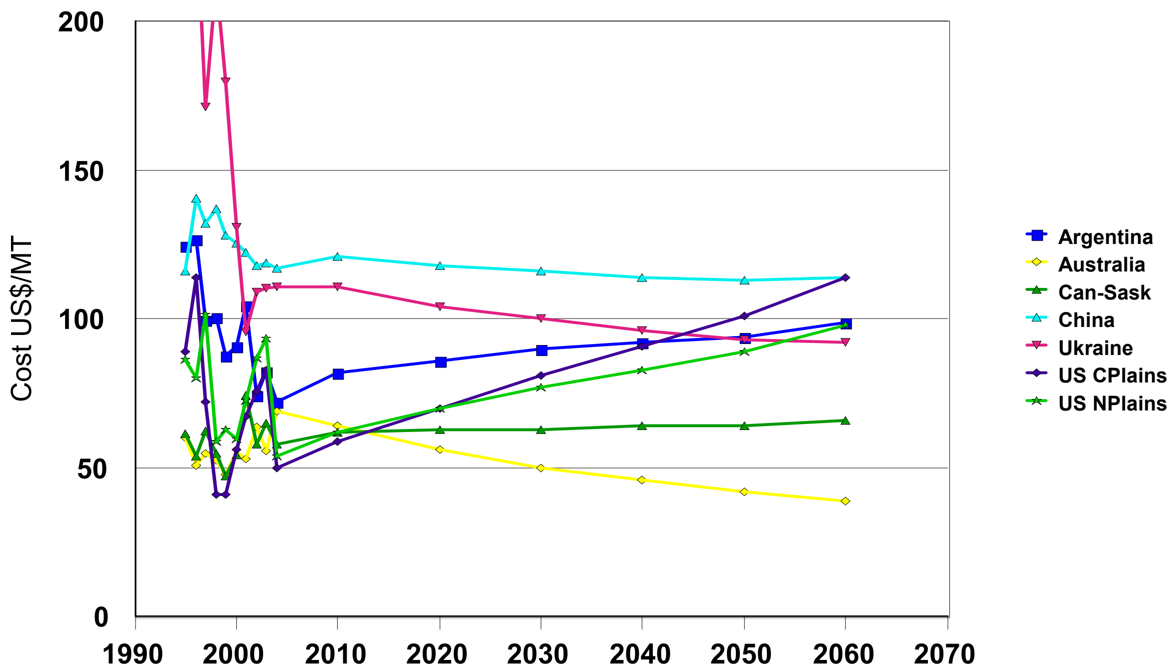

Figure 5.6 Wheat Cost of Production.

changing competitive position of the United States relative to competing countries.

5.3 Rail Rates on Barge Competitive Routes There has been a notable change in rail pricing that occurred within the time period of this study. In particular, rail rates declined and in some cases are lesser than rates on barge movements. These data were reviewed and compared among each other and relative to barge rates. From this, two sets of comparisons are made.

Iowa River and Rail Shipment: One relates to the overall rail rate from Iowa River for corn to the Western corn belt and to the Southeast. Compared to other grains and/or other origins these rates are extremely low. These are so low in fact, that this origin would be the lowest cost origin for demand in either of these two regions. And, if applied unconstrained in the model, flows from this origin to these destinations dominate and as a result there are nil shipments available to ship to the river. Upon further inspection of the STB data on volume it is apparent that shipment from this origin to the Southeast are near nil. However, shipment from Iowa River to the Western corn belt are not nil. In particular, rail shipments for this flow have increased from near nil in 2000 to 443,296 mt in 2004. And, the volume from Iowa West to the Western Corn Belt from 2000 to 2004 has been decreasing over time (1.6 mmt to 0.7 mmt).

Thus, the common perception that all corn in Iowa River goes to the river by truck is incorrect as there are several other competing regions and demands for this grain.

Rail-Barge Competition on Selected Movements: The data were also combined to make comparisons of some of the critical rail and barge rate relationships for illustration. The results are summarized in Tables 5.3.1-5.3.3. For each commodity comparisons are made between rail and barge costs using the average of the rates over the period 2000 to 2004. In each case the least cost movement is identified.

Some of the important relationships are noted below, particularly as they impact spatial competition amongst modes:

Corn: Shipments from Northern Illinois favor direct rail to the U.S. Gulf, followed by shipments via Reach 1. From Minnesota the least cost is by barge through Reach 2 and from Minnesota River regions the least cost is by barge from Reach 3;

Wheat: The least cost movement from Northern Illinois is direct rail (by nearly $7/mt); direct rail to Texas Gulf from Minnesota (by over $2/mt); and for shipments from the Minnesota River to Reach 3 and then barge to U.S. Gulf;

Soybean: Shipments via Reach 4 from Northern Illinois is least cost. Barge shipments via Reach 1 from Minnesota and from Reach 2 from Minnesota River are least cost. The advantage of Reach 1 versus Reach 3 is about $6/mt; and of Reach 2 versus Reach 3 is about $3.50/mt.

These relationships have a critical impact on commodity flows. However, there are a number of differences in the empirical model. First the model also allows for truck shipments to the Reaches. Second, handling costs and the differentials are important. Third, the model uses barge rate functions to determine volumes and rates

Table 5.3.1. Corn: Comparison of Rail-Barge vs. Direct Rail to Gulf, Average of 2000-2004 ($/MT)

	Rail	Barge	Total	Least Cost
Northern Illinois				
RCH1	6.55	5.81	12.36	
RCH4	3.95	9.97	13.92	
NOLA	10.69		10.69	**
Minnesota				
RCH3	8.36	14.03	22.39	
RCH2	10.16	10.71	20.87	**
RCH1		6.51		
NOLA	24.23		24.23	
TXGulf	24.12		24.12	
Minnesota River				
RCH3	5.53	14.03	19.56	**
RCH2	9.23	10.71	19.94	
RCH1	13.99	6.51	20.50	
NOLA	25.21		25.21	
TXGulf				

Table 5.3.2. Wheat: Comparison of Rail-Barge vs. Direct Rail to Gulf, Average of 2000-2004 ($/MT)

	Rail	Barge	Total	Least Cost
Northern Illinois				
RCH1	12.16	6.51	18.67	
RCH4		9.97		
NOLA	11.75		11.75	**
Minnesota				
RCH3	16.48	14.03	30.51	
RCH2	23.61	10.71	34.32	
RCH1	23.21	6.51	29.72	
NOLA	36.85		36.85	
TXGulf	28.16		28.16	**
Minnesota River				
RCH3	7.52	14.03	21.55	**
RCH2		10.71		
RCH1	18.46	6.51	24.97	
NOLA				
TXGulf	50.60		50.60	

Table 5.3.3. Soybeans: Comparison of Rail-Barge vs. Direct Rail to Gulf, Average of 2000-2004 ($/MT)

	Rail	Barge	Total	Least Cost
Northern Illinois				
RCH1	10.01	6.86	16.87	
RCH4	2.54	9.60	12.14	**
NOLA	13.19		13.19	
Minnesota				
RCH3	13.22	14.03	27.25	
RCH2	15.22	10.71	25.93	
RCH1	14.77	6.51	21.28	**
NOLA	24.56		24.56	
TXGulf	27.79		27.79	
Minnesota River				
RCH3	7.89	14.03	21.92	
RCH2	7.87	10.71	18.58	**
RCH1		6.51		
NOLA	23.62		23.62	
TXGulf	35.07		35.07	

These results indicate the intermodal competitive rivalry. Prior to about 2000 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 more recent years, the railroads are pricing to encourage grain to bypass the northern regions of the river with direct shipments direct to the US Gulf in some important movements. Indeed this is true in one of the most competitive markets is Illinois North both in terms of volume and its diversity of markets to which it can ship.

5.4 Barge Rate Functions and Delay Costs Barge rates were defined as a price-quantity relationship. In addition to this value, a delay cost was added.

Barge rate functions were derived for each Reach (Table 5.4.and Figure 5.4.1). Reaches 5-6 had the highest slope indicating a higher rate sensitivity to volume shipped. Reach 4 had the lowest slope, followed by Reach 2, 1 and 3.

Delay curves were derived for each of Reaches 1-4. For Reach 5 and 6, it was assumed that traffic would remain relatively low compared to lock capacity. Consequently, changes in delay costs were assumed to be insignificant. Delay costs were derived through simulation assuming normal levels of other traffic. These were derived for current capacity, as well as for planned capacity.

These transit curves reflect the relationship between total tonnage moving over the reach and expected delay costs. Grain originated on Reach 3 contributes to the traffic and delay in Reach 2 and in Reach 1. Shipments on Reach 1 would not contribute to traffic in Reach 2 or 3. Traffic levels for grain and non-grain during the base period (2000-2004) were used to calibrate

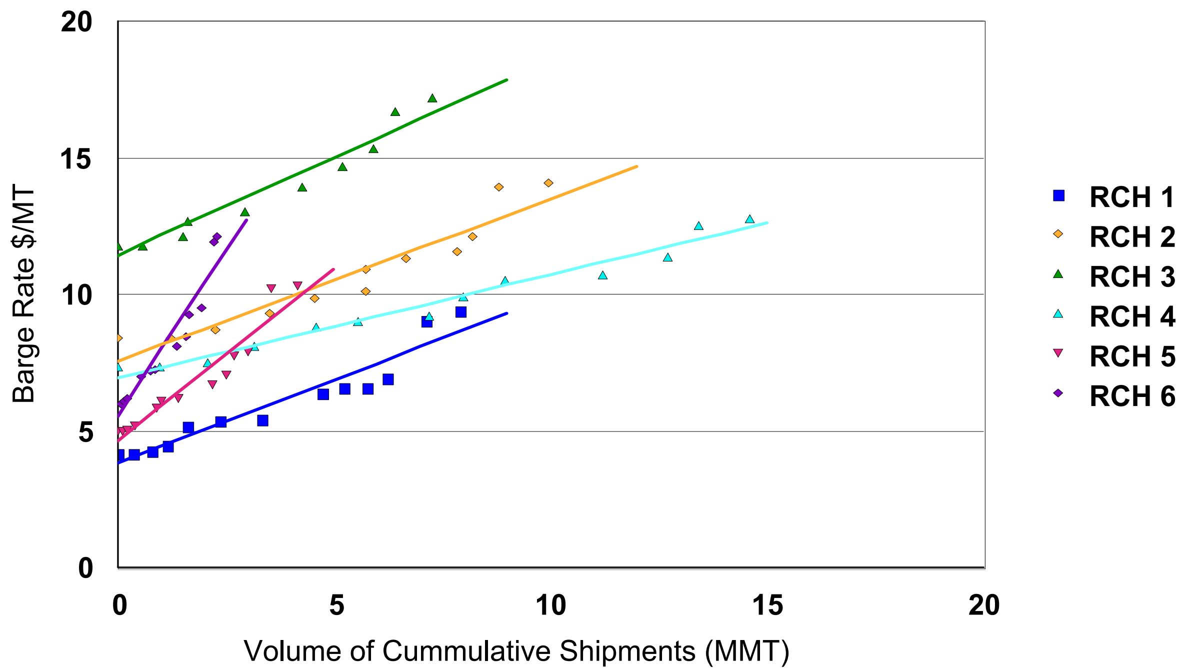

Figure 5.4.1 Estimated Barge Supply Functions.

the curves. The base assumption is for nil growth in non-grain traffic and a sensitivity is used to illustrate the impacts of this assumption. Finally, the delay costs were derived for both the existing capacity, as well as for an expanded lock system. It is anticipated that any expansion would take 13-14 years, so, the impact of an expansion is expected in 2020.

Figure 5.4.2 shows the delay costs and how they are impacted by volume for grain. The impact of non-grain volumes in addition to grain on delay costs (grain + non-grain) are shown in Figure 5.4.3.[10] Over a fairly wide range of tonnage that includes current traffic levels, delay costs are not particularly sensitive to changes in volume. At higher volumes, delay costs escalate and ultimately become nearly vertical. The latter is an indicator of capacity, i.e., the level of volume at which the delay costs become perfectly inelastic. For most Reaches, current volume is less than the level at which delay costs would begin to escalate sharply. In addition, in some cases there is a very slight negative delay cost.[11]

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[10] In the empirical model the delay cost curves were represented by estimated regressions using a double log-transformation of the data. We also represented these using an inherently nonlinear functional form but including this type of functional form in GAMS made it difficult to find a minimum, and we were not able to be certain the solution was a global minimum. Using double-log delay costs allowed GAMS to converge quickly, and resulted in a global minimum.

[11] To clarify, the solution for existing barge system occurs at lower values than the 5 year average. Thus, negative values should be interpreted relative to a reference point, and the change derived. The reference is the base period, 2000-2004, which imputes a certain level of delay cost. In the results, these are compared to alternative solutions and differences derived.

For Reach 2, the increased costs associated with delay for traffic less than about 28 mmt of grain traffic is near nil. Costs increase very sharply for traffic greater than about 30 mmt. In addition, there are slight negative delay costs for volumes less than about 18 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 38 mmt. At grain traffic of about 38 mmt, the increase in delay costs is very sharp. Finally, at Reach 4, delay costs are near nil up to about 28 mmt and then increase sharply. 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.

The delay curves would change if there were an expansion, as proposed. 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. In addition, the value of the negative delay costs for lower volumes are slightly greater than in the previous case.

The total cost of shipping by barge comprises the rate generated from the barge rate function and the delay costs. These are shown in Figure 5.4.4 for each Reach. As volumes increase, there is an increase in barge rates corresponding to the barge rate function. Thereafter, at some level, the delay costs begin to have an impact and further increases occur due to the delay costs.

This approach differs from Fuller et al., 1999. They estimated a capacity delay function 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 six hours.

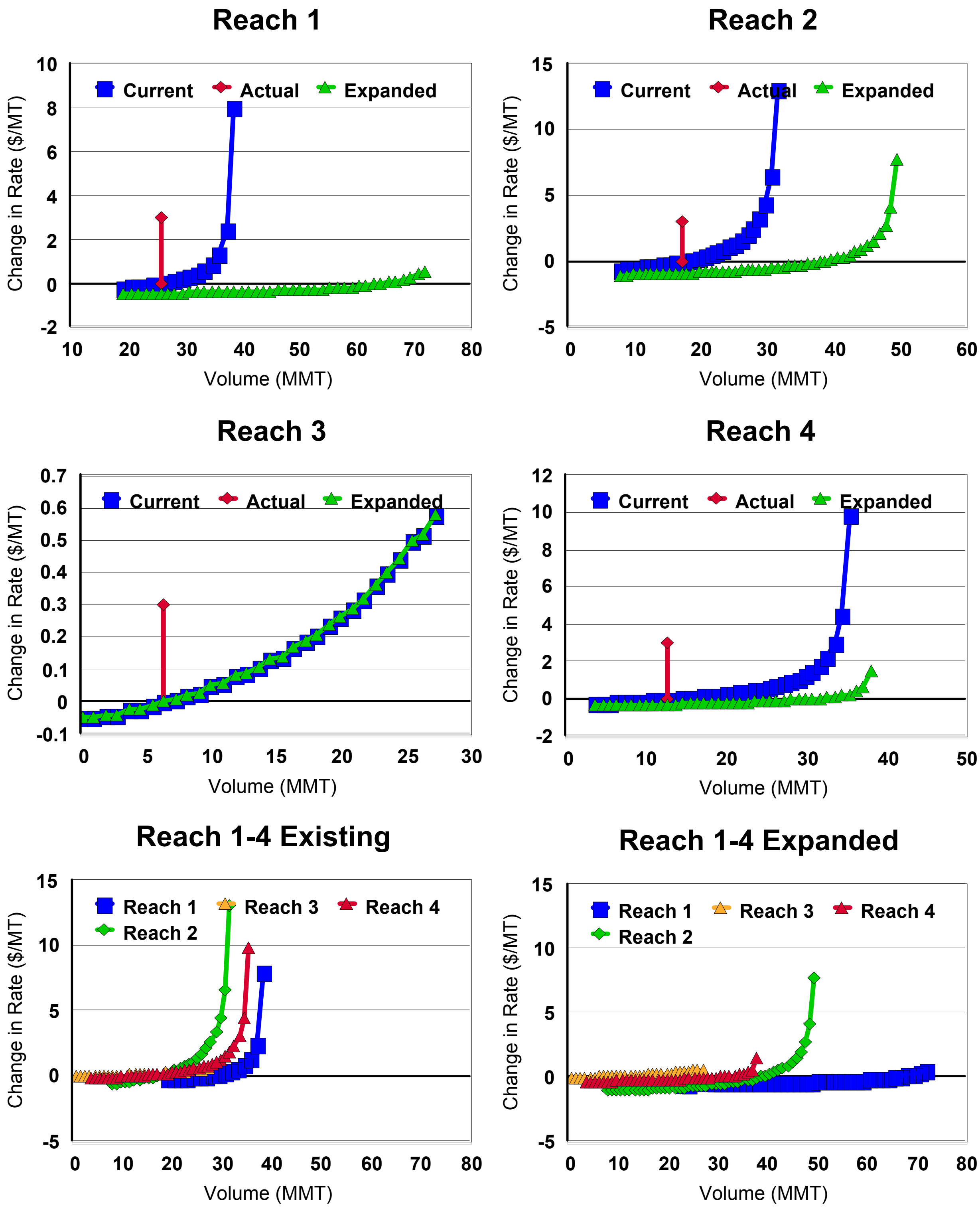

Figure 5.4.2 Delay Costs and Actual Volumes, Existing and Expanded Capacity: Grain Volumes Only.

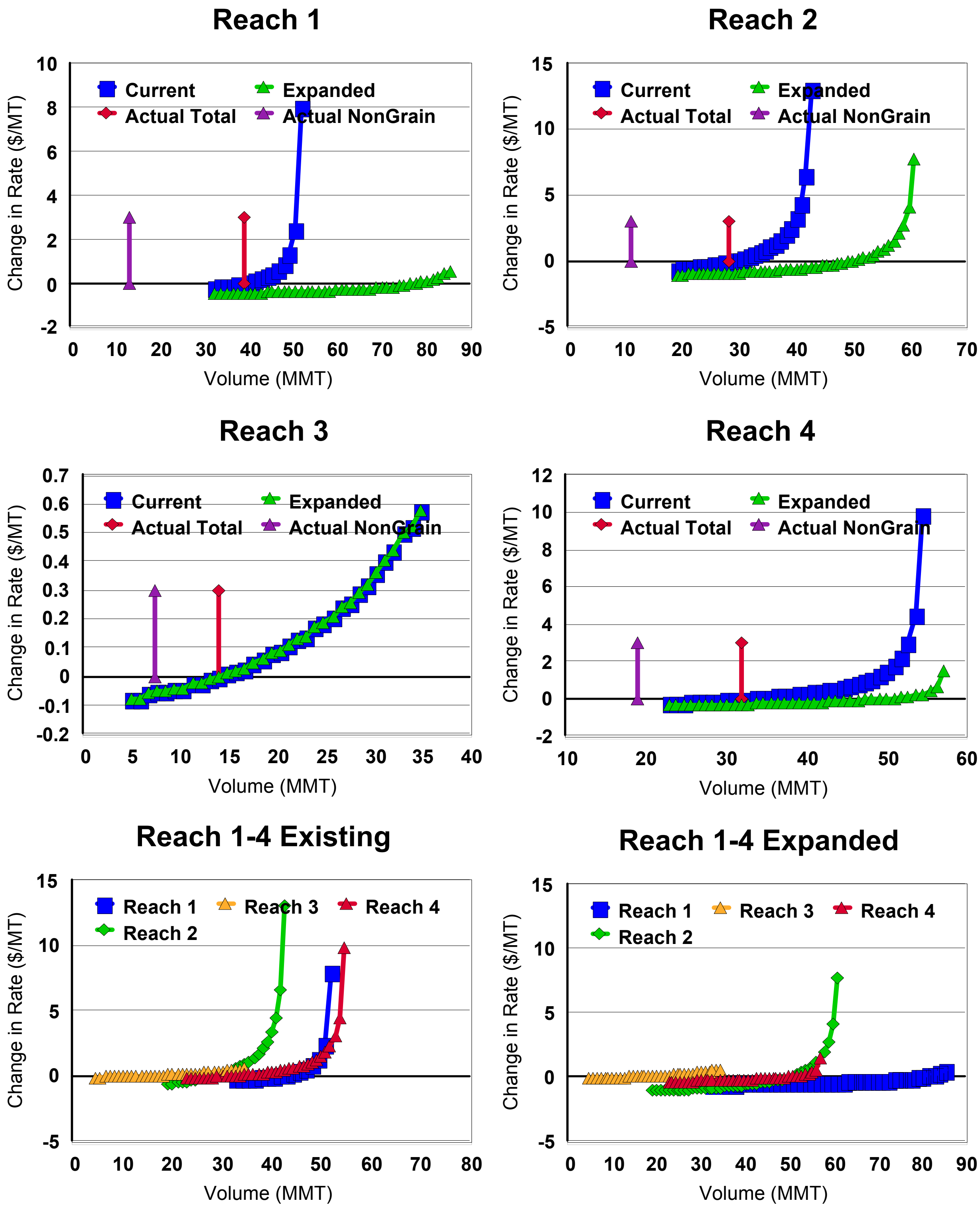

Figure 5.4.3 Delay Costs and Actual Non-Grain and Total Volumes, Existing and Expanded Capacity.

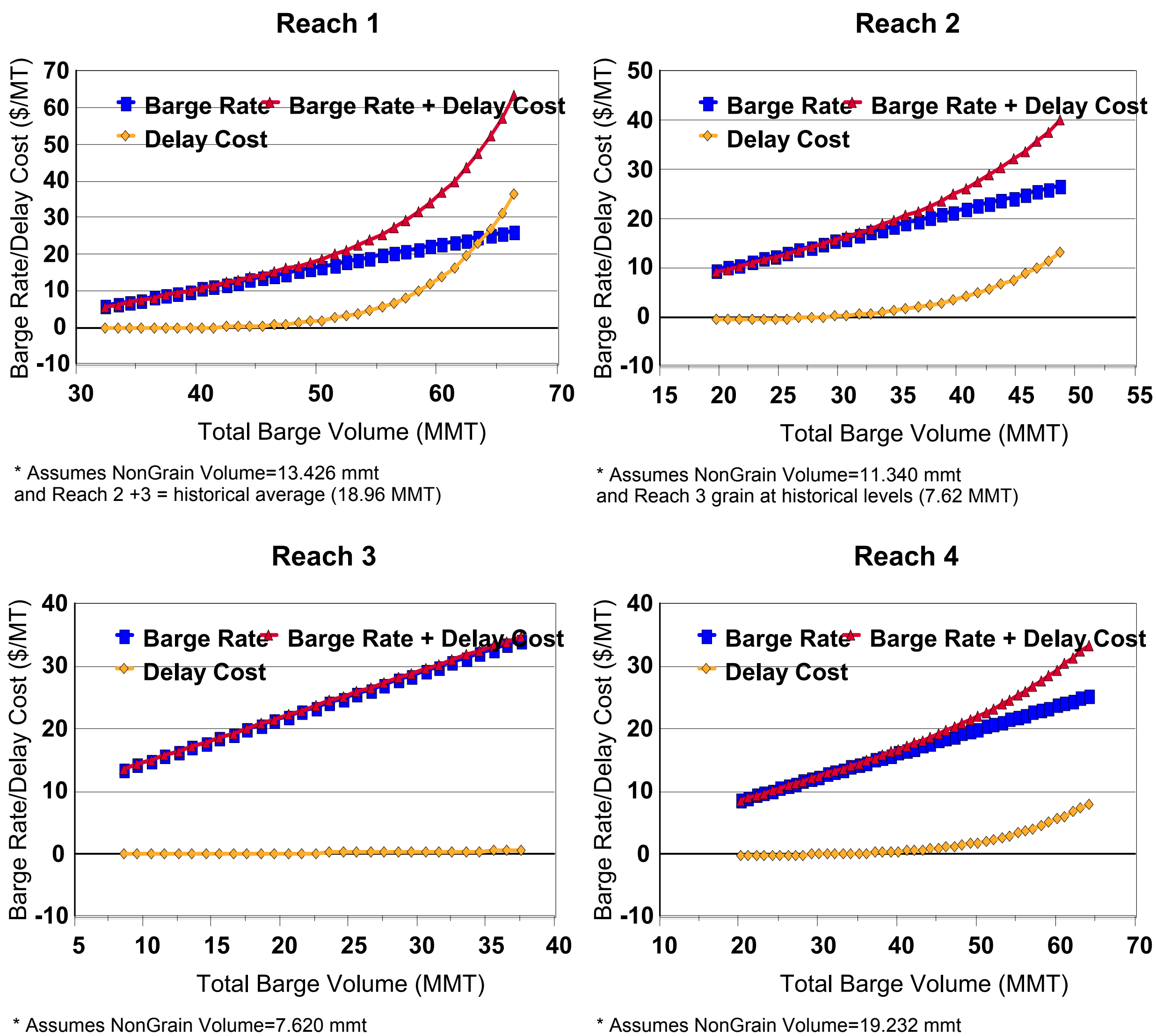

Figure 5.4.4. Barge Rates, Delay Costs and Total Barge Cost for Cumulative Barge Volume (Total Flows through Reach including Non-Grain Traffic), by Reach, Current Capacity.

5.5 Ocean Rates One of the more important variables 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. Historical values are shown in Figure 5.5.

Typically, this value trades in the range of about $5/mt, though there was quite a bit of volatility in more recent years. Values for individual trades to other Asian countries show similar but not exactly comparable behavior. As illustrated, the rate spread increased sharply in the period following January 2004. Specifically, the value used in our analysis for was $4.97/mt ($22.57 vs. 17.60). In contrast to the base period, the spread has increased, and then more recently declined.

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, global shipments of wheat and coarse grains are remarkably stable. 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 Capesize backlog is around 100 ships. And both of these are a large percent of the current fleet. In summary, these new builds will cause rates to fall, beginning in 2006.

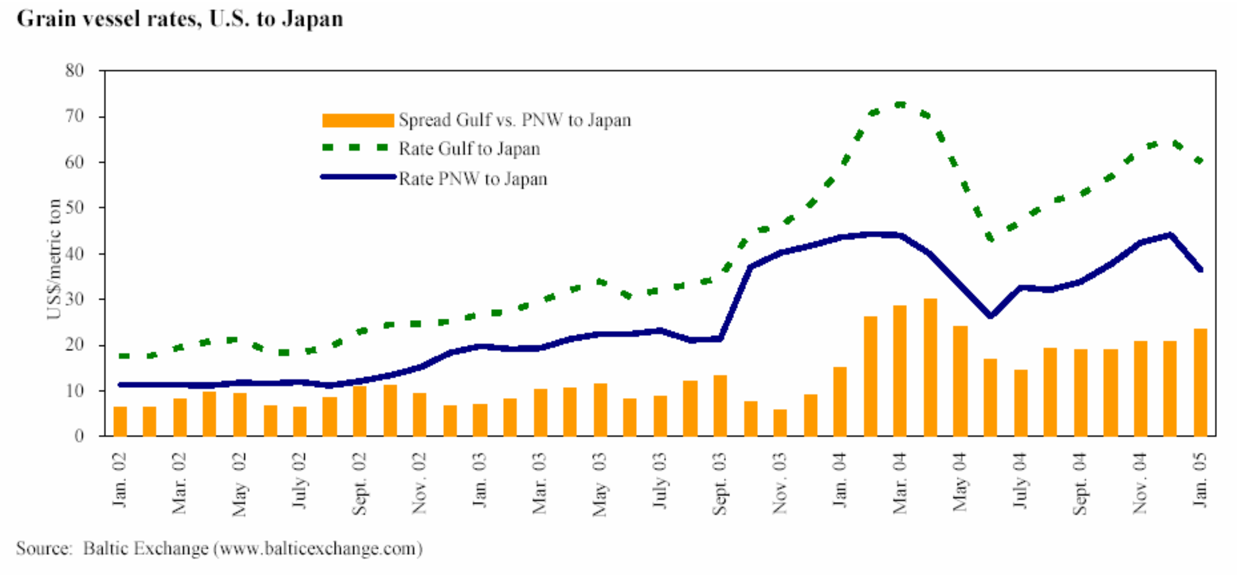

Figure 5.5 Grain Vessel Rates, U.S. To Japan.

6. Base Case Definition, Projection Methodology and Sensitivities

A base case is defined and used for comparison with results from alternative scenarios. The base case is interpreted as that reflecting the most likely (current) scenario and uses data for the period 2000-2004. The model was used to make projections. To do so, the following logic was used and applied and summarized as:

- Demand is projected for each country and region based on income and population projections from Global Insights;
- Yield and production costs for each producing region are derived;
- Production potential is determined in each country/region subject to the area restriction;
- US modal rates were derived for the period 2000-2004 and it was assumed that their spatial relationship was the same during the projection period.
- Ocean shipping costs were projected based on oil, trend etc.

Using these, the model was solved for each year in the projection horizon which was defined in 10 year increments for 50 years.

Table 6.1.1 define the major assumptions for the base period and projection period. Numerous variables prospectively impact barge shipments. The model was estimated assuming base case conditions at 2000-2004 values. It was estimated with and without expansion of the barge system. Modal rates were assumed at 2000-2004 average values, and barge rates were represented as a supply relation and subject to delay costs. Area to these crops in the United States was restricted to 100% of the historical area harvested and yields were based on longer-term trends. These were retained in the projection period, but, both were relaxed as sensitivities. Ethanol use of corn in the United States was assumed at the EIA 2005 (Energy Information Agency) projections. These were revised in 2006 and sensitivities allowed for this increased demand for corn for ethanol production.

Sensitivities and Calibration In calibrating the model, we experimented with numerous variables. Just to mention a few, these included: 1) restricting rail capacities in total and geographically; 2) not restricting US or ROW area planted; 3) a revision to allow for adjustments to stocks; 4) using mean barge rates instead of barge rate functions; among others. The impacts of these were generally mixed and were not included in the final model.

A few highlights from the calibration process are highlighted. The model excluded stock-holding. For this reason, it was not possible to make backward projections for individual years. In practice, trade in individual years periodically evolves even though world supplies are less than demand. In these cases, consumption is met in part from stocks. Thus, it is not possible nor practical to replicate trade flows for each individual year.[12] Technically, in these years, the model was infeasible. We experimented with including stocks, however, this created numerous conceptual problems. For these reasons, the model was calibrated for the years 2000-2004. The unrestricted model provides a longer-run solution which would likely be less appropriate for comparing the shorter-run results in particularly years.

One suggestion was to use mean barge rates instead of the barge rate functions. If we forced the model to use mean barge rates (weighted by volumes), the results are for total exports of 60 mmt by barge, and excessive movements on each of Reach 3 and 4 (about 30 mmt on Reach 4) and Reach 2 gets near nil shipments. These can be compared to the base case and historical values below. This really emphasizes the importance of the rate function which has the impact of precluding large jumps in flows as rates change.

Model results were evaluated relative to domestic flows during the base period 2000-2004. Data on actual rail and barge flows during the base period were used to compare to model results. If there was a substantial difference, we investigated as to the reason for the difference, and made adjustments. Generally, these involved making a series of restrictions on flows so as to not restrict those to or from the river system. These adjustments were made to the model in order to more accurately reflect these flows.[13] Finally, an exception regards East Coast shipments of corn and soybeans. Our model nearly always resulted in nil exports of these commodities through East Coast ports, even though generally there are about 1.5 to 2.0 mmt of corn and soybeans respectively. Restricting the model so these occurred improved the results

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[12]An alternative is to includes a level of exogenous stocks in the model, which can be used as a source of supply. But, to this it is essential to define the location at which those stocks are held.

[13]These are non onerous and are summarized in Appendix Table 2.2.

slightly, but it took it directly from River shipments. Consequently, we left this unrestricted.

Table 6.1.1 Base Case Assumptions

Model Assumption	Base Period 2000-2004	Projection Period	Sensitivities during projection period
Barge system capacity	141 mmt for grain origination	Existing and expanded capacity	
Non-Grain Barge	2000-2004 average levels	Assumed same as base case	
US rail car capacity	Restricted rail capacity		Restriction expanded
Modal rates	Rail from 2000-2004 average; barge rates represented as supply functions by Reach; ocean rates derived from a regression	Assumed same as based case	

US area restrictions	3 restrictions imposed:
	minimum total area=100% of recent 3 year average;
	maximum total area=100% of base;
	maximum area that can be switched among crops was 7% from the base period.
		Maximum changed to 107% in 2010 forward	Relaxed to allow expanded production as required

Rest of World (ROW) area restrictions	3 restrictions imposed: minimum total area=100% of recent 3 year average; and minimum area for any one crop=88% of base; maximum total area=107% of base; maximum area that can be switched among crops was 7% from the base period.	Maximum changed to 107% in 2010 107% in 2020 115% in 2030 115% in 2040 121% in 2060	Relaxed to allow expanded production as required
Ethanol production	EIA 2005 projections	EIA 2005 projections	EIA 2006 Projections and 7.5 billion gallons
China corn trade	Exports subsidized to 8 mmt	China exports=0	Relaxed restrictions on China imports and exports
Other Trade policies	Retained as in Appendix Table 2.1	Retained	

7. Results

7.1 Base Case Calibration The base case is reported along with the "calibrated" results which were used to evaluate the models' performance in identifying movements for key shipments.

The base case model was calibrated relative to the average of flows during the base period 2000-2004. The reason for calibrating it to this period is that during 2000-2004, relationships were relatively stable.[14]

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 optimal shipments through each port area, by each mode, and through each Reach. 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.[15]

Model results are compared first at the world trade level, then at US export ports and finally for Reach shipments. In each case, model results were compared to actual results over the base period.

Exports by country/region: Region definitions used in reporting these results are aggregations of countries and regions and the abbreviations are in Table 7.1.

The model replicates well the total quantity of exports from the United States as well as most competitor countries. See Table 7.1.1. The level of exports by country and region suggest these are very comparable to levels that existed during the base period. Total US exports are 101 mmt and comprising 44, 30 and 27 mmt for corn, soybeans and wheat respectively. World trade in these grains is 83, 61 and 119 mmt respectively, for a total of 264 mmt.

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[14]In an earlier version of this model, we conducted extensive "backcasting" whereby the solution for individual years was compared to historical values of barge shipments by Reach. Since we updated the base period and years, there was an important change. Most important is that in the period 2000 to 20004 there were drastic changes in stocks of most grain, but notably corn. In particular, China reduced stock, but the world increased stocks. In some of these years, there was a net reduction in stocks meaning that demand exceeded supplies. As a result, in those years, the model could not solve. In lieu of this we calibrated the base case to the values that existed for the average of the period 2000-2004. Further, the agronomic and policy conditions of this period are likely more representative of the future than the conditions that existed during the 1990s.

[15]The appendix to this report provides these details as well as the level of exports and imports for each country and region, as well as Reach shipments and harvested area. Also, detailed spreadsheet pivot tables have been prepared with results of all simualtions that can be extracted in numerous dimensions of grain type, mode, country/region, etc.

Table 7.1. World Region Definitions.

Region	Countries Contained within
ARG	Argentina
AUS	Australia
BRZ1	Brazil North
BRZ2	Brazil South
CAL	Alberta, Canada
CBC	British Columbia, Canada
CMB	Manitoba, Canada
CON	Ontario, Canada
CSK	Saskatchewan, Canada
CHI	China
EUR	EU-25, Eastern European Countries
FSU-ME	Former Soviet Union and Middle East Countries
JAP	Japan
LAT	All Latin America except for Argentina, Brazil and Mexico
MEX	Mexico
NAF	Algeria, Egypt, Lybia, Morocco and Tunisia
SAF	All other African Countries
SA	Bangladesh, India and Pakistan
KOR	South Korea
SEA	All Southeast Asian and Indonesia

Comparing model results to actual exports suggests these are very similar. A few clarifications are in order. Canada exports as shown here exclude the shipments to the US by rail which are interpreted (in the model) as domestic flows and are three mmt, which, when taken together with other Canada are about equal to their exports. Europe (as defined above to include Eastern Europe) exports corn which includes shipments from these other countries.

Table 7.1.1 Base Case Exports by Port and Region, Total and by Crop, (000 MT)

	Total	Corn	Soybeans	Wheat
Argentina	28,962	11,122	7,997	9,842
Australia	19,817	17	0	19,799
Brazil N	11,147	0	11,147	0
Brazil S	9,904	1,432	8,472	0
Can EC	512	0	0	512
Can WC	11,912	0	0	11,912
China	8,000	8,000	0	0
Europe	44,631	19,000	0	25,630
Latin Am.	3,696	0	3,696	0
Mexico	0	0	0	0
South Asia	24,721	0	0	24,721
US EC	2,554	0	0	2,554
US Gulf	65,215	32,767	19,924	12,524
US PNW	24,594	9,923	6,101	8,570
US Mex Dir	8,234	1,005	3,995	3,234
Grand Total	263,899	83,266	61,333	119,299
US Total	100,597	43,695	30,020	26,882

* Note the export number in this and future tables and figures do not include the direct rail shipments from U.S. to Mexico.

There are a couple of cases in which the projections differ more sharply from actual flows. One is Argentine soybean exports which are higher than actually realized during this period. Second are the US exports via the East are only comprising wheat, which are mostly from the Lakes, though some is from the Atlantic. There are nil exports of corn and soybeans from this node. This contrasts with actual flows where corn and soybeans comprise about 2-3 mmt, most of which goes to Europe or North Africa. Exports from these regions have been declining for a number of years. These results suggest that Argentina would likely shift to greater exports of soybeans over time. It also indicates the diminished role of exports from the US east. We were unable to detect reasons why the model results differ from these. Hence, the implications are that likely these are longer term inevitable results as markets adjust.

US Port shipments See Table 7.1.2. Results from the model are very comparable to actual shipments. Export volumes from the US are comparable by grain type as are interport exports. The exception is East Coast exports which as discussed above should be sightly greater than generated from the model. Otherwise, interport shipments are very comparable.

Table 7.1.2. Comparison of Historical U.S. Export Shipments by Port Area and Crop to Base Case Results

Historical U.S. Export Shipments (2000-2004)				
	Total	Corn	Soybeans	Wheat
East Coast/Lakes	5,960	1,507	2,049	2,405
Gulf	67,774	33,952	19,908	13,915
PNW	20,663	6,521	3,749	10,393
Internal	4,426	1,878	1,991	557
Total	98,823	43,858	27,969	27,269
Base Case - Current Capacity				
	Total	Corn	Soybeans	Wheat
East Coast/Lakes	2,554	0	0	2,554
Gulf	65,215	32,767	19,924	12,524
PNW	24,594	9,923	6,101	8,570
Internal - Mexico	8,234	1,005	3,995	3,234
Total	100,597	43,695	30,020	26,882

Note: Internal Shipments to Mexico Added to U.S. Export Numbers to be Comparable to Historical.

Reach Shipments: Reach shipments are shown in Tables 7.1.3 and 7.1.4 with comparisons to the actual shipments average over the period 2000-2004. Actual shipments were 47 mmt, and varied from 43 to 51 mmt with sharp declines commencing from 2002. Shipments decreased from 51 mmt to 43 mmt over this period.

Reach shipments are also fairly reflective of historical shipments during the base period. The model results compare very favorably with a total of 51 mmt. These are concentrated with about 15 mmt soybeans, 33 mmt corn and 3 mmt wheat. These are generally comparable when aggregating across reaches, as well as within reaches. Important differences are that the model overestimates the amount being shipped from Reach 4 and underestimates that being shipped from Reach 2. Upon further experimentation, there are very close interrelationships among shipments from Illinois and Iowa to Reach 2 and Reach 4, as well as to shipments in the Western Corn Belt and the South East for domestic shipments. The model also has greater shipments through Reach 3 than observed in practice. However, the sum of shipments on Reach 2 and 3 are comparable[16]

[16] Upon further examination, the model has about 12 mmt from Minn. River to Reach3. This exceeds observed volumes of 7.5 mmt. We were unable to reconcile this difference. There is sufficient supplies and demand to rationalize this shipment, and historically, shipments occur on this node which is all corn and soybeans, by truck

Table 7.1.3. Comparison of Average Barge Reach Loadings and Base Case (Corn + Soybeans + Wheat)

Reach	Average 2000-2004	Base Case	Difference
	(000 MT)	(000 MT)	(000 MT)
Reach 1	7,909	7,154	(755)
Reach 2	10,626	3,781	(6,845)
Reach 3	7,450	12,235	4,785
Reach 4	14,608	21,771	7,163
Reach 5	4,169	4,184	15
Reach 6	2,317	2,050	(267)
Total	47,079	51,175	4,096

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to Reach 3.

The only way to reduce this within the model would be to increase truck rates (see below), or increase barge rates. We did neither. However, to explore this issue further, we adjusted truck rates to Reach 2, 3, and 4 to better capture the observed inter-reach allocation. In this case inbound truck rates to each Reach would have to change as follows: Reach 2 -3$/mt; Reach 3 +$6/mt; and Reach 4 +$5/mt. Again, this was only explorative and are explained here for interest, however, these truck rate adjustments were not used in the model.

Table 7.1.4. Comparison of Average Barge Reach Loadings and Base Case by Grain

Reach	Total	Corn	Soybeans	Wheat
Avg. 2000-04	(000 MT)	(000 MT)	(000 MT)	(000 MT)
Reach 1	7,909	4,144	2,227	1,538
Reach 2	10,626	7,483	3,007	136
Reach 3	7,450	5,384	1,680	386
Reach 4	14,608	10,853	3,557	199
Reach 5	4,169	2,758	982	430
Reach 6	2,317	1,214	985	118
Total	47,079	31,836	12,438	2,805
Base Case	(000 MT)	(000 MT)	(000 MT)	(000 MT)
Reach 1	7,154	2,834	2,556	1,764
Reach 2	3,781	3,781	0	0
Reach 3	12,235	8,657	3,578	0
Reach 4	21,771	14,463	6,945	364
Reach 5	4,184	2,625	1,283	276
Reach 6	2,050	408	804	838
Total	51,175	32,767	15,166	3,242

Dominant US Domestic and Export Shipments: Domestic and export flows within the United States are shown in Tables 7.1.5-7.1.6. All of the movements generally coincide with expectations. Shipments to domestic consumption are as expected and comprising both rail and trucks. There are large barge flows from each of the Reaches to the points of export and by rail to the PNW.

There are a couple of notable shipments. Much of Illinois North is shipped to Reach 4, though as noted in Table 5.4.1, the relative rates favor rail direct to NOLA. Thus, if there is adequate rail capacity, this is the optimal shipment which displaces barges. The other is that Iowa River ships to Reach 2, as well as to the Western Corn Belt. This is as expected and verified in the STB data.

Table 7.1.5. U.S. Shipments from Production Regions to Export Reaches, Base Case (All Grains, Rail and Truck Movements, 000 MT)

U.S. Production	U.S. Export Reaches										
Regions	RCH1	RCH2	RCH3	RCH4	RCH5	RCH6	Toledo	Duluth	New Orleans	PNW	TX Gulf
USCP							407				4,900
USCPR									2,447		
USD									863		1,046
USIAR		3,781									
USILN				21,771							
USILS	1,571										
USINR					4,184						
USMN										2,656	
USMNR			12,235								
USMOR	3,505										
USMOW	1,321										340
USNP								2,147		14,328	138
USOH	758					2,050			1,448		
USPNW										1,798	2,858
USSE											
USSP										1,608	
USW											
USWIS											
USWIW											
USWNP										4,204	

Table 7.1.6. U.S. Shipments from Production Regions to Domestic Consumption Regions, Base Case (All Grains, Rail and Truck Movements, 000 MT).

U.S. Production	US Consumption Regions									
Regions	USCPC	USDC	USECBC	USNEC	USNPC	USPNWC	USSEC	USSPC	USWC	USWCBC
USCP	31,186						1,175			
USCPR	7,175	6,277				3,165			4,927	2,622
USD		8,297								
USIAR										13,428
USIAW										43,781
USILN			14,255				702			
USILS			5,125				15,583			
USINN			22,565							
USINR			1,423							
USMI			9,082							
USMN								3,832	3,593	1,790
USMNR										6,785
USMOR										234
USMOW			2,466					7,511		696
USNE			615	7,722						
USNP			2,662		10,229					
USOH				4,576			8,544			
USPNW						2,151			2,000	
USSE							18,515			
USSP								10,696		
USW									2,188	
USWIS			7,488							356
USWIW			3,006							15
USWNP					215					

7.2 Base Case Projections: The model was used to make projections on shipments 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 and relationships. Projections were made in 10 year increments for 50 years.

The model was first simulated assuming existing capacity on the barge system, then with expanded capacities. The other critical assumption is about China. Here China is restricted to export eight mmt in the base period, and thereafter their exports and imports were restricted to nil. In a sensitivity we relax this assumption.

In some cases it was necessary to make adjustments to maximum area allowed to be planted in order get a solution, i.e., so supplies exceeded demand on a world level. To do this, we retained the base case assumptions as much as possible, and then made adjustments for this purpose. In each case the adjustment was increased until a solution was attained. This is interpreted as a percentage of base total projected area, which varies through time (see model overview). For some countries there have been gradual reductions in area planted (e.g., US, EU and China) whereas in others there have been increases (e.g., Argentina and Brazil). The percentage adjustment was made relative to that projected area and in all cases was treated as a maximum restriction. For each simulation we report these. Those for the base case projections are shown below. The strict interpretation of this is that in order to produce adequate supplies to meet demand, and with the US maximum area fixed at 107%, the area devoted to these crops in the row would have to increase by these values.

Maximum Area Limit Relative to Projected Base Area to Achieve a Solution (%)

	Base	*2010*	*2020*	*2030*	*2040*	*2060*
US	100	107	107	107	107	107
ROW	107	106	107	119	115	123

7.2.1 Projections With Existing Capacity: The model was first solved assuming existing capacity. Results are shown in Figures 7.2.1a to 7.2.1c.

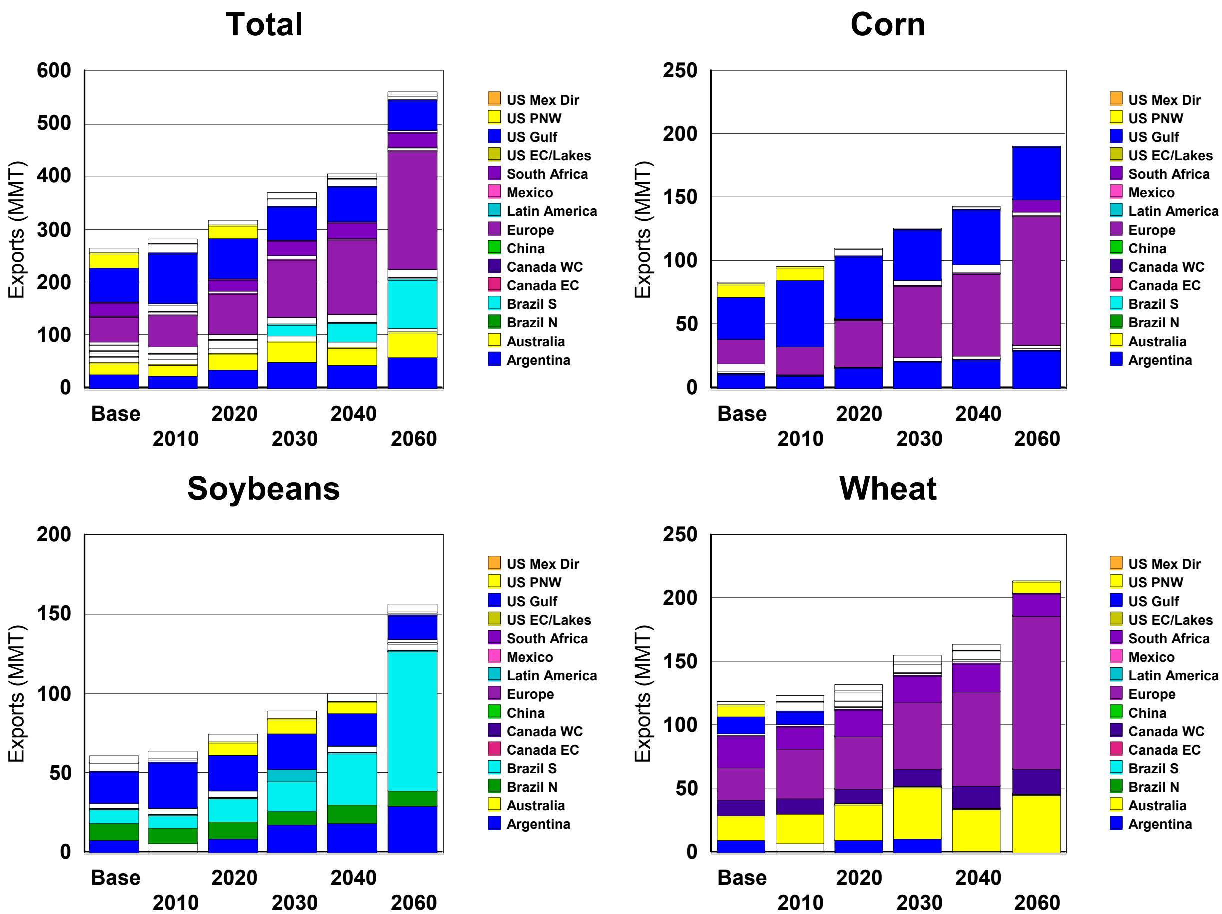

Figure 7.2.1a. Base Case Projections: Exports.

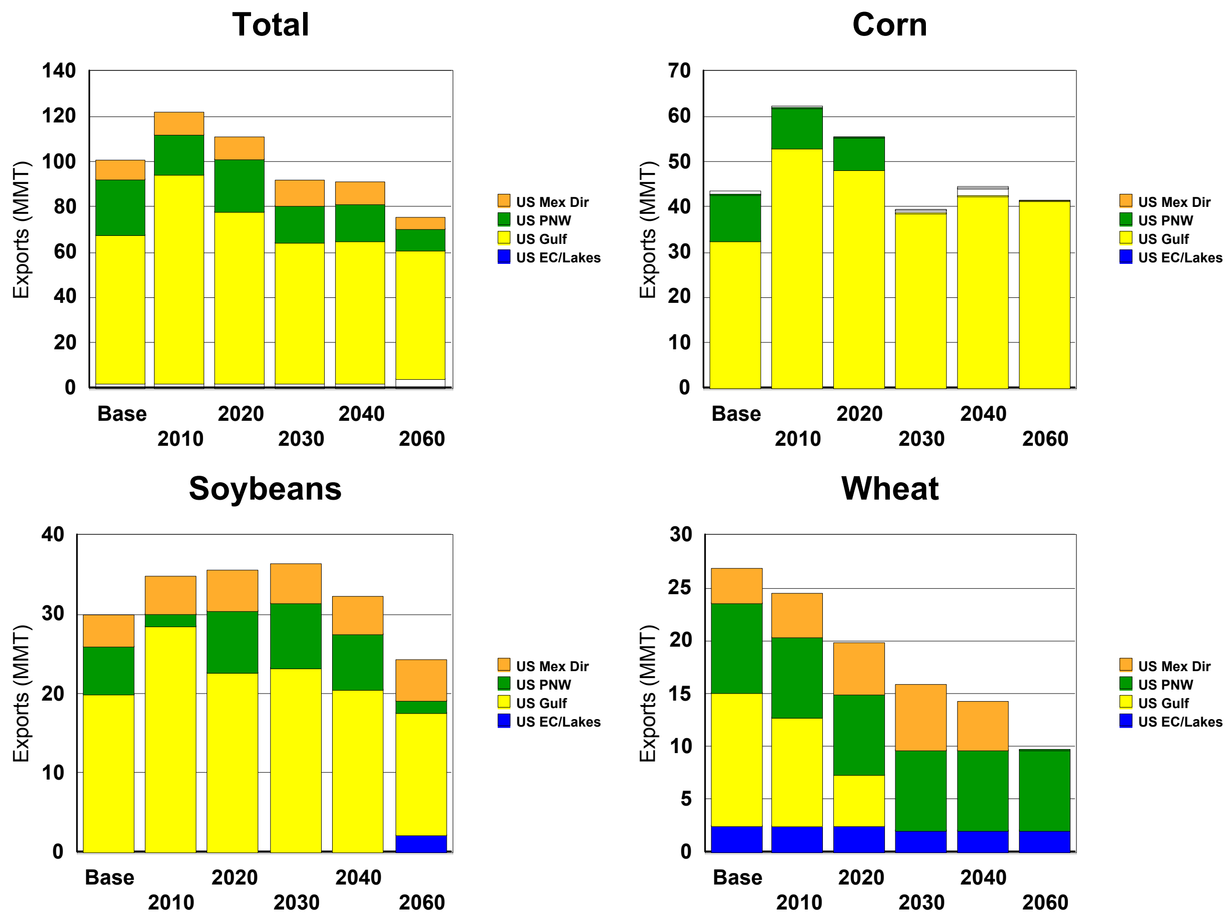

Figure 7.2.1b. Base Case Projections: U.S. Exports by Port Area.

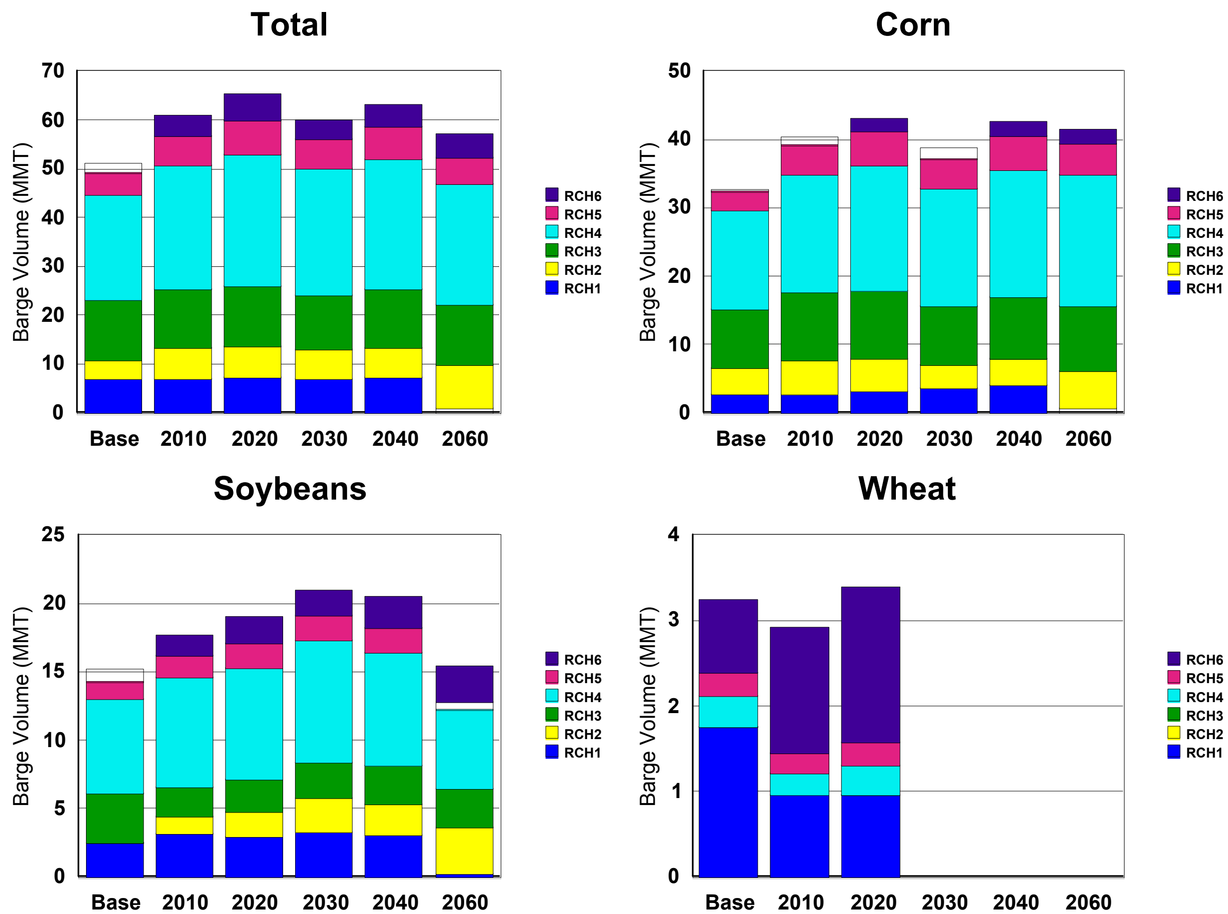

Figure 7.2.1c. Base Case Projections: Barge Reach Volumes.

Exports by country/region: Results indicate that total world trade increases from base values at 264 mmt to nearly 406 mmt in 2040 and 561 mmt in 2060. That for the US increases from 101 mmt to a peak at 122 mmt in 2010 and then declines. Countries and grains that have notable increases are Argentina (corn and soybeans, but wheat declines substantially), Australia wheat, Europe corn and wheat exports which includes Eastern Europe, Brazil soybeans which increase from about 20 to 97 mmt. Thus, the shift is for increased corn from Argentina and Eastern Europe, soybeans from Brazil and Argentina, increased wheat from Australia and Canada; and reduced wheat from Argentina and the United States. It should be noted that part of the increase, particularly in off-shore countries in the latter years is due to the need to expand area available in those countries to increase supplies to get a model solution.

Exports from the United States increase from the base period to 2010 in part due to the assumption that the maximum area for plantings would increase to 107% and in part due to that China's corn exports are reduced from eight mmt to nil in 2010. Thereafter China exports stay at nil. This implies a relaxed CRP (as represented by the 7% increase) and/or taking area from other crops (i.e., other than corn, soybeans and wheat). The decline that occurs after 2010 is in part due to increasing competitiveness of other exporting countries, increased domestic use of these crops (notably ethanol) which requires a shift in area planted amongst these crops. US corn exports decline the most, from a peak of 62 mmt to 42 mmt. Wheat exports decline substantially but soybeans increase, falling only in 2060.

Exports from the United States are concentrated in the US Gulf (including Texas Gulf) and decline from 101 to 76 mmt after reaching a peak in 2010. Exports from the PNW decline slightly from 25 mmt to 9 mmt in 2060. Again the reason for this is the increased domestic use and shifting amongst crops.

There are important area shifts amongst US crops (See Section 7.5). Most important is for an increase in corn area planted (recall, this was restricted to shift a maximum of 7%), and soybeans. These are offset by reductions in wheat area.

Finally, the results illustrate that the United States remains an important exporter of soybeans and this conclusion persists in other scenarios. There are reasons for this result. First, the United States is a lower cost producer of soybeans, compared to other countries and to Brazil North. Second, most of the growth for soybeans is international. Finally, Brazil has a higher amount of land to bring into production than the other soybean producers.[17] The cumulation of these means the United States retains its soybean production to the extent it is technically feasible (including substituting acres for corn, etc.), and exports the remainder. As the world needs more soybeans due to demand growth, it attracts that by increasing area devoted to soybeans, primarily in Brazil North, even though these are a higher cost.

For comparison and to illustrate the importance of US area restrictions, we ran the model for 2010 assuming the maximum area was 100%, as opposed to 107% shown here. The impacts of this are to shift area and exports to other countries as expected. From a port perspective, the PNW shipments decline from 18 mmt to 9 mmt; and those through the US gulf decline from 92 to 72 mmt.

Reach Shipments See Figure 7.2.1c. Reach volume increases from the base period at 51 mmt to 65 mmt in 2020. Thereafter, shipments decline to a longer term level at about 57 mmt. The reduced volume comes from both reduced wheat shipments which declines drastically (from three mmt to nil) and soybeans which occurs in 2060.

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[17]The model allows the following maximum restrictions on Brazil area (in mil ha):

	2010	**2030**	**Possible Increase in Maximum Area %**
Brazil North	12.5	16.3	30
Brazil South	10.4	10.8	4

7.2.2 Projections With Expanded Capacity: The model was run assuming the capacities at each of Reaches 1, 2, and 4 were expanded and reflected in changes in delay costs. The upward-sloping delay functions were changed to reflect that of an expanded lock capacity. The changes would occur and in these estimates would be completed by 2020. Results are shown in Figures 7.2.2a-7.2.2c and changes are summarized in Table 7.2.1.

The results indicate a change in barge shipments by about +4 mmt by 2020, nearly all of which would be for corn and soybean in equal amounts. Thereafter, the change in barge shipments would be about +1 mmt to +2.5 mmt, with most of it being soybeans. Changes would also occur in Reach shipments. In 2020, there would be increases in shipments on Reach 1, 2 and 4, but decreases in Reach 5 and 6. These suggest that inter-Reach competition is important. As delay costs decrease in the Upper Reaches, shipments from the lower Reaches decline.

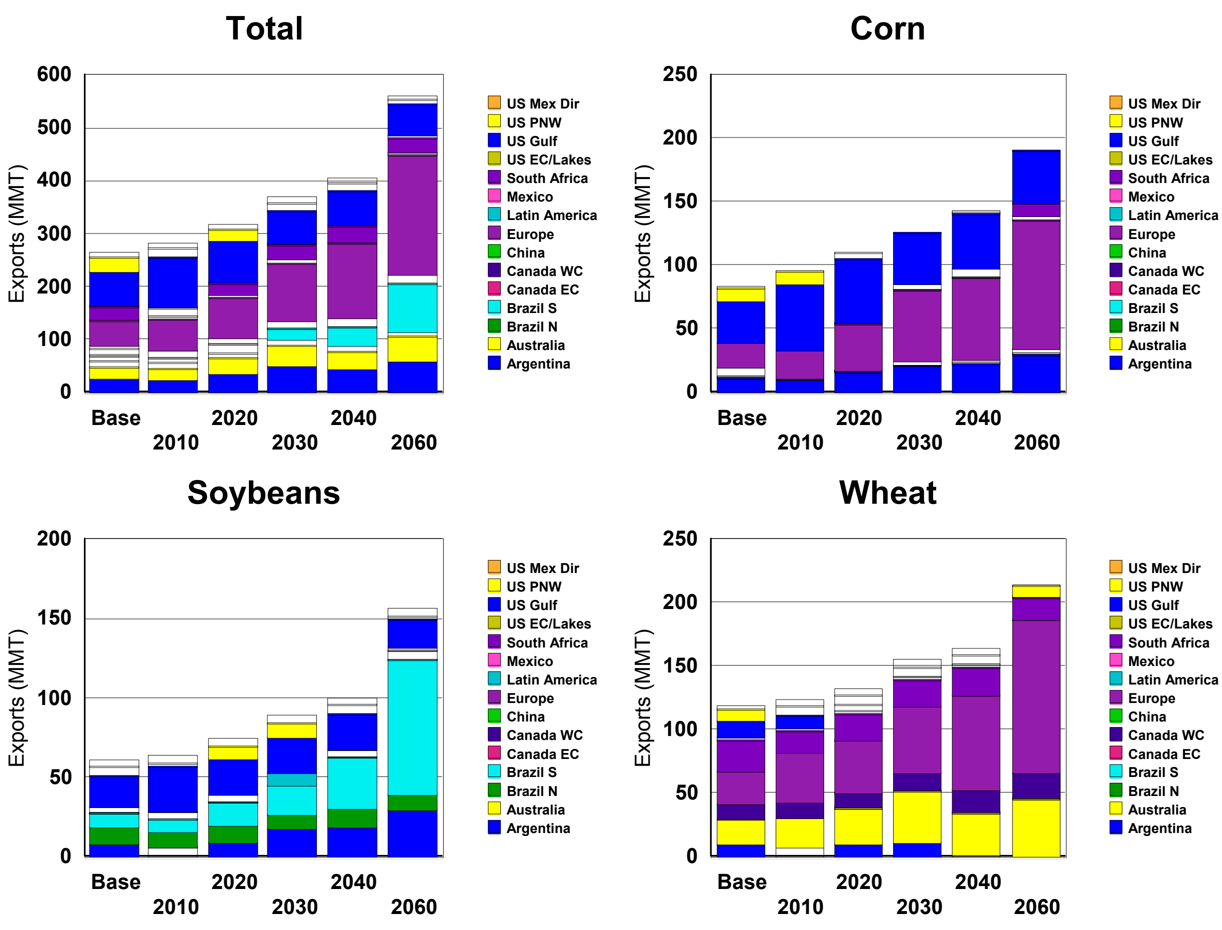

Figure 7.2.2a. Expanded Barge Capacity: Exports.

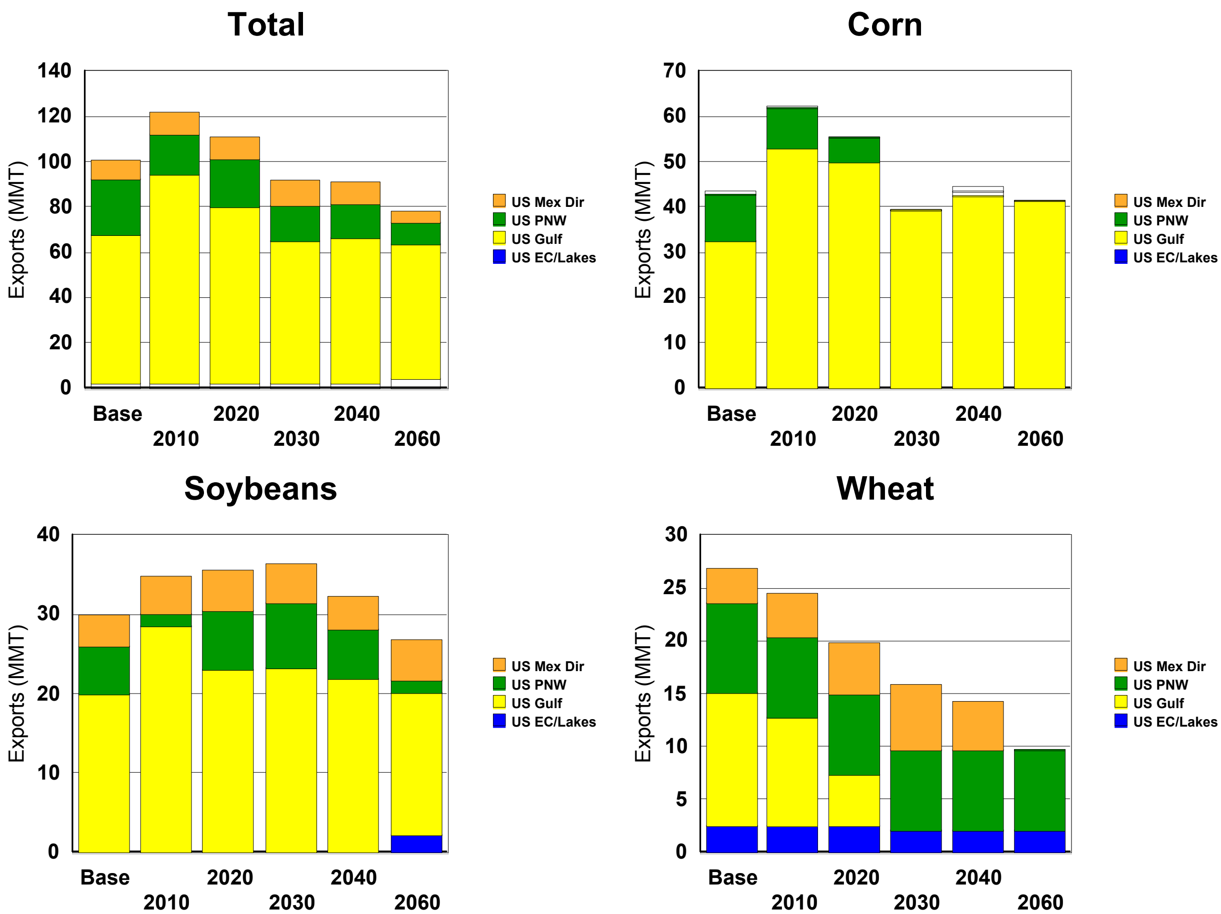

Figure 7.2.2b. Expanded Barge Capacity: U.S. Exports by Port Area.

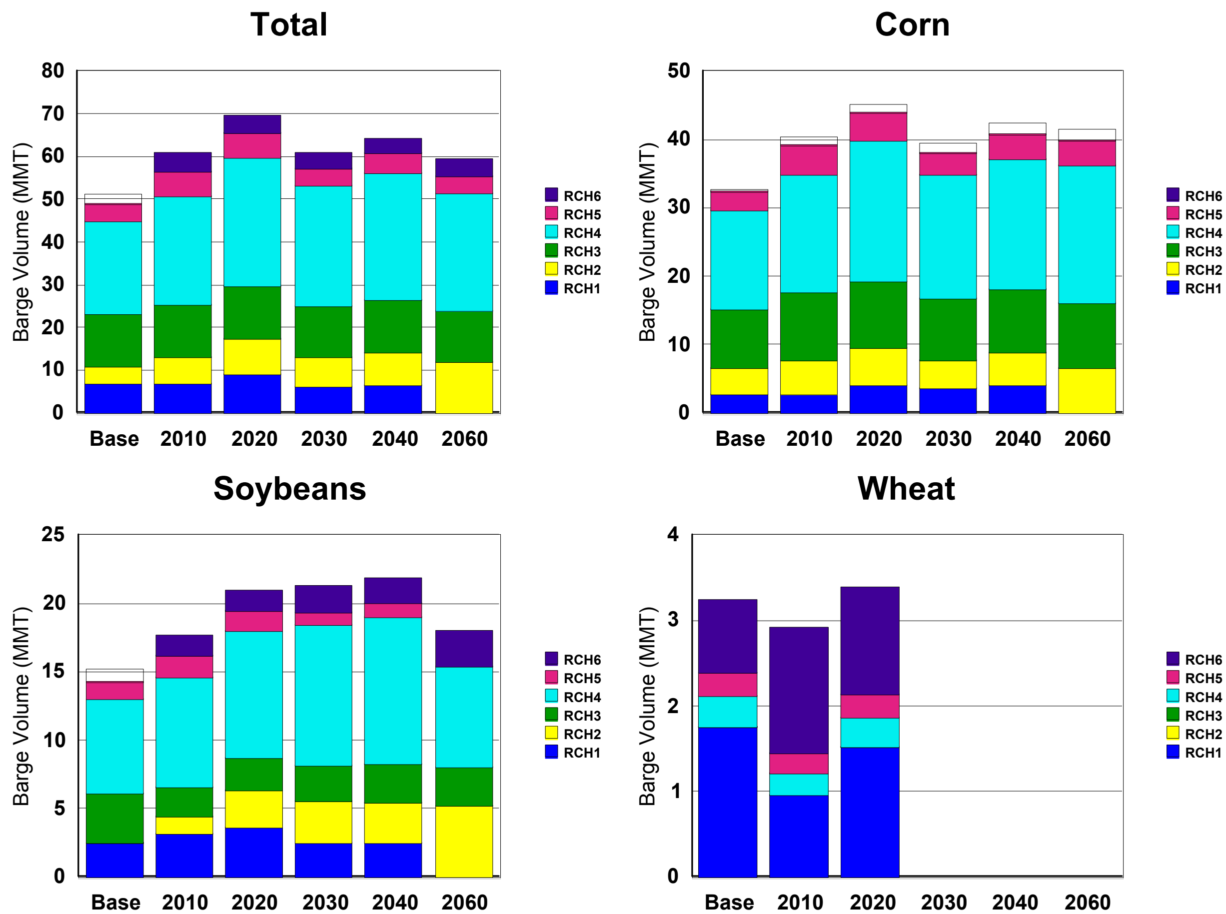

Figure 7.2.2c. Expanded Barge Capacity: Barge Reach Volumes.

Table 7.2.1. Change in Barge Volume (Expanded Capacity-Current Capacity), Total and by Grain, by Reach, 2020-2060.

Change in Barge Volume 2020	*Total*	*Corn*	*Soybeans*	*Wheat*
RCH1	2,018	799	653	566
RCH2	1,644	688	956	0
RCH3	0	0	0	0
RCH4	3,147	2,086	1,061	0
RCH5	-1,216	-980	-236	0
RCH6	-1,566	-500	-500	-566
Total	4,027	2,092	1,935	0
Change in Barge Volume 2030	*Total*	*Corn*	*Soybeans*	*Wheat*
RCH1	-860	0	-860	0
RCH2	1,161	526	635	0
RCH3	427	427	0	0
RCH4	2,418	1,037	1,381	0
RCH5	-1,983	-1,136	-846	0
RCH6	-207	-208	0	0
Total	956	646	311	0
Change in Barge Volume 2040	*Total*	*Corn*	*Soybeans*	*Wheat*
RCH1	-563	0	-563	0
RCH2	1,340	689	651	0
RCH3	304	304	0	0
RCH4	3,086	627	2,459	0
RCH5	-2,204	-1,378	-827	0
RCH6	-831	-434	-397	0
Total	1,132	-192	1,323	0
Change in Barge Volume 2060	*Total*	*Corn*	*Soybeans*	*Wheat*
RCH1	-1,143	-830	-312	0
RCH2	3,187	1,324	1,863	0
RCH3	0	0	0	0
RCH4	2,561	953	1,608	0
RCH5	-1,577	-953	-624	0
RCH6	-493	-493	0	0
Total	2,535	0	2,535	0

Delay costs were quantified for each simulation on each Reach. These are the delay costs accrued in the model solution. Technically, the delay costs are the "lock-processing time" including the added queuing time for going through the locks. As barge volumes increase, there is an increase in barge rates. As barge rates increase, there are slight shifts to other modes, routes, or potentially crops. This traffic diversion is not quantified. As barge shipping costs increase further due to delay costs, some barge shipments may continue despite the higher costs. It is these additional delay costs that are quantified. These are shown in Table 7.2.2 for the base case without any expansions, and then for the expanded barge capacity. The implicit assumption here is that there is nil-growth in non-grain traffic (relaxed below).

Table 7.2.2. Comparison of Delay Costs ($/MT) by Reach for Current Barge Capacity, Expanded Barge Capacity and Change.

Delay Costs: Current Barge Capacity ($/MT Barge Volume (Grain + Non-Grain))						
	Base Year	2010	2020	2030	2040	2060
Reach 1	-0.12	-0.04	-0.02	-0.09	-0.04	-0.14
Reach 2	-0.19	0.08	0.14	-0.08	0.03	0.55
Reach 3	0.10	0.10	0.10	0.08	0.09	0.10
Reach 4	0.45	0.86	1.08	0.94	1.04	0.80
Delay Costs: Expanded Barge Capacity ($/MT Barge Volume (Grain + Non-Grain))						
	Exp Base	Exp 2010	Exp 2020	Exp 2030	Exp 2040	Exp 2060
Reach 1	-0.12	-0.04	-0.46	-0.47	-0.47	-0.47
Reach 2	-0.19	0.08	-0.90	-0.94	-0.92	-0.79
Reach 3	0.10	0.10	0.10	0.09	0.10	0.10
Reach 4	0.45	0.86	0.06	0.00	0.53	-0.03
Delay Costs: Change from Current Capacity to Expanded Barge Capacity						
	Base Year	2010	2020	2030	2040	2060
Reach 1	0.00	0.00	-0.44	-0.39	-0.42	-0.34
Reach 2	0.00	0.00	-1.04	-0.86	-0.95	-1.34
Reach 3	0.00	0.00	0.00	0.01	0.01	0.00
Reach 4	0.00	0.00	-1.01	-0.93	-0.52	-0.83

In the base case, without expansion, negative delay costs are accrued for shipments on Reach 1 and 2, and positive delay costs occur on Reach 3 and 4. The negative delay costs are slight and are reflective that shipments are slightly less than normal during the base period, resulting in a cost savings. These values are relatively small. The delay costs that occur on Reach 4 are more substantive at $0.45/mt. As barge shipments increase on Reach 4, barge rates increase, and when shipments begin to approach about 32 mmt, delay costs are accrued without any traffic diversion. The amount of this added cost due to delay is the delay cost reported in Table 7.2.2. Through time, without an expansion, the delay cost on Reach 4 increases to $1.08/mt in 2020.

Expanding lock capacity has the effect of reducing delay costs, and increasing capacity. The delay costs associated with these scenarios are shown in the middle-panel of Table 7.2.2 and changes versus the base case are shown in the lower panel. An expanded lock system would result in lower delay costs at each Reach. Those at Reach 4 decline by about $1.01/mt. Similar declines occur at Reach 2 ($1.04/mt) and those at Reach 1 are about $0.44/mt.

Evaluation of the change in delay costs include both a price effect and a substitution effect, as illustrated in Figure 7.2.3a. The price effect is the impact of switching to the lower delay cost function which results in lower total barge shipping costs due to the lower delay costs for any given volume. Here the price effect is calculated as the reduction in barge shipping costs[18] at Q1 and the reduction in costs is equivalent to the shift in delay costs from D1 to D2. In addition to this, there is a substitution effect which is the cumulative result of substituting increased barge shipments, due to the now lower barge shipping costs, for alternative modes and routes. This is shown by the movement from Q1 to Q3 along the new expanded capacity delay cost function which also reflects a movement along the total barge cost function. Here, due to the reduced delay costs (and subsequent lowering of total barge shipping cost), there is a shift from other transit modes to barge which we refer to as the substitution effect. In addition to the price and substitution effects on barge volumes, there is an impact on other modes, routes and production and shipping of other commodities. This can be evaluated by comparing the equilibrium solution from the model without the expansion, to a model including the expansion. In this case the impact of the expanded barge capacity is for increased barge shipments (as described above), which has the impact of reducing rail shipments, potentially changing the composition of port area shipments (e.g., from the PNW to the US Gulf), and potentially causing a slight shift in the composition of production and shipments amongst commodities.

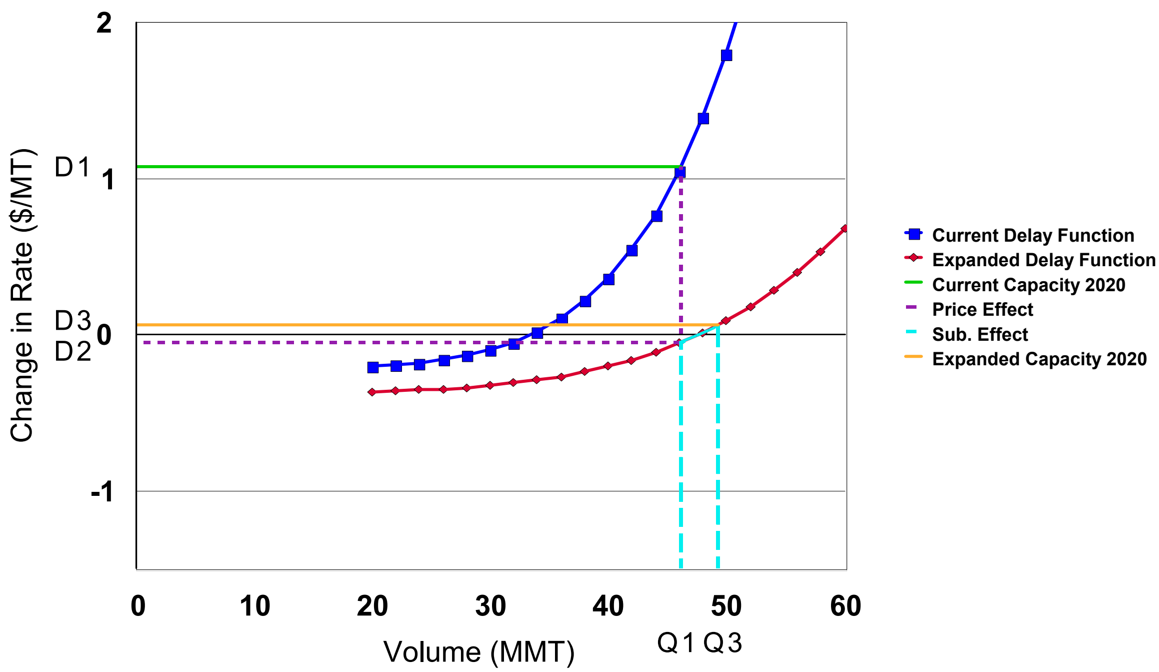

Figure 7.2.3a. Price, Substitution and Total Effects on Barge Reach Volume of Shift from Current to Expanded Barge Capacity, Reach 4, 2020.

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[18] Since total barge costs are the barge rate plus delay costs at any given volume and barge rates for a given volume are unchanged, the change in total barge shipping costs is the change in delay costs.

These impacts were each evaluated and summarized below. The direct impacts on barge volumes are explained first and shown in Table 7.2.3. The first panel shows the delay costs accrued by reach with current barge capacity. These are largest for Reach 4, and, slightly negative in Reach 1. Panel 2 reflects the delay costs estimated with the expanded barge capacity delay function at Q1. Here, the delay costs are about $-29.9 million and are largely a result of reduced delay costs at Reaches 1,2 and 4. The total effect on delay costs is shown in Panel 3. The lower portion of Table 7.2.3 shows the effects on barge delay costs for the price effect, Panel 4, the substitution effect in Panel 5, and the total effect in Panel 6. As shown in Panel 6, the impact of expansions on delay costs are in the area of $61 million, inclusive of both the price and substitution effects. Most of this is accrued on Reach 4, followed by Reach 2 and 1.

The effect of the expansion on the change in equilibrium between the base case without expansion in 2020 and that with an expansion was also evaluated. The expansion results in reduced delay costs of $61 million (about $1.02/mt), which includes the effect of a shift to a delay curve with slightly greater negative costs. As a result, there is an increase in quantity shipped by barge, which results in a slightly higher barge rate i.e., a movement along the barge rate function. This is an increase in cost of about $50 million, or, $0.84/mt. In total, barge shipping costs including delay costs are reduced by $11 million, or, $0.18/mt. Other impacts are for reduced shipping costs by rail to ports and reaches of about $59 million, increased rail shipments to domestic, and slightly greater ocean shipping costs, $10.4 million, due to an increase in shipping from the US Gulf. Taken together, the effect of the expansion is to reduce these costs by $52 million.

The model was also simulated assuming increases in non-grain traffic on the river. Recall that the base case was for nil-growth in non-grain traffic. If non-grain traffic increases, this shifts delay costs upward along the curve for total barge volume and reduces the volumes of grain that can be shipped at a given delay cost. It is not clear the extent of potential increase in non-grain traffic. Consequently, to give a range we simulated different percentage changes in non-grain traffic.[19] These results are shown in Figure 7.2.3b-c and summarized in Table 7.2.4.

The results show that if the non-grain traffic grows by 50%, (i.e., cumulatively over the base period to 2020), then delay costs increase and grain traffic would decrease by about 7 mmt. At this growth rate, and without any expansion, the delay costs in 2020 would increase on each Reach. Those on Reach 4 would increase from $1.08 to $2.15/mt. With an expanded barge capacity, these delay costs would increase to $0.54/mt. Expansion would result in reduced delay costs on each Reach. Delay costs would decrease by $61 to $76 million depending on the percentage increase in non-grain traffic with most of the delay costs reductions occurring in Reach 4, followed by Reach 2 and 1.

[19] A 50% increase over a 15 year period reflects a 2.7% compound annual growth rate.

Table 7.2.3. Total Delay Costs by Reach, Current Capacity, Expanded Costs for Current Capacity Volumes, Expanded Costs for Expanded Volumes, and Differences, by Reach and Year

	Base	2010	2020	2030	2040	2060
1) Delay Costs: Current Capacity ($ 000)						
Reach 1	-2672	-1133	-394	-2072	-1125	-3015
Reach 2	-2983	1488	2631	-1338	619	11519
Reach 3	1222	1176	1222	937	1126	1222
Reach 4	9795	21967	28989	24298	27904	19841
Total	5361	23498	32448	21825	28524	29567
2) Delay Costs: Expanded Costs at Current Capacity Volumes ($ 000)						
Reach 1	-2672	-1133	-12243	-11492	-11974	-10588
Reach 2	-2983	1488	-17533	-16457	-17077	-18597
Reach 3	1222	1176	1222	937	1126	1222
Reach 4	9795	21967	-1313	-2013	-1476	-2659
Total	5361	23498	-29868	-29026	-29401	-30622
3) Delay Costs: Expanded Costs at Expanded Capacity Volumes ($ 000)						
Reach 1	-2672	-1133	-13642	-11798	-12413	-11471
Reach 2	-2983	1488	-18355	-17474	-18007	-19112
Reach 3	1222	1176	1222	1060	1222	1222
Reach 4	9795	21967	1896	10	1564	-826
Total	5361	23498	-28879	-28201	-27633	-30187
4) Change in Delay Costs: Expansion Effect (2-1)						
Reach 1	0	0	-11849	-9420	-10849	-7573
Reach 2	0	0	-20164	-15119	-17696	-30116
Reach 3	0	0	0	0	0	0
Reach 4	0	0	-30302	-26311	-29380	-22500
Total	0	0	-62316	-50851	-57925	-60189
5) Change in Delay Costs: Change in Volume Effect (3-2)						
Reach 1	0	0	-1399	-306	-439	-883
Reach 2	0	0	-822	-1017	-930	-515
Reach 3	0	0	0	123	96	0
Reach 4	0	0	3209	2023	3040	1833
Total	0	0	989	825	1768	435
6) Change in Delay Costs: Total Effect (3-1)						
Reach 1	0	0	-13248	-9726	-11288	-8456
Reach 2	0	0	-20986	-16136	-18626	-30631
Reach 3	0	0	0	123	96	0
Reach 4	0	0	-27093	-24288	-26340	-20667
Total	0	0	-61327	-50026	-56157	-59754

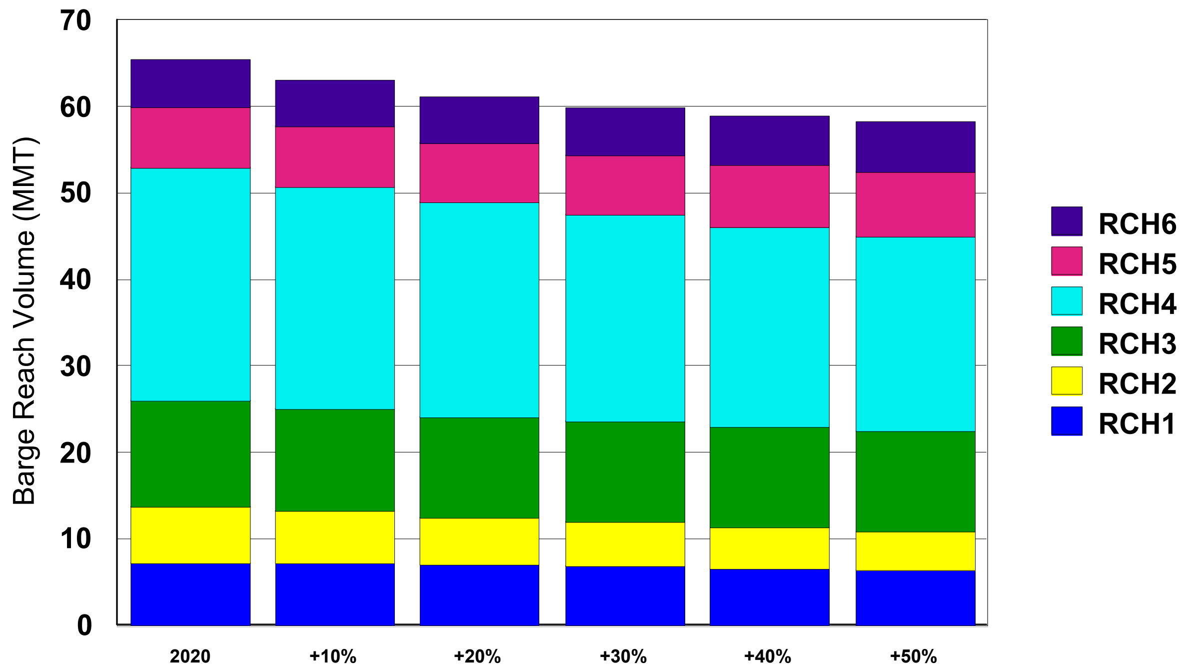

Figure 7.2.3b. Sensitivity of Barge Reach Volumes in 2020 to Non-Grain Traffic Increases (for Non-Grain in Reaches 1-4), Current Barge Capacity.

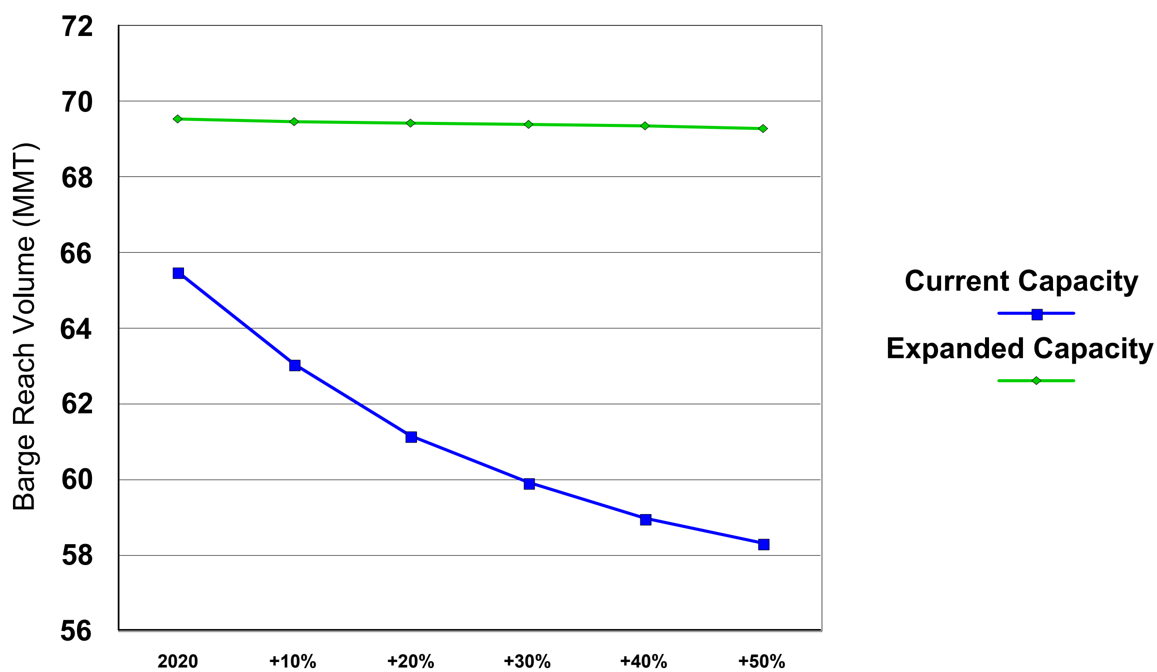

Figure 7.2.3c. Sensitivity of Total Barge Reach Volumes for Current and Expanded Capacity in 2020 to Non-Grain Traffic Increases.

Table 7.2.3. Sensitivity of Delay Costs to Changes in Non-Grain Barge Traffic, 2020

Delay Costs: Current Barge Capacity 2020 ($/MT Barge Volume (Grain + Non-Grain))						
	2020	+10%	+20%	+30%	+40%	+50%
Reach 1	-394	-15	676	1,752	2,932	4,560
Reach 2	2,631	2,804	3,970	6,027	8,618	11,651
Reach 3	1,222	1,251	1,363	1,529	1,700	1,876
Reach 4	28,989	31,148	33,737	37,544	42,725	48,561
Total 1-4	32,448	35,188	39,746	46,852	55,976	66,648
Delay Costs: Expanded Barge Capacity 2020 ($/MT Barge Volume (Grain + Non-Grain))						
	Exp 2020	+10%	+20%	+30%	+40%	+50%
Reach 1	-13,642	-13,486	-13,313	-13,122	-12,911	-12,678
Reach 2	-18,355	-17,784	-17,134	-16,397	-15,567	-14,636
Reach 3	1,222	1,394	1,571	1,753	1,940	2,132
Reach 4	1,896	4,148	6,658	9,433	12,490	15,807
Total 1-4	-28,880	-25,728	-22,218	-18,334	-14,048	-9,375
Delay Costs: Change 2020 (Expanded - Current Capacity)						
	2020	+10%	+20%	+30%	+40%	+50%
Reach 1	-13,248	-13,471	-13,990	-14,875	-15,843	-17,238
Reach 2	-20,987	-20,588	-21,103	-22,424	-24,185	-26,287
Reach 3	0	143	208	224	240	256
Reach 4	-27,093	-27,000	-27,079	-28,111	-30,235	-32,754
Total 1-4	-61,327	-60,916	-61,964	-65,186	-70,024	-76,022

Finally, in assessing these estimates of delay costs, it is important they are derived assuming a very conservative number for ethanol production. The effect of this is for more exportable supply which impacts the aggregate delay costs. If ethanol production expands further, the exportable supplies will decline (as shown in the next section), and though the unit cost savings associated with delay would likely not change, the aggregate costs would differ.

7.3 Ethanol Scenarios: One of the major changes in US grain agriculture is emergence of ethanol. Base case projections allowed expanded ethanol demand for corn based on current projections for ethanol demand for corn in United States using the EIA estimates in 2005. Since then, the Energy Bill was signed and would result in prospectively a greater amount of ethanol to be produced. The base case assumed EIA 2005 projections of corn use in ethanol demand, 107% of US base area and longer-term yield growth rates by region.

To explore the prospective impacts of further changes in ethanol, the model was revised assuming the EIA 2006 estimates of ethanol produced from corn.[20] In this case, corn used in ethanol production increases from four billion gallons to nearly 10 billion gallons in 2015, and then converge to about 11 billion gallons for 2020 forward. In the period after 2015 a minor portion of this will be met by ethanol from cellulose (EIA 2005). All other assumptions from above are retained. Area assumptions necessary to reach a feasible solution are:

Maximum Area Limit Relative to Projected Base Area to Achieve a Solution (%)

	Base	*2010*	*2020*	*2030*	*2040*	*2060*
US	100	107	107	107	107	107
ROW	107	109	118	132	129	134

Results are summarized for this high ethanol demand scenario in Figures 7.3.1a-7.3.1c. In addition, we solved the model assuming an ethanol production of 7.5 billion gallons, for comparison.

Exports by country/region: Results indicate substantial changes in production and exports amongst exporting countries and regions, as well as the Reaches. World exports from these countries decrease slightly, suggesting there is increased domestic production in some countries. In particular, world trade in 2020 declines from 318 mmt in our base case to 296 mmt.

Exports from the following countries increase sharply, with the change from the base to 2020 in ( ):

» Argentine corn (16 to 18.5 mmt);
» Europe and Eastern European corn (36 to 46 mmt);
» Brazil soybeans declined (25 to 23 mmt), in part due to a shift to corn in Brazil South;
» Wheat exports from Australia increase (29 mmt to 32 mmt), Europe decreases (41 to 31 mmt), US decreases from 20 to 19; and Canada increases marginally.

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[20] For comparison, ProExporter's (ProExporter 2006e) "Blue Sky" model has ethanol growing to 18.7 billion gallons by 2015-16.

Exports from the United States with high ethanol demand decline from 101 mmt in the base year to 78 mmt by 2020, vs. the base case which increased over the same period from 101 to 111 mmt. Gulf and PNW exports in 2020 with high ethanol demand decrease to 51 mmt and 15 mmt, respectively vs. base case exports of 76 mmt and 23 mmt, respectively. Most of the decline in 2020 exports is due to decreases in corn and wheat shipments. Soybeans decline to 28 mmt for the same reasons described above. Wheat exports from the United States decrease substantially.

Reach Shipments: Reach shipments change as well (Figures 7.3.1c and summarized versus the base case in Table 7.3.1). There is a slight increase through 2010. Thereafter, shipments decline to 48 mmt in 2020 and lesser values in years beyond. This contrasts with values of about 65 mmt in 2020 in the base case. The decline is greatest for corn, and then wheat.

Compared to the base case, the decline to 2010 is about -9.4 mmt, which grows to 18 mmt in 2020 and about 39 mmt in years thereafter. In 2010, the largest decline is from Reach 3, followed by Reach 2 and Reach 4. Interestingly, shipments from Reach 1 increase. In latter years, the magnitude of the decline increases and the decline from Reach 4 increases sharply. Virtually all of the decrease is in corn shipments. However, in later years, there are decreases in soybeans and wheat as land is shifted from those crops to produce corn.

Major Changes in Flows: In the high-ethanol scenario, there are changes in flows (compare results in Tables 7.3.1-7.3.2 to 7.1.5-7.1.6).

Within the United States, grain flows in 2010 change substantially. Most interesting are the drastic increase in shipment to the Eastern and Western corn belts reflecting the increase in domestic demand for ethanol use. Also of interest are changes in flows from the Northern Plains which had previously exported most of its corn through the PNW. A substantial portion of these is now shifted to domestic shipments.

There are substantial changes in flows from US production regions to the Reaches and port areas. Most important are reductions in shipments from Iowa River to Reach 2, Minnesota River to Reach 3, and Illinois North to Reach 4. There are reductions from most regions to New Orleans, but, an increase from Illinois South to New Orleans. There are also substantial reductions from Northern Plains to the PNW, declining from 14 mmt to 6 mmt.

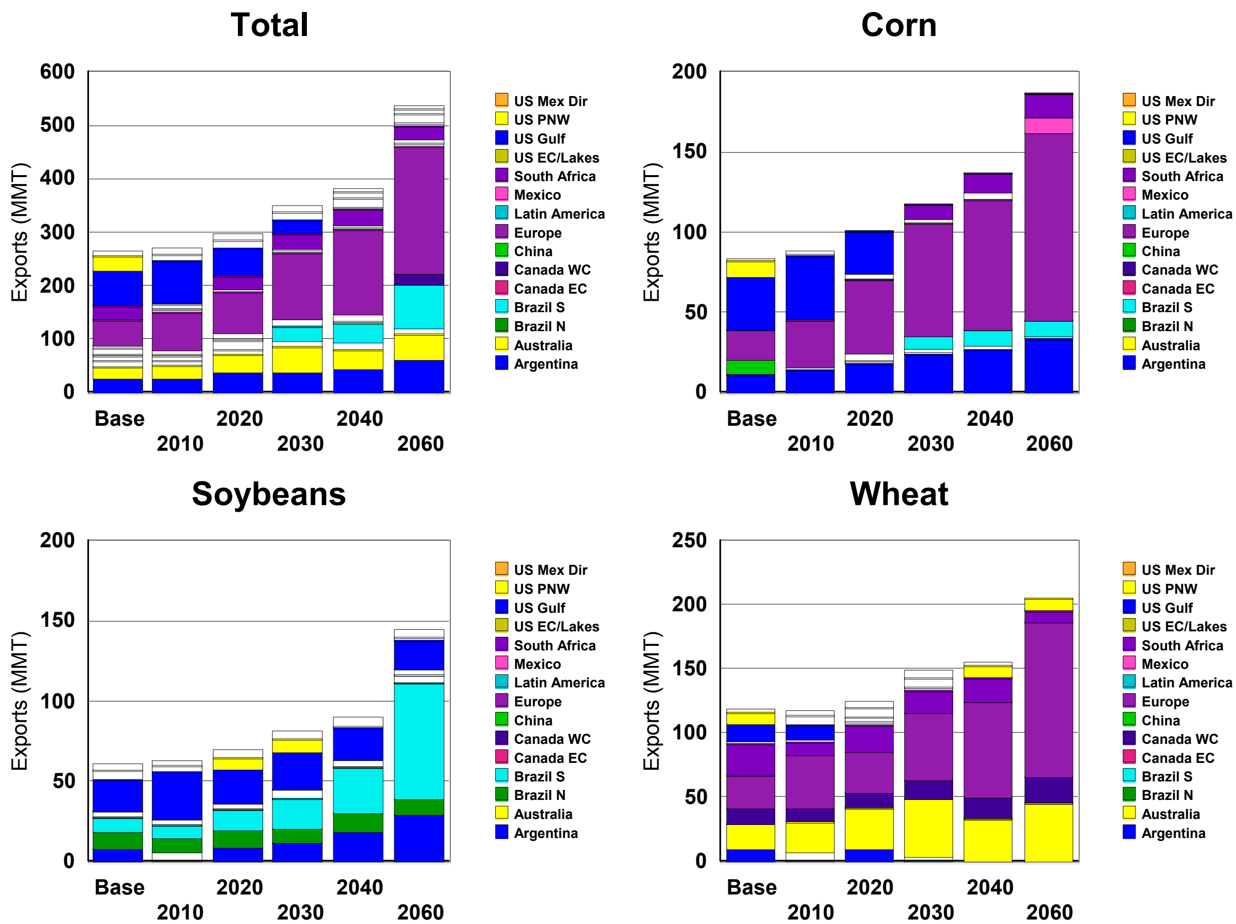

Figure 7.3.1a. High Ethanol Demand Scenario: Exports.

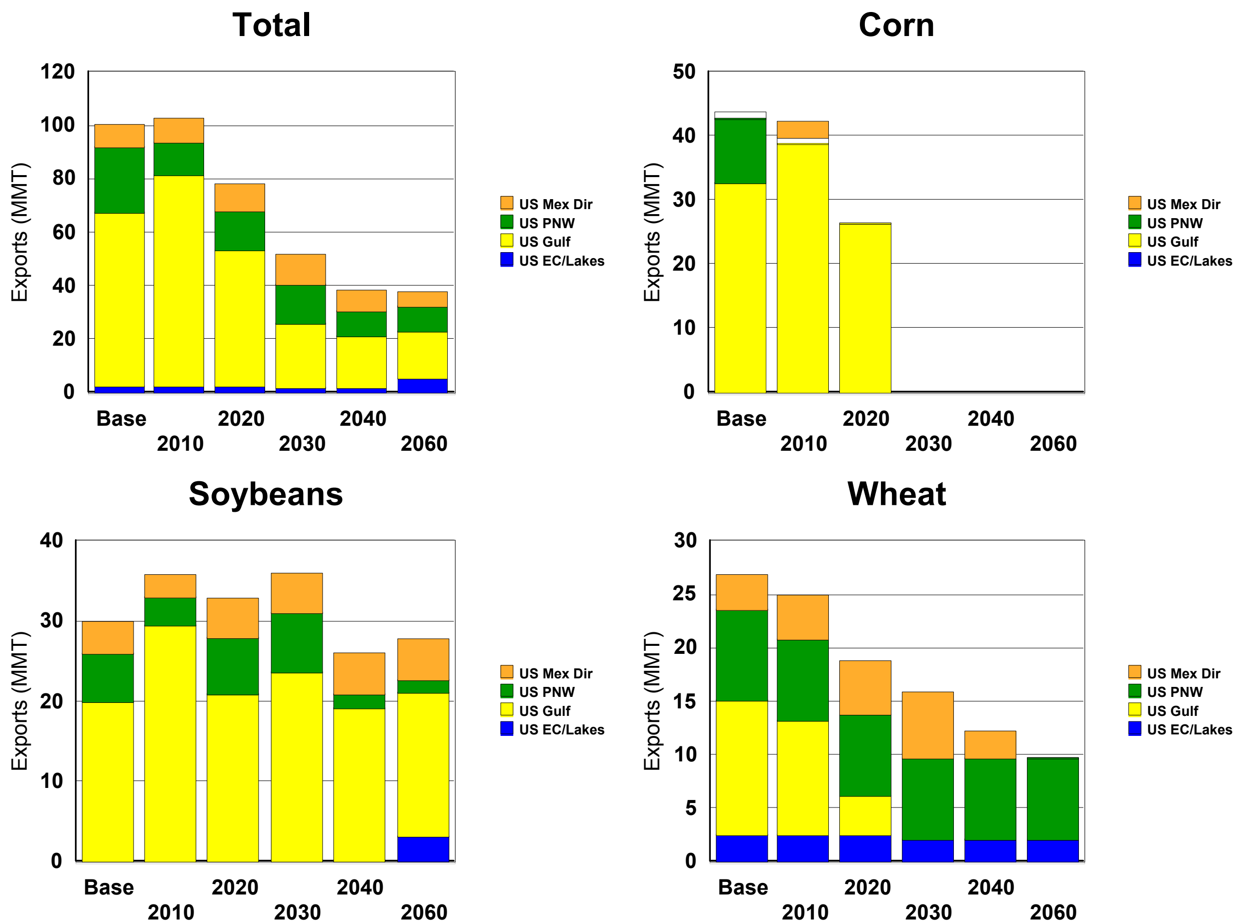

Figure 7.3.1b. High Ethanol Demand Scenario: U.S. Exports by Port Area.

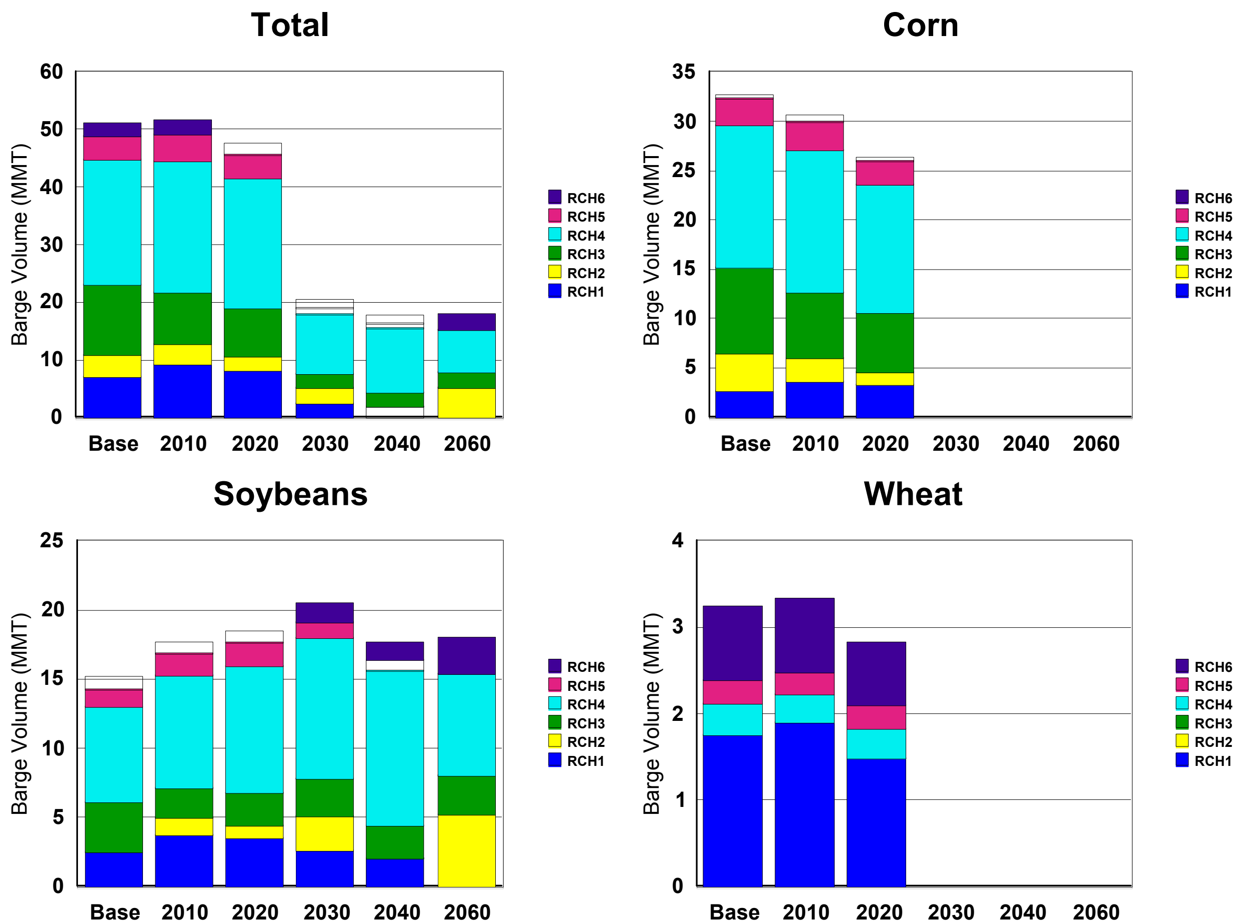

Figure 7.3.1c. High Ethanol Demand Scenario: Barge Reach Volumes.

Table 7.3.1. Change in Barge Volume (High Ethanol Demand - Current Capacity), Total and By Crop, 2010-2060.

Change in Barge Volume, 2010				
	Total	***Corn***	***Soybeans***	***Wheat***
RCH1	2,363	790	623	950
RCH2	-2,753	-2,650	-103	0
RCH3	-3,225	-3,266	41	0
RCH4	-2,490	-2,688	141	57
RCH5	-1,308	-1,349	0	41
RCH6	-2,032	-704	-702	-625
Total	-9,445	-9,867	-1	423
Change in Barge Volume, 2020				
	Total	***Corn***	***Soybeans***	***Wheat***
RCH1	1,086	9	551	526
RCH2	-4,308	-3,367	-941	0
RCH3	-3,814	-3,820	6	0
RCH4	-4,404	-5,489	1,084	1
RCH5	-2,820	-2,667	-154	1
RCH6	-3,529	-1,358	-1,082	-1,089
Total	-17,788	-16,691	-535	-561
Change in Barge Volume, 2030				
	Total	***Corn***	***Soybeans***	***Wheat***
RCH1	-4,566	-3,814	-752	0
RCH2	-3,233	-3,368	135	0
RCH3	-8,624	-8,618	-6	0
RCH4	-15,792	-17,150	1,359	0
RCH5	-5,010	-4,307	-703	0
RCH6	-2,081	-1,606	-476	0
Total	-39,305	-38,863	-442	0
Change in Barge Volume, 2040				
	Total	***Corn***	***Soybeans***	***Wheat***
RCH1	-5,324	-4,254	-1,070	0
RCH2	-6,087	-3,890	-2,196	0
RCH3	-9,538	-9,035	-503	0
RCH4	-15,548	-18,484	2,936	0
RCH5	-5,905	-4,912	-992	0
RCH6	-3,100	-2,024	-1,076	0
Total	-45,501	-42,600	-2,901	0
Change in Barge Volume, 2060				
	Total	***Corn***	***Soybeans***	***Wheat***
RCH1	-1,143	-830	-312	0
RCH2	-3,579	-5,442	1,863	0
RCH3	-9,419	-9,419	0	0
RCH4	-17,553	-19,183	1,630	0
RCH5	-5,285	-4,661	-624	0
RCH6	-2,072	-2,071	0	0
Total	-39,049	-41,606	2,556	0

Table 7.3.1. Shipments from U.S. Production Regions to U.S. Export Reaches, High Ethanol Demand in 2010 (All Crops, Rail and Truck Movements, 000 MT).

U.S. Production Regions	U.S. Export Reaches											
	RCH1	RCH2	RCH3	RCH4	RCH5	RCH6	Toledo	Duluth	East Co.	New Orleans	PNW	TX Gulf
USCP							433				660	4,660
USCPR										3,913		
USD										1,555		831
USIAR		1,152										
USILN				22,976						5,609		
USILS	1,739									6,048		
USINR					4,629							
USMN												
USMNR			8,866									
USMOR	4,408											
USMOW	2,310											
USNP								2,147			5,996	
USOH	963					2,257				2,939		
USPNW											1,798	1,843
USSE												
USSP												
USW												
USWIS		2,368										
USWIW												
USWNP											3,825	

Table 7.3.2. U.S. Shipments from Production Regions to Domestic Consumption Regions, High Ethanol Demand, 2010 (All Grains, Rail and Truck Movements, 000 MT).

U.S. Production	U.S. Consumption Regions									
Regions	USCPC	USDC	USECBC	USNEC	USNPC	USPNWC	USSEC	USSPC	USWC	USWCBC
USCP	31,405						1,685			
USCPR	13,851	5,619								2,561
USD		9,714								
USIAR										20,024
USIAW										53,591
USILN			16,783							
USILS			6,871				12,314			
USINN			28,089							
USINR			2,008							
USMI			11,228							
USMN						3,288			3,339	2,058
USMNR										5,814
USMOR			205							4
USMOW			2,333					9,610		966
USNE			828	8,989						
USNP	10		5,415		14,353			682	5,404	
USOH				3,865			11,250			
USPNW						2,257			2,065	
USSE							22,259			
USSP								12,615		
USW									2,414	
USWIS			3,350							829
USWIW			2,394							16
USWNP					269					

Summary of Ethanol Impacts: Impacts of these scenarios are summarized in Figure 7.3.1d. These include the base case, the high ethanol case which implies ethanol production of 12 billion gallons. In addition, we illustrate impacts of a 7.5 billion gallon ethanol scenario. For each, we show the total barge shipments, as well as for the individual commodities. As illustrated, in the high ethanol case, barge shipments decline sharply, eventually to the 18 mmt rage. Corn shipments by barge decrease and fall to nil by 2030. Soybean shipments by barge increase through to about 2030 and then the combination of competition from corn in the United States and off-shore increases in production results in reduced barge exports. Finally, wheat shipments by barge decline from the 3 mmt range in all cases to nil by 2030.

It is important that these are only exports by barge. As shown above in the detailed results, exports from other ports do not fall to zero, but, do suffer from similar pressures.

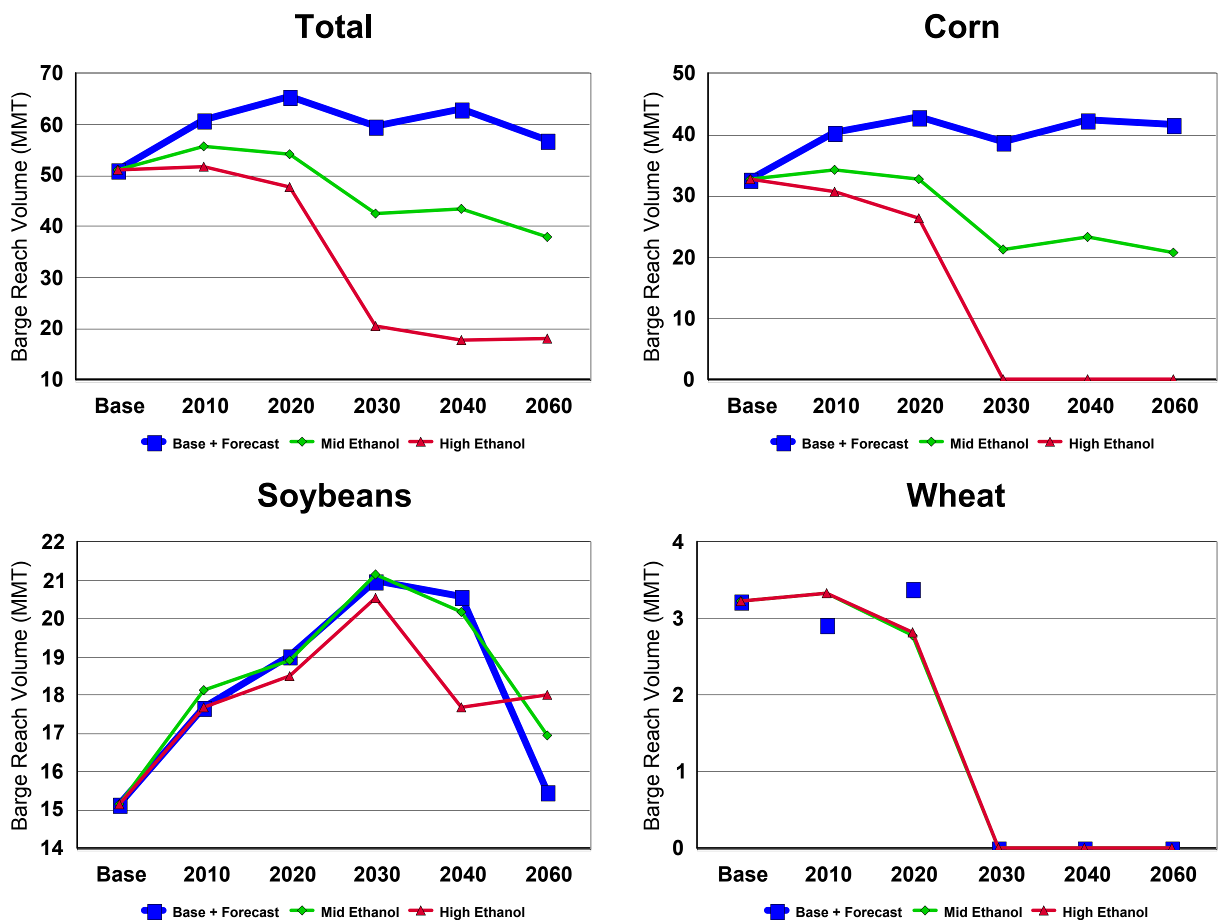

Figure 7.3.1d. Comparison of Barge Reach Volumes for Ethanol Scenarios, Base Case, Mid Ethanol and High Ethanol Demand Scenarios, by Crop and Total.

Qualifications and Stylized Assumptions On the High-ethanol Scenario: The scenario above was posed for illustration purposes, in part because of the overriding importance of ethanol in the United States grain economy and how important these developments are on the barge system. Of particular importance is that if EIA 2006 demand were to be realized, and corresponding with the spatial distribution of current ethanol plants, the model needs to make some extreme assumptions in order to get a solution. In particular, it requires expanding U.S. acres by 7% reflecting approximately land available in CRP, and, in addition, increasing area available elsewhere in the world. In this case, most of the increase ends up at what we define as Europe (including Eastern Europe). These regions of the world have some capacity for expanded area, but not as much as would be projected here. Note also that our base case has China exports at nil. If this were relaxed, China exports corn and ultimately would compete with Eastern European corn exports.

All these topics are debatable. Most important are those related to yield increases, the ability to expand area in the United States, and demand for non-ethanol corn. If corn prices increase, demands in some segments within the United States and/or off-shore would be impacted. Impacts of course, would change the potential Reach flows as generated from this scenario.

In order to evaluate the robustness of the model and the assumptions about these critical variables, we simulated the model with alternative assumptions with respect to two variables for the year 2020. These are: yields in 2020 were increased 5%;[21] area harvested as 88 million acres versus 67 million acres in our base case. This implies 97 million acres planted to corn, or 32% increase from the base. The land area for soybeans and wheat were reduced so that the maximum land for these three commodities was unchanged. However, ultimately the model chooses which crops are grown and where, so these changes reflect maximums allowed and may not be fully utilized. These are representative of some of the analysis that have been posed to assess the impacts of ethanol.[22]

These values are at the national level and were implemented in the model as proportionate changes by region. These assumptions have the impact of increasing U.S. supplies of corn. Note, these are by assumption as opposed to model solutions. Most important is that the model requires reconciling shifts in acres relative to the competing crops (corn, soybeans and wheat), in the United States as well as competitor countries.

The results of the model are compared in Figures 7.3.2a to 7.3.2.c to the results from the unrestricted high-ethanol solution for 2010 and 2020. Results from the revised assumptions are labeled as "Revised 2020." Most striking in making these comparisons are:

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[21]For perspective, the yield productivity growth rates in our data are shown in the Appendix. These values reflect longer term growth rates normally in the area of .5% per year.

[22] Technically, this results in area harvested as follows, and all values are in million acres: corn 88, soybeans 77 and wheat 44. Production is as follows with values in ( ) the base case value, and each are in million mt.: corn 367 (340), soybeans 93 (82), and wheat 53 (33).

» Total exports from the United States, increase as opposed to decreasing in our base case by 2020. Total exports are 129 mmt in 2020 and 86 mmt and 29 mmt from the US Gulf and PNW respectively;

» Corn exports from the United States increase to nearly 83 mmt, as opposed to decline to 26 mmt for the base high ethanol demand 2020. In the revised 2020 solution, corn exports also decrease from Argentina.

» Soybean exports from the United States decline to 28 mmt vs 36 mmt for the 2010. Those from Brazil increase sharply vs. our solution. In our high-ethanol solution, soybeans expand in Brazil from 23 mmt for 2020 to 32 mmt in the revised case.

» Wheat exports would increase from each of the competitors. Those from the United States decline, but, by not as much as in our unrestricted high-ethanol case.

» Finally, barge shipments increase from 48 mmt in the unrevised 2020 case to 70 mmt in the revised 2020 case. Most of the increases would be from Reaches 2-6 with the largest increases in Reaches 2 and 4. However, volume in Reach 1 would drop from 8.4 mmt in the unrevised 2020 case to 5.9 mmt in the revised case.

These are very interesting and illustrate that minor tweaking of assumptions result in fairly important changes. These are not inconsequential. In making these comparisons, there are a number of important differences:

1) The base case model also has important underlying growth in world demands for corn and soybeans that must be satisfied;

2) The ability to expand area is important. Our results suggest it would come mostly from wheat (for perspective, the assumed increase in area is approximately equivalent to 60% of the wheat area in North Dakota), CRP and/or from other minor crops not included in the model. Some could come from soybeans, but there is substantial international competitive pressures and demand for the United States to retain its soybean area;

3) These results also differ from other studies. These may appear more drastic because as we kept ethanol demand at EIA 2006 projections, and forced corn yields up and allowed for increased corn area. Hence, we had greater exports. Other studies assume an expansion of ethanol beyond the EIA 2006 projections, and then, see how many acres are necessary to support that growth.

4) Yield increases and ethanol conversion improvements are based upon assumed anticipated genetic and technological improvements, whereas those from the base solution are based on a continuation of past trends.

5) Finally, soybean competition is critical and a source of fundamental difference versus other studies. In our case, the US exports more soybeans for two reasons. One is that it is

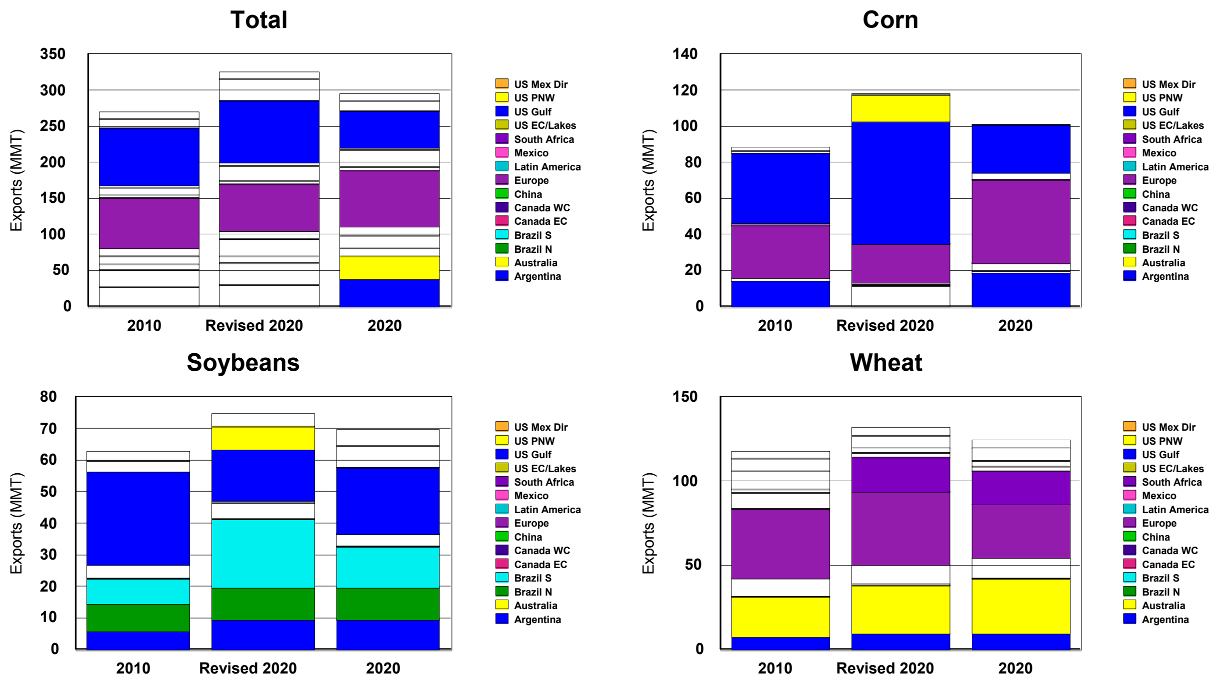

Figure 7.3.2a. Comparison of Exports by Port Area for High Ethanol 2010 and 2020 with Revised 2020 Scenario, by Crop and Total.

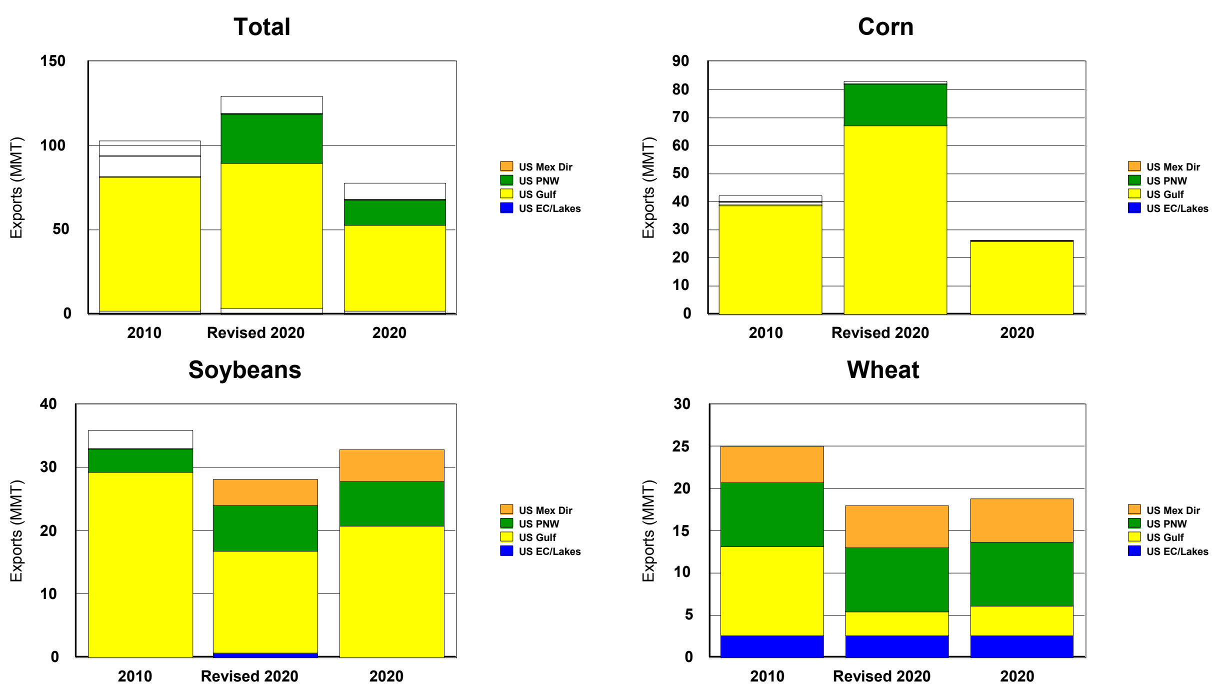

Figure 7.3.2b. Comparison of U.S. Exports by Port Area for High Ethanol 2010 and 2020 with Revised 2020 Scenario, by Crop and Total.

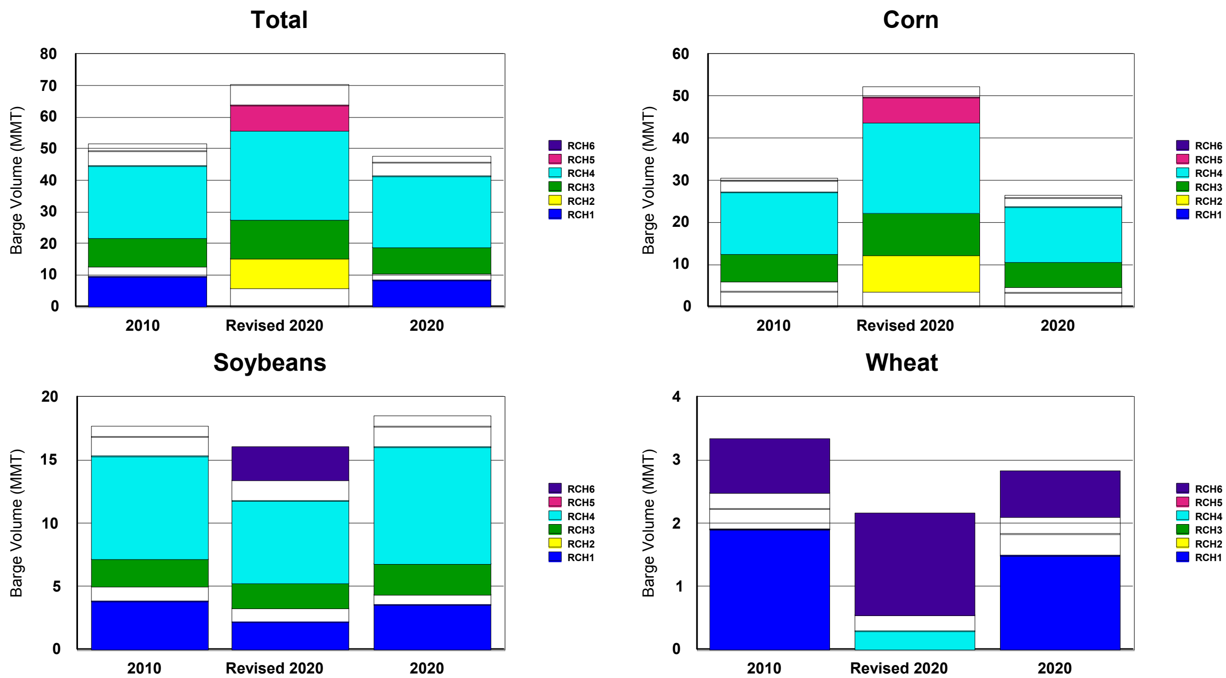

Figure 7.3.2c. Comparison of Barge Reach Volumes for High Ethanol 2010 and 2020 with Revised 2020 Scenario, by Crop and Total.

a lower cost producer than the new-areas in South America. Second, is due to the logistical costs that favor shipments from the United States to some key destinations. The impact of this is to constrain the ability to expand area planted to corn for higher-ethanol demands.

7.4 China Trade Policies: One of the most dynamic countries in the world grain market is China. This country is experiencing rapid increases in income and a large and growing population. In addition, there are changes in consumer patterns and trade policies with respect to corn export subsidies. But China is also a large producer and has potential to improve productivity substantially. In this section sensitivities were conducted to illustrate China's role in some critical policies. Two policies are simulated, each with respect to corn.

7.4.1 *China imports corn*: In this sensitivity, we ran the 2010 model assuming China imports 5 mmt of corn. Results are shown in Figure 7.4.1. These indicate that the results depend on the ethanol assumption. Under base case ethanol scenario, shipments on the barge system increase slightly (61.1 mmt to 61.2 mmt). Under a high-ethanol assumption, barge shipments decrease to 51.6 mmt.

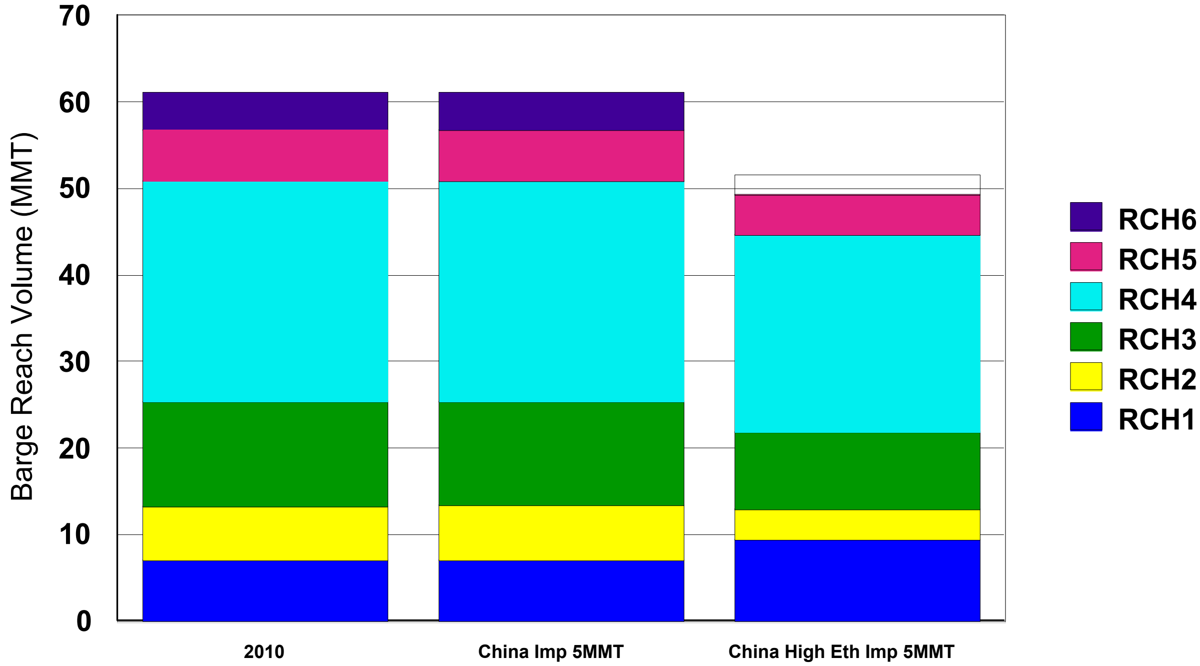

Figure 7.4.1. Sensitivity of Barge Reach Volumes in 2010 to China Corn Imports.

7.4.2 *China as a corn exporter*: The alternative would be for China to continue to export. Instead of forcing exports, the amount that would be exported would depend on its availability and cost competitiveness relative to other countries. The model was run for the projection period under base case ethanol assumptions and a high ethanol assumption. For base case ethanol assumptions the model required an increase in the maximum area in the ROW at 107%. After experimentation, at 105% the model was infeasible.

In this case, China competes with Europe in terms of exporting corn. By allowing China to export corn, their corn exports increase to 40 mmt by 2030. This is largely taken away from corn exports from Europe which increase now from 19 to 30 mmt in 2030 vs. the base case of 19 to 54 mmt. Of course other countries are impacted, but, this is the most important effect.

Total exports from the US decrease from 122 mmt in 2010 to 92 mmt in 2030, vs. the base case decline of 122 to 92 mmt. Reach shipments are also impacted but only slightly.

The high ethanol scenario was also run with China being a potential exporter in 2010 forward. To reach a solution, the following area assumptions were made:

Maximum Area Limit Relative to Projected Base Area to Achieve a Solution (%)						
	Base	*2010*	*2020*	*2030*	*2040*	*2060*
US	100	107	107	107	110	115
ROW	107	106	107	115	115	121

Under this scenario, China's exports increase more for earlier years (2010-2030) and then are similar to those in with base ethanol. Again, this largely takes away from the growth in exports from Europe and Eastern Europe. The results on Reach shipments are similar to that in the high ethanol case without China as an exporter.

7.5 Summary of major projections and policies. The above are the major projections and policy issues affecting barge shipments. Figures 7.5.1 and 7.5.2 show projections for barge shipments and area devoted to each crop in the United States.

These results show how barge shipments would vary under different scenarios. Overall the trends are the same: increase to 2010 and decline thereafter. Differences amongst these are one of magnitude. The most optimistic scenarios from a barge shipment perspective are if ethanol remains at base case values.

Figure 7.5.2 shows the shift in area devoted to these crops in the United States for each scenario. In all cases, there are shifts from wheat to corn and soybeans, and slightly from soybeans to corn. Differences are also a matter of magnitude. It is important that this is really constrained by competitive factors and that the model imposed a maximum switch amongst crops of 7% of the area devoted to that crop in the base period, as well as the necessary change in maximum area restrictions identified above.

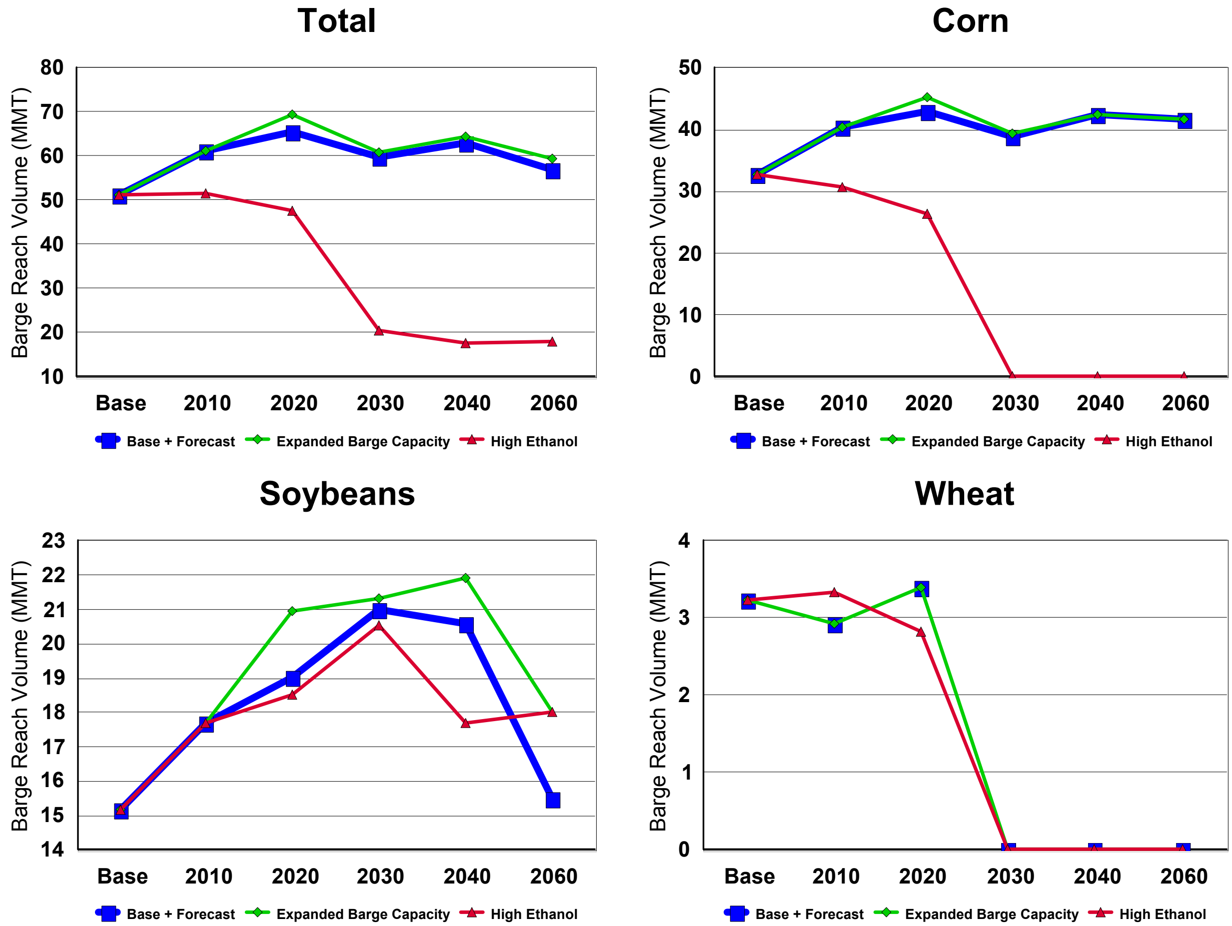

Figure 7.5.1. Barge Reach Volume, Total and By Crop for Base Case, Expanded Barge Capacity and High Ethanol Demand Scenarios.

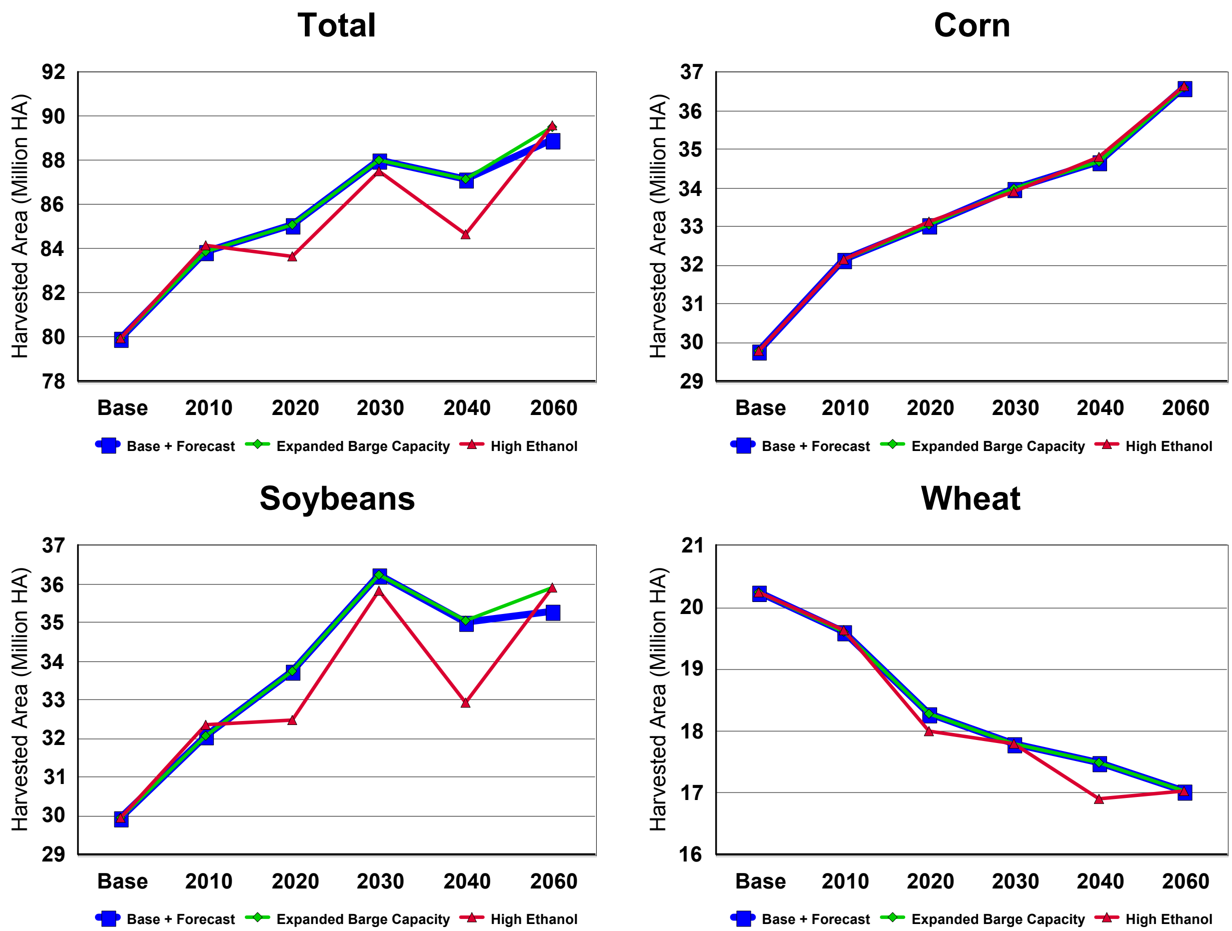

Figure 7.5.2. Comparison of U.S. Harvested Area, Total and By Crop for Base Case, Expanded Barge Capacity and High Ethanol Demand Scenarios.

7.6 Other Trade and Agricultural Policy Scenarios: The model was used to evaluate the impacts of a number of other agricultural and trade policies. These include the impacts of South America competitiveness on soybeans, the CRP program in the United States, as well as alterative macro-trade policies. These results are reported below. These are not reported as exhaustively as the projections above, but are used to illustrate the major impacts on barge demand.

7.6.1 South American competitive position. With the rapid growth in South American soybeans, two sensitivities were evaluated. One was an increase yield productivity. The other was for reduced shipping costs due to development of interior transportation infrastructure.

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 and allows it to expand subject to maximum land available. In addition, yields in both Brazil and Argentina lag those in the United States (See Table 4.9). In this simulation, we allowed these yields to increase to equal the average of those in the United States. This could occur due to more extensive adoption of GM varieties, more targeted breeding that focuses on the geography of the expanded area and due to the rapid cross-border transfer of technology.

To analyze this impact the model was run for 2010 and compared to the base case above. Yields in Brazil and Argentina were increased to average 3.03 mt/ha. This has the impact of reducing costs per mt and increasing production. Results are shown in Figure 7.6.1.

The results indicate that Brazil soybean production would increase from 58 mmt in 2010 base case to 61 mmt. Reach shipments decrease from 61.1 to 59.7 mmt, but the change in not radical. The reason for this is due to a number of factors including that the United States is lower cost producer and expands production subject to its limits.

The second major change in Brazil relates to interior transportation infrastructual investments. These are highly uncertain but as noted in Section 3.1 BR 163 was recently approved for development. It is unclear exactly how much these projects would impact interior shipping costs, nor the timing of them. Nevertheless, to evaluate their prospective impacts we ran the model in 2010 assuming reduced shipping costs from Brazil North by $5 and $10/mt.

Results suggest that decreasing internal shipping rates in Brazil North would in fact result in a very slight decrease in exports via barges. At $5 less shipping costs reach volumes declined from 61.1 mmt to 61.0 mmt and at $10 less shipping costs were only 60.8 mmt.

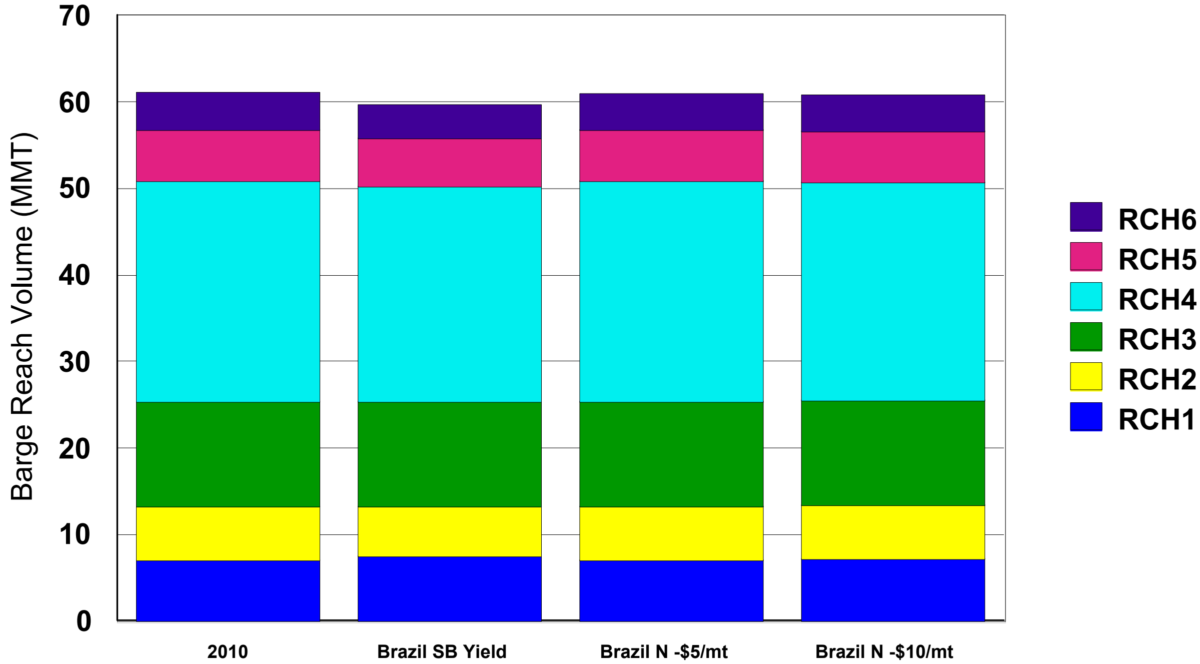

Figure 7.6.1. Sensitivity of Barge Reach Volumes to Changes in Brazil Soybean Yields and Northern Brazil Shipping Costs.

7.6.2 Conservation Reserve Program (CRP): One of the more important US policies in the near term that could impact these results is the administration of the CRP program. This is particularly true in light of the recent expansion in ethanol.

The CRP is a voluntary program to protect environmentally sensitive lands. In 1998, 18.5 million acres were put under the program. Many of these acres could be brought back into the program commencing in 2007 as illustrated in Table 7.6.2.

Currently, there are 37 million acres in the CRP program. These acres are mostly concentrated in the dry sections of the Great Plains. There are 13.7 million acres in Texas, Montana, North Dakota, Kansas and Colorado. There is some in the corn belt states, including 2 million in Iowa and 1.1 million in Illinois. Most of these acres are not up for renewal anytime soon. Of the 16 million acres coming up for renewal in 2007, 3 million acres are currently slated to expire and not re-enter the program. The bulk of these are in the plains, with expiring Iowa acreage of 114,000 and Illinois at just 70,000 acres.

Table 7.6.2. 2007 expiring CRP acres for specific crops and model base area

	2007 CRP	%
Corn	1.9	0.03
Soybeans	2.6	0.04
Wheat	9.3	0.19
Total	13.8	0.07

* CRP area adopted from Hart (2006a).

These values represent 7 percent of the land in the model's base period. If prices are strong during the expiration period, it may result in a portion of these being returned to production. Hart (2006a) indicated that USDA has been notifying producers on their eligibility to extend current CRP acres or to re-enroll under a 10-15 year contract; and, that USDA has opened a general CRP sign up for the spring of 2006. This implies that there are 13.8 mill acres in corn, wheat, soybeans that expire in 2007. In early June 2006 USDA announced it had re-enrolled or extended all 2007 expiring CRP contracts except those involving voluntarily withdrawals. These contracts covered 13 million acres that were previously scheduled to expire on Sept 2007 (NGFA 2006). USDA indicated there were 12 million acres scheduled to expire between 2008 -2010.

During late 2006 there was discussion that USDA would announce a more meaningful shift in the CRP system this winter that will have a big impact over the coming decade (as reported by Mann Global Research, 2006a, amongst others). There was an idea that USDA would enact policies to substantially increase US corn planting, beginning in 2007, and then expanding dramatically over the coming decade. While this will presumably be a several point plan, the crux will center around a racheting back in CRP acreage, and a corresponding shift into grain and oilseeds crops. This was subsequently suggested by Secretary of Agriculture Johanns as baseless, but, it remains hotly debated (Tomson).

To assess the importance of this, the model was used to evaluate these impacts. Results are not repeated here since a maintained assumption was that the maximum area would increase by 7% the acres commencing with the 2010 projection. The result of our base case projections implies a return of these acres to production. As noted above, if these were not, the implication would result in competitor countries expanding their area.

To explore this further, the model was run for 2020 assuming an additional 7% increase in area available for planting where this 7% was allocated based on the distribution of CRP acres by production region. The results are show in Figure 7.6.2 and illustrate that if this were to occur, the amount shipped by barge would increase by about 5 mmt. Most of the increase would be in Reaches 2, 4, 5 and 6.

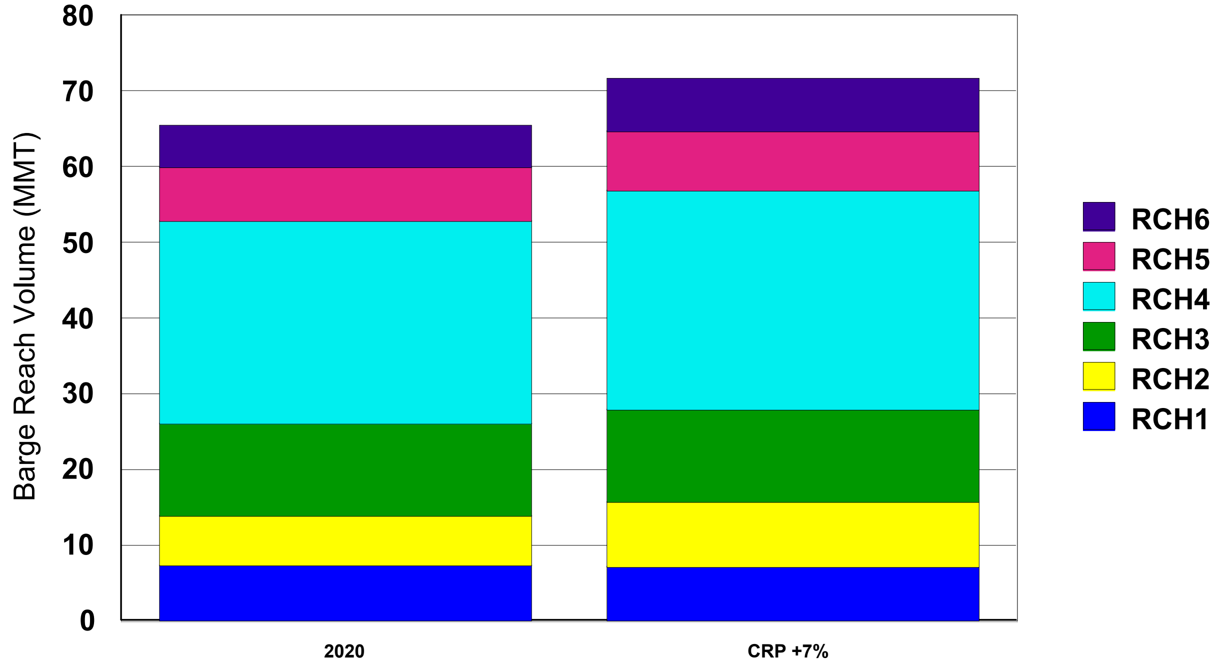

Figure 7.6.2. Effect on Barge Loadings of Increased Production Area in U.S. from CRP (7%), based on Regional Adoption of CRP.

7.6.3 Increase in the Rate of Switching Among Commodities: The base case had a maintained assumption that the maximum area that could be shift in plantings among the commodities was 7%. This was applied to individual regions and based on historical observations. This as potentially an important impact on barge shipments. To analyze this we relaxed the assumption and illustrate its impact on the 2010 solution. Figure 7.6.3 shows barge shipments under different values of this parameter, ranging from 12 to 20%. The result illustrates that increasing the rate of switching to 12% drops total barge volume from 61 to 60 mmt, but increases from 12% to 15-20% does not have a huge impact on the results.

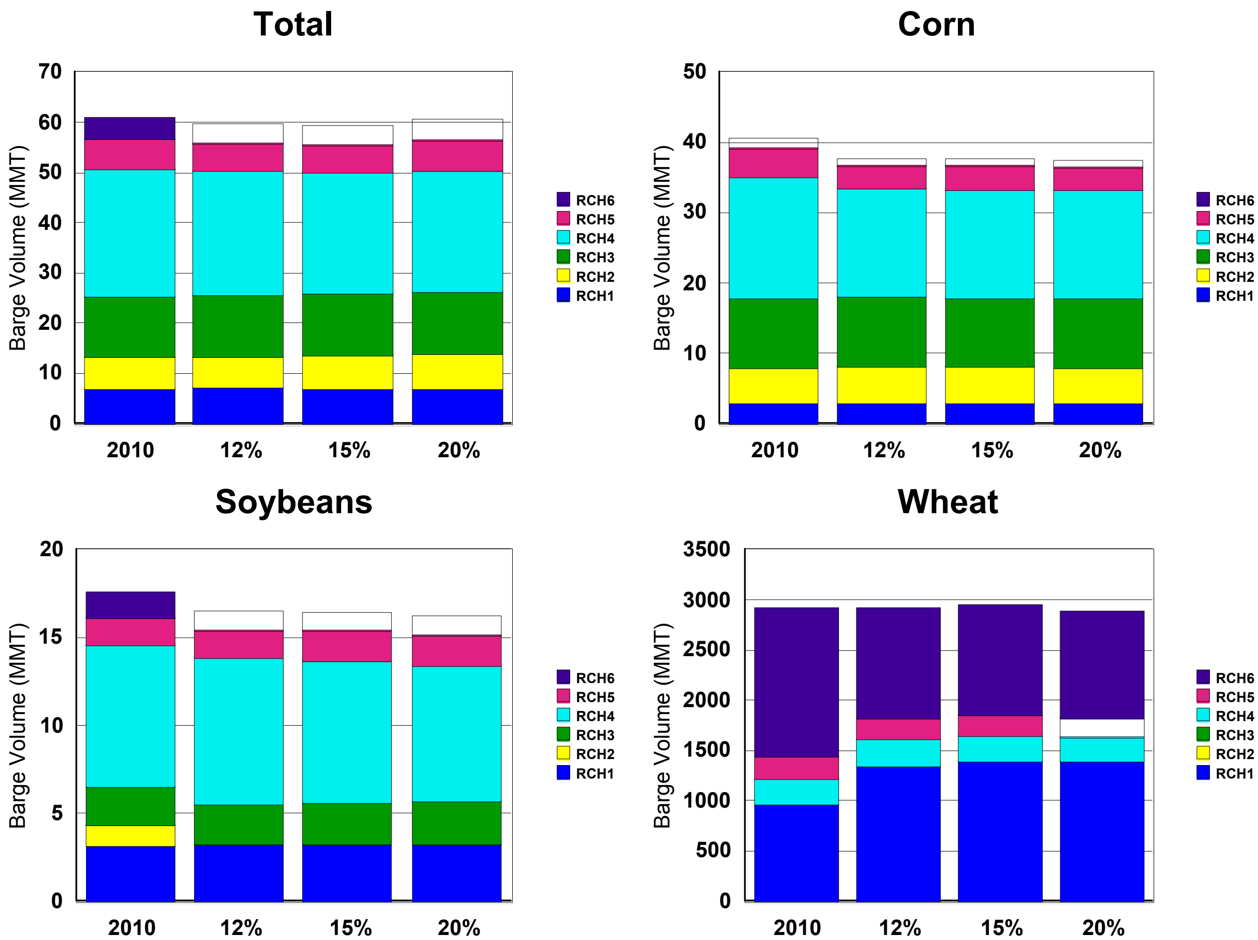

Figure 7.6.3. Sensitivity of Barge Reach Shipments to Crop Switching Rate (%).

7.6.4 *Free Trade*: The base case model assumed that production and export subsidies and import tariffs were equal to the values that existed in the base period. 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. 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 Figure 7.6.4. Results illustrate that under free trade with no subsidies, barge shipments would be unchanged.

7.6.5 *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. Differences in these costs across regions are important. To illustrate the impacts of production costs, the projections were also estimated assuming production costs were nil. This was done for the base case. The results are a model in which trade flows are determined nearly completely by shipping costs.

Results are shown in Figure 7.6.4. Under a zero production cost scenario, barge shipments by Reach would increase not change.

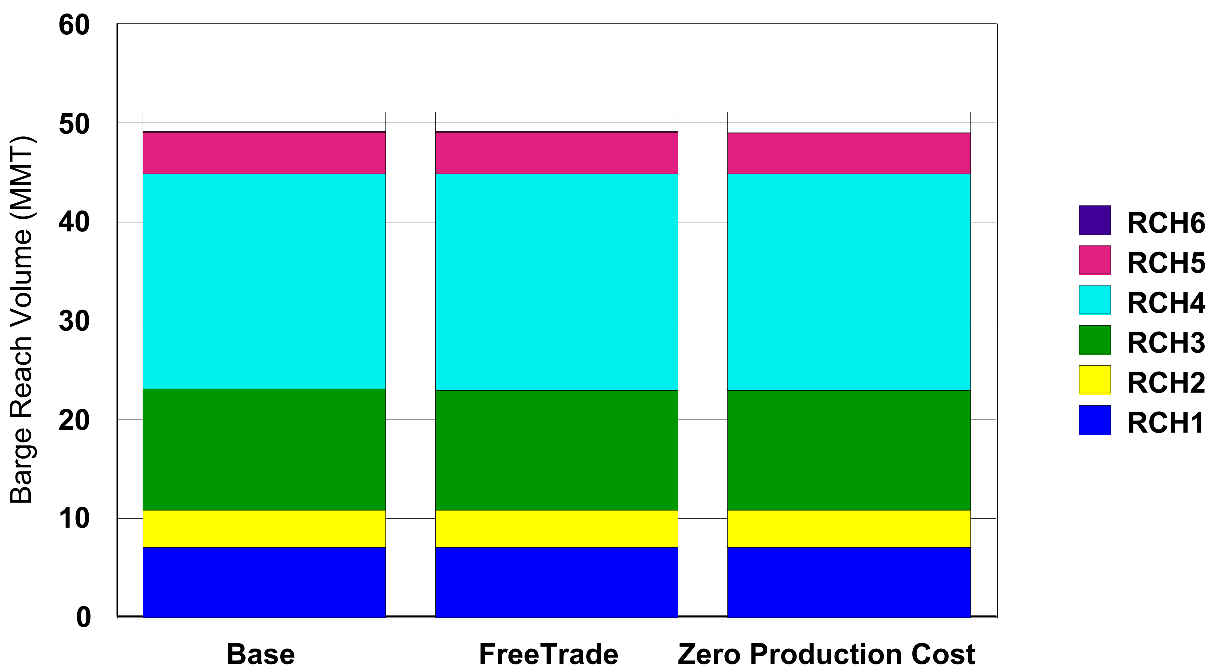

Figure 7.6.4 Sensitivity of Barge Reach Volumes for Free Trade and Nil Production Costs.

7.7 Logistical System Scenarios A multitude of issues concern the barge system. Sensisitivies were conducted with respect to a some of these and compared to base case results (as identified below as appropriate).

7.7.1 Barge demand functions: The model was used to trace out a synthetic demand function for barges. These allow for numerous adjustments in the model, including modal shifts, spatial shifts in shipments, spatial shifts in area planted and shifts in shipment patterns, both internationally and domestically. Thus, these should be interpreted as the longer-term elasticity for barge shipping.

To illustrate this effect, barge rates were increased by 20% to 200%.[23] See Figure 7.7.1. Results indicate the extent of the reduction in total barge shipments as rates increase. Increasing barge rates decreases barge demand, but has a differential impact on Reach shipments. In particular, an increase in barge rates by 20% reduces total barge shipments by 5%. Reductions occur in each of Reaches 2-6, with the largest reduction in Reach 6 (-16%). Interestingly, there are slight increases in shipments from Reach 1.

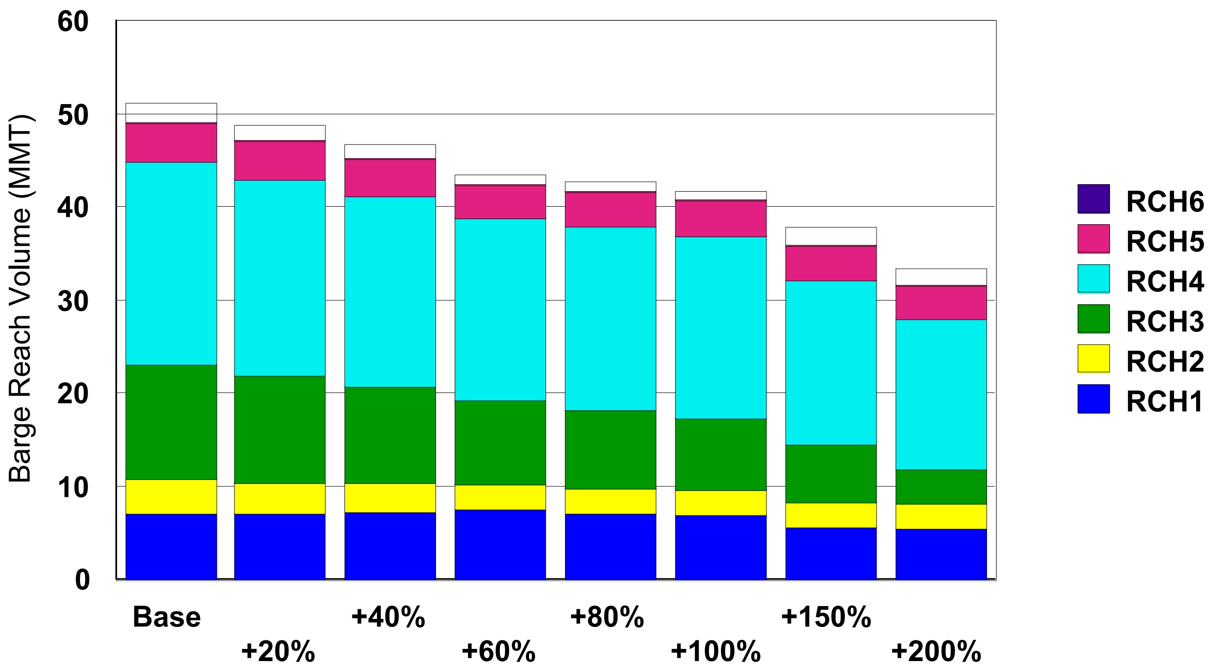

Figure 7.7.1. Sensitivity of Barge Reach Volumes to Increase in Barge Rates, by Reach.

[23]Effectively and equivalently, this was done by shifting the intercept of the barge supply functions.

This is the longer-term demand relationship 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. The derived arc elasticities for the total system are -.23 and -.22 for 20% and 40% increases in barge rates. These are much less than some of the previous studies. However, the elasticity varies by Reach. For a 20% increase in rates, elasticities for shipments on Reach 2, 3, and 4 are -0.67, -0.28 and -0.16 respectively, and for a 40% increase in rates are -0.48, -0.36 and -0.15 respectively. Thus, there is substantial inter-Reach substitution as barge rates change.

7.7.2 *Rail restrictions* The model was specified to include a rail capacity restriction. Capacity could be due to either having enough cars, track space, crew or locomotives, or some combination thereof.[24]

The base case assumed rail capacity at the maximum of the observed shipments during the base period. Such a restriction impacts the ability of rail to compete with barges, even though in some cases rail rates are less. In fact, this is a very critical variable, particularly in light of some of the rate relations illustrated above, and, that there has been a general increase in rail capacity over time.

As example, a recent *Grain Journal* survey indicated that each of the major railroads (Burlington Northern Sante-Fe, Canadian Pacific Rail, Dakota, Missouri and Eastern, Norfolk Southern and the Union Pacific) were expanding their grain car fleets and/or locomotives. The BNSF in particular indicated "Right now, we're the only railroad that continues to add aggressively to its agricultural fleet....This year, we'll add another 2,500 cars." This is in addition to an expansion in use of shuttle trains which has the impact of increasing grain shipping capacity.

To evaluate the impact of this restriction on barge flows, the model was solved assuming rail capacity at the equivalent of 131 mmt up to 201 mmt to evaluate how expanded rail capacity would impact shipments through the barge system. Results are shown in Figure 7.7.2. Increases in rail capacity have an inverse impact on barge shipments. Notably, increases in rail capacity, holding rates and everything else constant, reduces equilibrium barge shipments. However, this effect is not very substantive until capacity reaches about 161 mmt. Increases beyond this level reduce barge shipments. The results are important, particularly as rail capacity has been increasing during the past decade, as well as car turnaround which effectively increases capacity.

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[24] The base case was specified with a restriction on rail capacity. However, this should be strictly interpreted as a short-run capacity restriction. It is not inconsequential to define longer-term rail capacity. Upon further investigation it is not apparent how to quantify rail grain hauling capacity considering impacts of alternative movement types (e.g., shuttles) as well as the componsion of domestic vs. export traffice, each of which impact cylce times. Several data series that could be suggestive of capacity (e.g., AAR, USDA-AMS, etc, as well as selected statistics from individual railroads). However, none of these could be strictly interpreted as a longer term capacity. As example, car loadings is an observiaton of equilibrium shipments, not capacity.

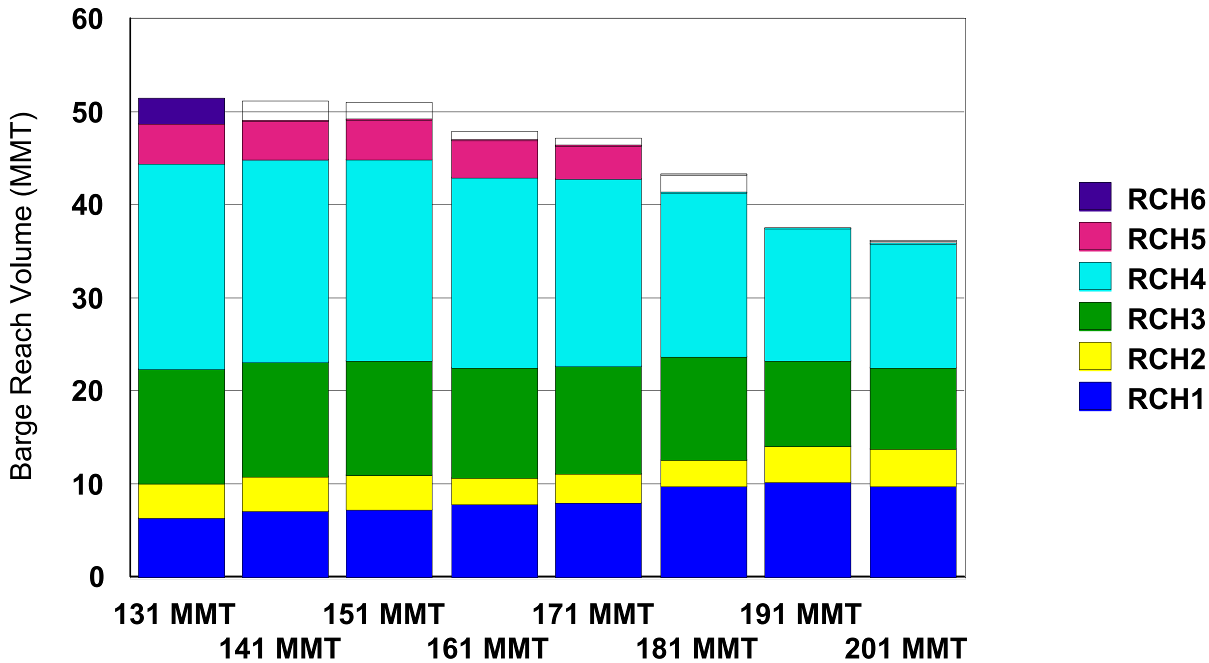

Figure 7.7.2. Sensitivity of Barge Reach Volumes to Changes in U.S. Rail Capacity.

7.7.3. Impact of ocean rate spreads on barge shipments: An important factor impacting barge demand is the ocean spread going to Asia for shipments from the US Gulf versus the PNW. The base case reflects values during the 2000-2004 period. Sensitivities were conducted to evaluate how changes in the spread impacts demand for 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 2000-2004 values and highly reflective of ocean shipping differentials at that time, and historical values to that time.

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. The model was run for the 2010 Base case scenario.

The results are shown in Figure 7.7.3. These differentials impact the level and composition of barge shipments. Barge shipments decline when the differential increases, and those shipments are shifted to the PNW. This impact is not very apparent until the differential increases to $15/mt. The biggest reductions are for shipments from Reach 2, 3 and 6. In total, at a $15/mt ocean rate differential barge shipments decline from 61 mmt in our base case to 59 mmt; and at $20/mt ocean rate differential, barge shipments decline to 54 mmt.

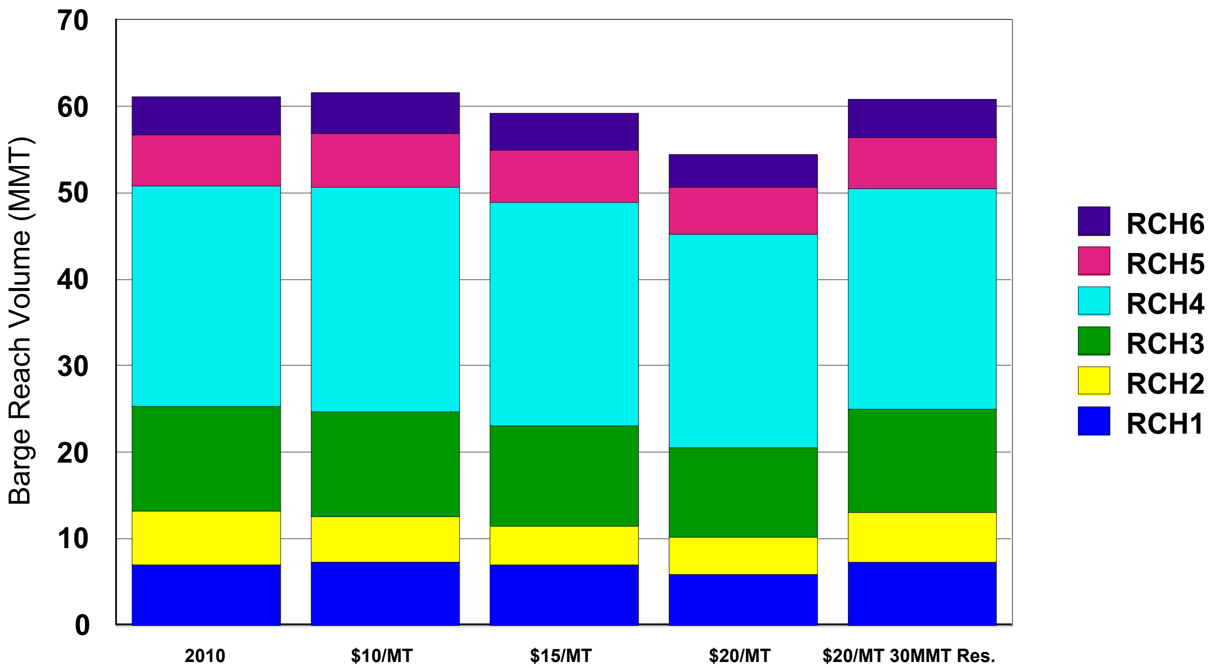

Figure 7.7.3. Sensitivity of Barge Reach Volumes to Changes in U.S. Gulf-PNW Spreads.

The reduction in barge shipments is absorbed mostly by increased shipments through the PNW. However, the above simulations did not impose any form of restriction on PNW handling capacity which in recent years appears to be about 30-40 mmt. With unrestricted PNW handling capacity, PNW exports increase to 55 mmt at a $20/mt differential. If capacity at the PNW were restricted to 30 mmt with a $20/mt differential, PNW shipments are 30 mmt and those on barges is just over 61 mmt (Figure 7.7.3).

7.7.4 *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; Martinez) and the decision is expected to be made in late 2006 following a referendum. If approved, it would cost $5.2 billion, take 10 years or so to finish and result in both an expanded capacity for transits, as well as to allow for larger ships (Admin, 2005). 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.

There are likely 3 important impacts of the Panama Canal expansion. The impacts of these can be inferred for illustrations. One is for an increase in tolls by $1/mt for construction period (expected to be about 10 years).[25] The second is that an expanded canal would allow for Panamax vessels to be more fully loaded out of the US Gulf (comparable to the PNW). The impact of this is to increase the volume in a ship by about 6000 mt beginning in year 10 which would reduce shipping cost by about $4/mt net of the toll impact.[26] Each of these impacts was assumed in this sensitivity. The third impact may be for the adoption of larger vessels. This impact is highly speculative and would otherwise impact all ports and thus, was not included in the sensitivity.

To explore these prospective issues, the model imposed the above on the ocean shipping relationships. Specifically, ocean shipping costs through the Canal were reduced by 4 $/mt. Results are in Figure 7.7.4. These results suggest that an expansion of the Panama Canal would result in a minor increase in shipments through the barge system. Most of the increase would be from Reaches 2, 4, 5 and 6. Specifically, these change would result in an increase shipment through the Reaches from 61.1 mmt to 61.6 mmt.

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[25] On June 26, 2006, the president of Panama asked lawmakers to consider a bill calling for a referendum on expanding the Canal. On October 22, 2006 Panama voted in a national election to support the expansion of the Canal (*Fortune*, 2006, p. 52). The plan would cost $5.25 billion and would widen canal from 2 to 3 lanes, double its capacity, and allow larger ships to transit. It is expected to be done by 2015.

Interestingly, just about concurrently, the Government of Nicaragua announced their intention to build a $20 billion canal linking the Pacific and the Atlantic oceans to accommodate ships too large to use the Panama Canal (as reported in Brennan, 2006). This canal would have a deeper draft than the Panama Canal. It would use a 60 mile wide Lake Nicaragua and follow part of the route initially proposed in the 19th century. This had been studied for 6-7 years and would take 10 years to build. Representatives of the Panama Canal indicated there was insufficient ship traffic to support both a widened Panama Canal and a Canal through Nicaragua.

The Panama project suggested the expansion would be financed through toll increases during the construction period to finance the project. It is not clear of the value of this, so we used the values above for illustration.

[26] This value was derived using empirical data and an economic engineering model of ocean shipping costs.

Figure 7.7.4. Sensitivity of Barge Reach Volumes for 2010 and with Panama Toll Adjustment.

8. Stochastic Analysis of World Grain Trade

8.1 Model Specification The deterministic model was converted to a stochastic optimization model. The purpose is to capture relevant sources of uncertainty and derive impacts of these on barges shipments.

The model was specified as a chance-constrained specification which accounts for right-hand side uncertainty (Charnes and Cooper 1959).[27] In this model, forecast variances are inputs to the model specification. The specification assumes the decision maker is willing to allow constraint violations with some specified probability, α. The model constraints are written as, for example, Prob(total shipments $\geq$import demand) $\geq \alpha$. Treating the stochastic elements as a chance constraint has the effect of converting this to a deterministic model.[28] Thus, variability in the stochastic elements of the problem can be interpreted by examining the impacts of α on barge demand.

The value and role of α is important. Technically, it is the probability of meeting demands, i.e., of there being adequate transport capacity and grain production (which are tied to each other since transport is a derived demand from production and consumption) to meet all demands. A value of α=1.0 means that production and shipping capacity are required to meet demands 100% of the time. At a value of α=.5, demands would be met a minimum of 50% of the time, i.e., 50% of the time there is a possible shortage either due to production or shipping capacity. Thus, a value of α=1.0 is extremely conservative. A value of α=.5 is a looser requirement and less demanding. Results with a value of α>.5 are more conservative than the deterministic model. The deterministic model is roughly the equivalent of the stochastic model with $\alpha = 0.5$, i.e., demands are satisfied with confidence 50%. Finally, values of α<.5 are used to assess substantially reduced certainty requirement of meeting demands.

A chance constraint can be specified if the distribution of import demand is known and integratable. 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 objective function is specified as the sum of expected production, transportation and

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[27]The appendix (Section 10) describes this model in detail.

[28]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.

Early in the model development stage it was decided to model barge delays was through a cost rather than as a constraint. Specifically, the implicit cost of added delay was derived and added to the cost in the objective function. Barge capacity was not interpreted as a constraint, but, rather a cost. And, as expected, expansion results in a reduced delay cost.

delay costs. Model constraints include satisfaction of demands, acreage limits and that exports are 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. Shipping by barge is 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.

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 consumption and yield were characterized by their respective variance/covariance matrixes.

Modal rates were specified as a group of econometrically specified functions. Ocean rates which were related to distance, origin and destination dummies, fuel costs and trend. Barge rates which were related to volumes and these relationships varied across Reaches. Domestic rail rate functions were estimated separately for each crop, and related to distance, distance to barges and trend. Export rail rates, estimated for each crop, were related to distance, distance to barge, Reach origins and port dummies, as well as trend. Each was estimated separately to accommodate the data and other restrictions.[29]

Finally, the role of modal productivity is important. In the case of rail shipping, time trend for rates (specified as a log-linear variable) is significant and negative. The implication of this is that there have been productivity increases in rail shipments over time, which have resulted in reduced rail shipping costs. This has not occurred in barges. As this is extrapolated forward, it results in continued reductions in rail rates, albeit at reduced rates of decline.

The model is similar to the deterministic model, but there are several differences. One is the treatment of rail rates. In this case we used regression functions whereas the deterministic model used means and rates were generated for each origin-destination combination. Second, here there were no restrictions on China imports or exports. The restriction on wheat marketing to reflect quality demands were similar. The results below had the same maximum area restrictions (Table 8.1.1). Specifically, the ROW had a maximum area of 108.5% of the recent 3 year average, that for the US in 2004 was 100%, and in 2010 and 2020 this was changed to 107% for both the US and ROW. Finally, the model allowed for a 12% change in area planted to each crop in 2010 and 2020, similar to the deterministic model (Table 8.1.1).

The results are not expected to be the same as those from the deterministic model for a number of reasons. These include the differences above. In addition, and most important is the role of α. If the model and data were exactly the same, the results should be comparable at the

[29] In particular, the rate functions for each mode were estimated from pooled data, but the dimensions varied. Joint estimation requires some type of a priori restrictions on the pooling which was thought to be more onerous than the efficiency gains from joint estimation.

α=.5. For calibration purposes, we estimated the model and compared it to the base case deterministic model described above (assuming α=.5). For purposes of illustration below, we show the results assuming α=.9 and then conduct sensitivities on the impact of α.

Table 8.1.1 Maximum Area Restrictions and Deviation for Base Allocation by Year for U.S. and ROW.

Maximum Area as % of Base Area						
	2005	2010	2020	2030	2040	2060
US	100	107	107	120	120	125
ROW	108.5	107	107	120	120	125
Maximum deviation from Base Allocation Percentages						
	2005	2010	2020	2030	2040	2060
US	0	12	12	20	20	25
ROW	0	12	12	20	20	25

The model was used to evaluate the base case, and make projections with and without expanded barge capacity and to evaluate the high-ethanol case

8.2 Base Case Calibration and Projections With Existing Capacity

The base case period calibrated well with respect to observed shipments. A summary of these are in Table 8.2.1-8.2.2 for barge reach volumes and exports by port area.

Table 8.2.1 Comparison of Historical and Stochastic Base Case Barge Reach Volumes by Reach and Crop.

	Total	Corn	Soybeans	Wheat
Historical Average (2000-2004)				
RCH1	7,909	4,144	2,227	1,538
RCH2	10,626	7,483	3,007	136
RCH3	7,450	5,384	1,680	386
RCH4	14,609	10,853	3,557	199
RCH5	4,170	2,758	982	430
RCH6	2,317	1,214	985	118
Total	47,081	31,836	12,438	2,807
Stochastic Model Base Case (Alpha=0.9)				
RCH1	6,942	2,270	3,667	1,006
RCH2	3,256	0	3,256	0
RCH3	11,426	11,426	0	0
RCH4	16,895	12,119	4,412	364
RCH5	1,559	0	1,283	276
RCH6	1,925	0	1,925	0
Total	42,003	25,814	14,543	1,646

Table 8.2.2. Comparison of Historical Exports by Port Area and Crop With Stochastic Base Case Values.

	Total	Corn	Soybeans	Wheat
Historical Average (2000-2004)				
EC	5,960	1,507	2,049	2,405
Gulf	67,774	33,952	19,908	13,915
PNW	20,663	6,521	3,749	10,393
Internal	4,426	1,878	1,991	557
Total	98,823	43,858	27,969	27,269
Stochastic Model Base Case (Alpha=0.9)				
EC	4,000	0	587	3,413
Gulf	50,818	25,814	15,385	6,920
PNW	32,746	15,969	9,688	7,089
Internal	8,511	915	4,085	3,511
Total	96,075	42,698	29,745	23,633

The results calibrated very well. Results approximately reflect US exports in total, by crop and by port area. The one exception is that in this case, the model generates slightly larger volumes through the PNW ports. The reason for this is largely that the rail rate functions result in lower rail rates for longer rail movements and if adjusted for shuttle rates would only reduce these further. To deal with this we did not adjust rail rate functions for shipment to the PNW to reflect shuttle rates in the stochastic model. Finally, Reach flows are captured with model results of 42 mmt vs 47 mmt during the base period. And, in contrast to the deterministic model, the deviations on Reach 4 were not as great.

The projections are summarized in Figures 8.2.1-8.2.4. For the base year, world trade in these grains is about 268 mmt (at α=.9) and US exports are 96 mmt, growing to 113 mmt in 2010 and declining to 77 mmt in 2060. Barge traffic is 42 mmt, increases to 64 mmt in 2030 and then declines. Barge shipments are concentrated in Reach 4, followed by Reach 3, 1 and 2.

Demand must be satisfied with 90% confidence i.e., 90% of the time. Also, forecast variability increases over time (see below). The stochastic model was estimated with confidence levels of 0.0 to 1.0 in increments of 0.1 and results are used to illustrate differences attributable to α. The base case assumes α= 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 lower.

Sensitivities with respect to α was conducted (Figures 8.2.3-8.2.4). Results illustrate how changes in α impacts barge demand. An increase in α results in an increase in barge shipments. By 2010, increases in α have a greater impact on Reach 1 and Reach 4 shipments. These results in part suggest that barge shipments vary with respect to the choice of α. This is particularly true for α>.5 vs, α<.5. For most values of α>.5 barge shipments are relatively stable. This is due to low variability of total world demand. This implies that increases in certainty of meeting demands to not have a drastic impact on barge shipments. Given that exports vary little with α, it follows that barge traffic should be relatively stable.

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. For illustration we allowed this to increase to 20%. In other words, area planted could shift between crops in all countries by 20% from the base period, 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 corn, and 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.

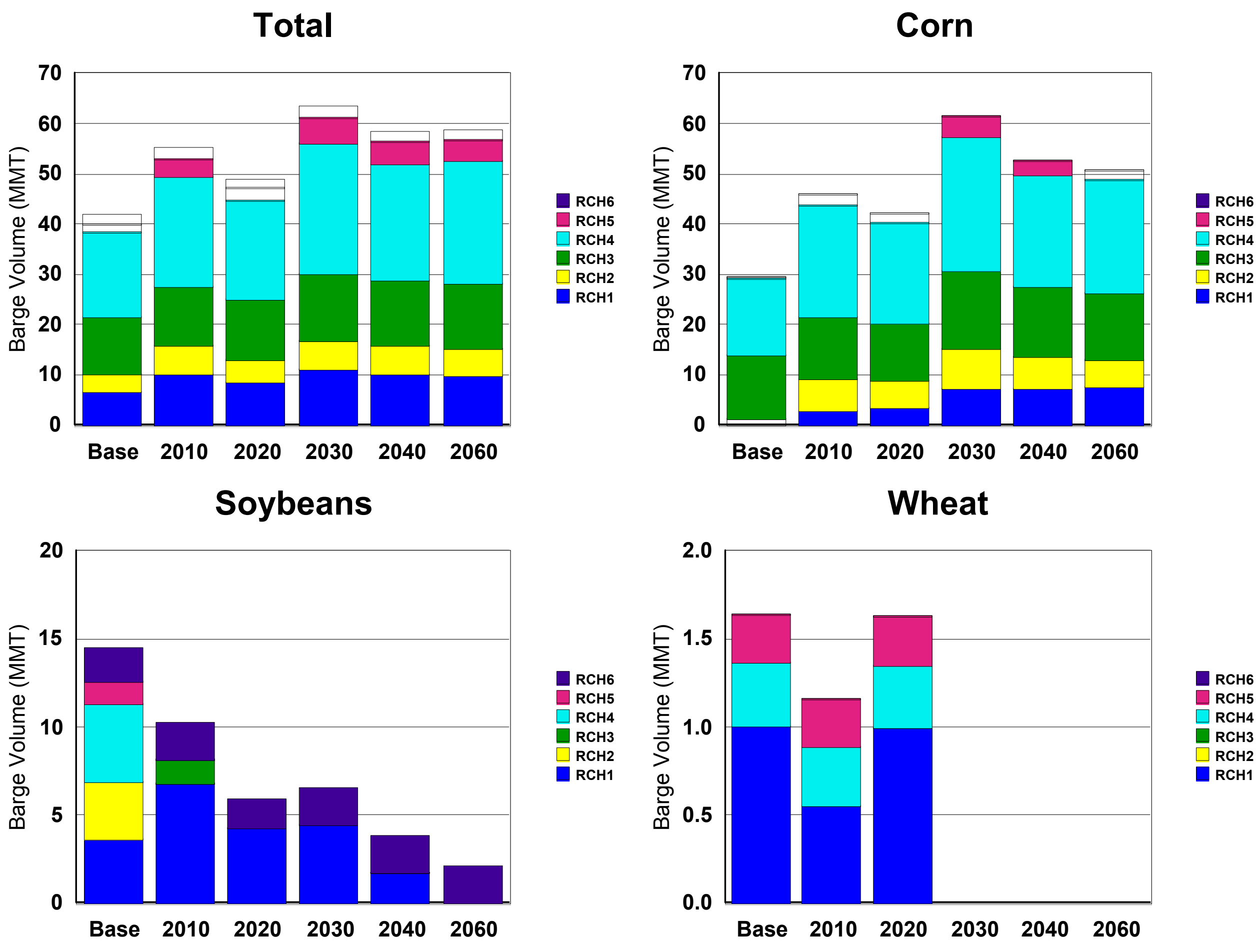

Figure 8.2.1. Base Case Projections: Barge Reach Volumes, Current Capacity, Alpha=0.9.

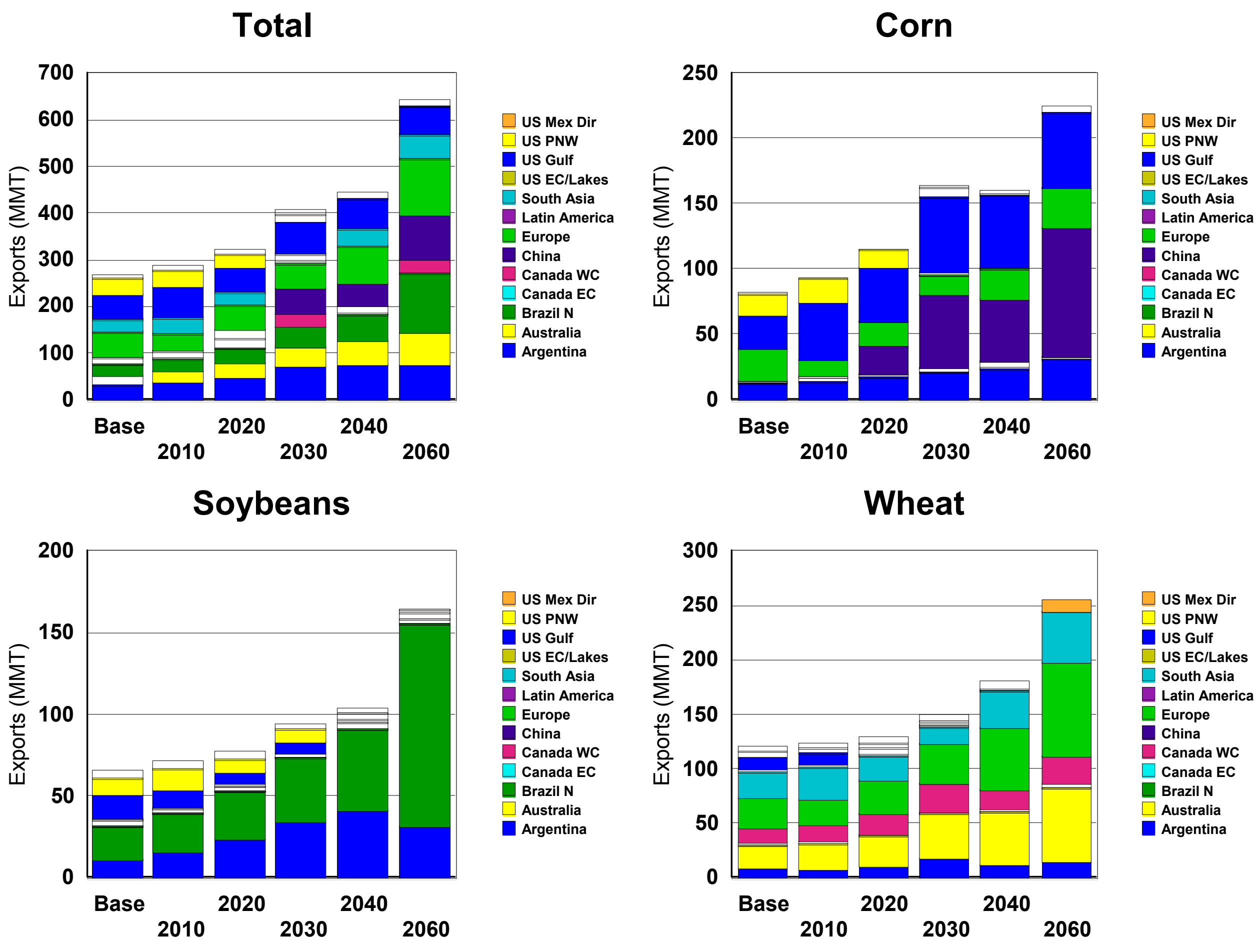

Figure 8.2.2. Base Case Projections: Exports, Current Capacity, Alpha=0.9.

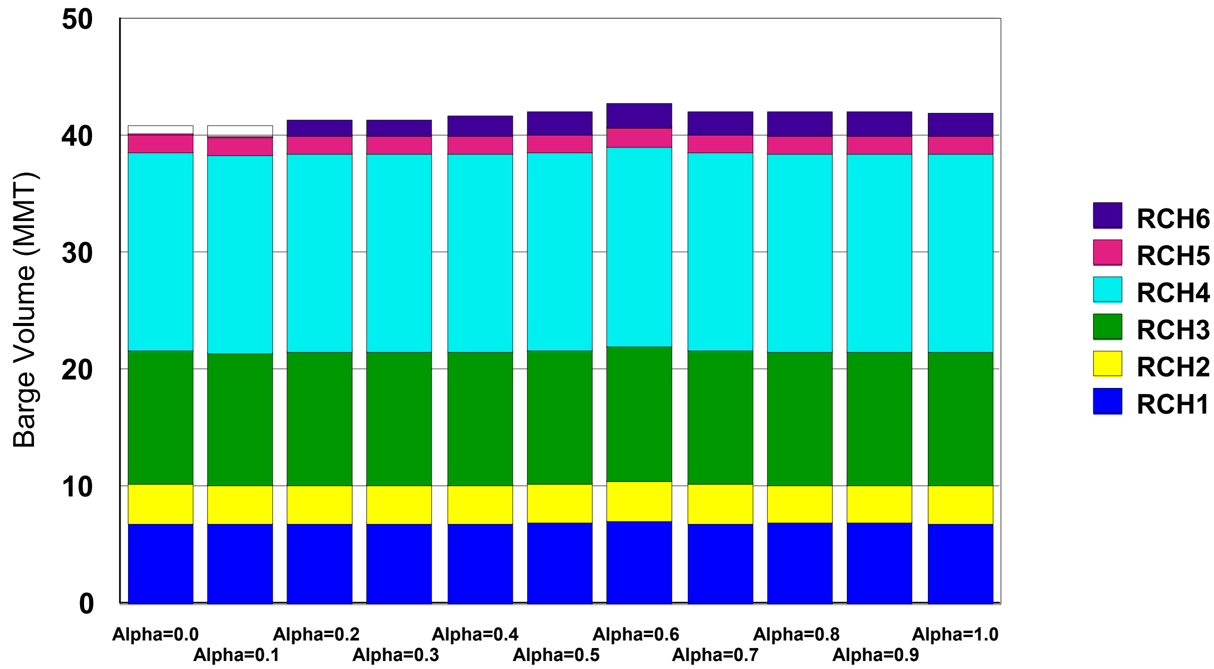

Figure 8.2.3. Effect of Alpha on Total Barge Volume for Base Year, Current Capacity.

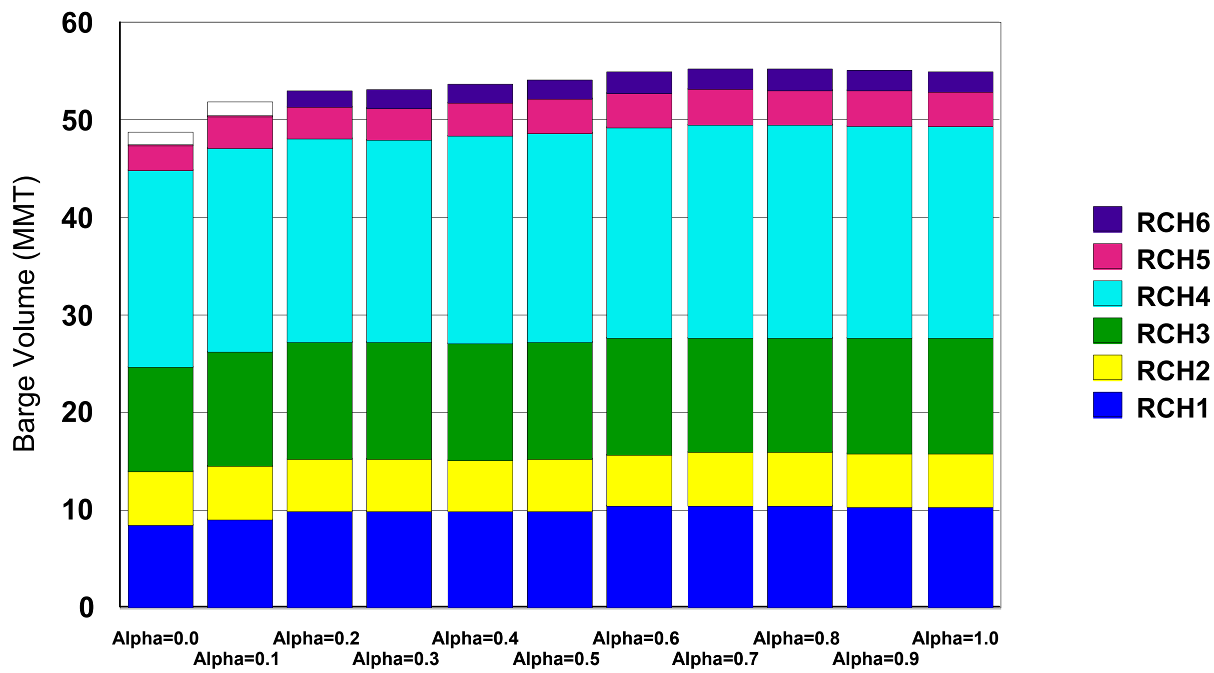

Figure 8.2.4. Effect of Alpha on Total Barge Volume for 2010, Current Capacity.

8.3 Projections With Expanded Capacity: The model was simulated assuming each of the proposed expansions were adopted. These results are shown in Figures 8.3.1-8.3.4.

Results reflect increased barge volumes over the current capacity scenarios for the years 2020 to 2060. Increases are largest in 2030 and decline to 2060. Differences are highlighted in Figure 8.3.3. Changes in barge volumes with expanded capacity varied by reach with increases largely in reaches 2-4, with decreases in most years in reaches 5 and 6.

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 less. The reason for that is because the simulation allows for numerous other simultaneous changes. As a result of expanding barge capacity, delay costs decline some, barge movements increase on some flows, and concurrently there are some changes in production in the United States and elsewhere. Thus, given these longer-run adjustments, the impact of expansions is less. Finally, rail rates are a declining function of time in this model, but not in the deterministic model. This fact, along with that rails both compete with (e.g., origin shipments direct to ports) and complement barges (e.g., origin to barge shipping points for transloading) has an important impact on the results.

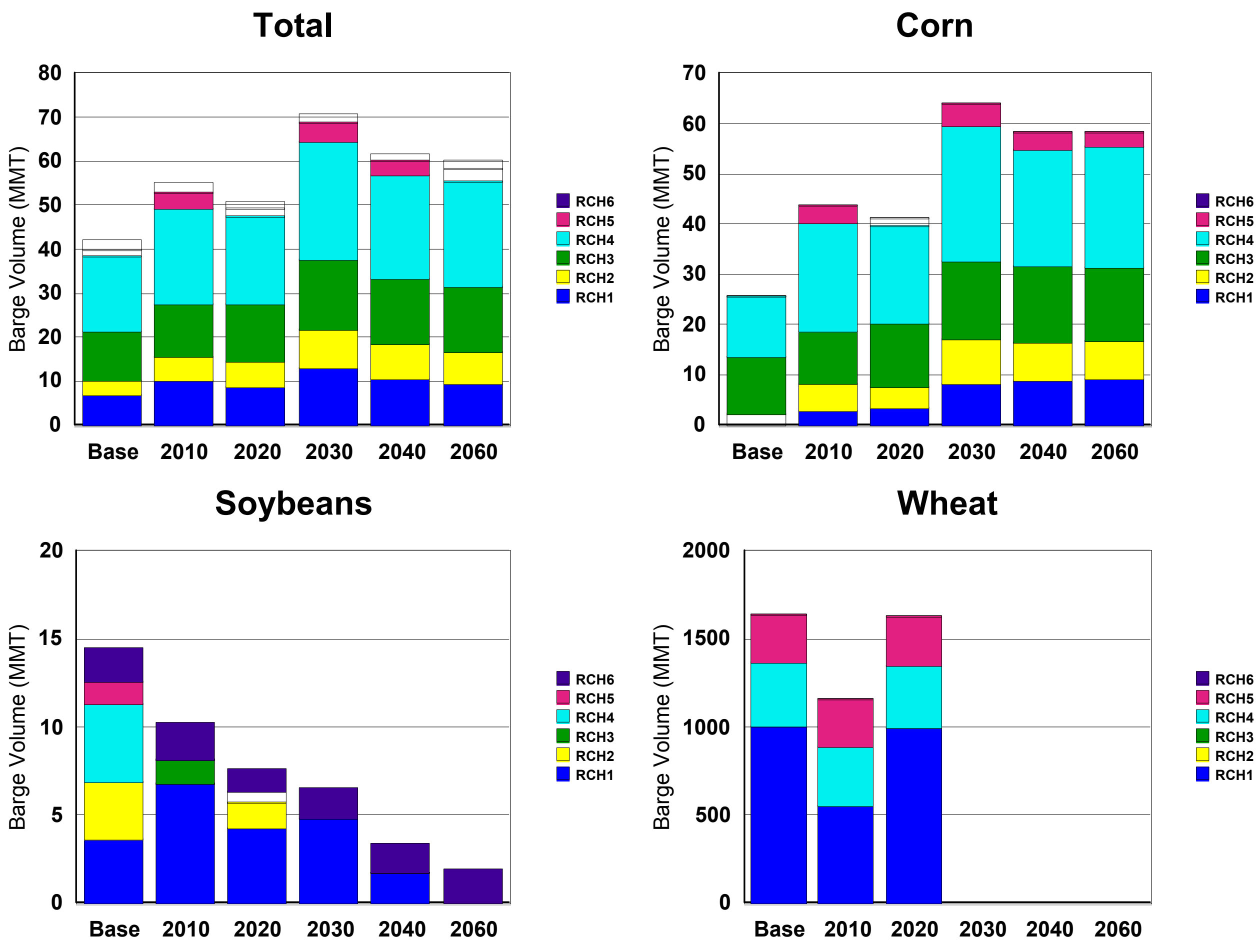

Figure 8.3.1. Barge Reach Volume by Crop and Total, Expanded Capacity, Alpha=0.9.

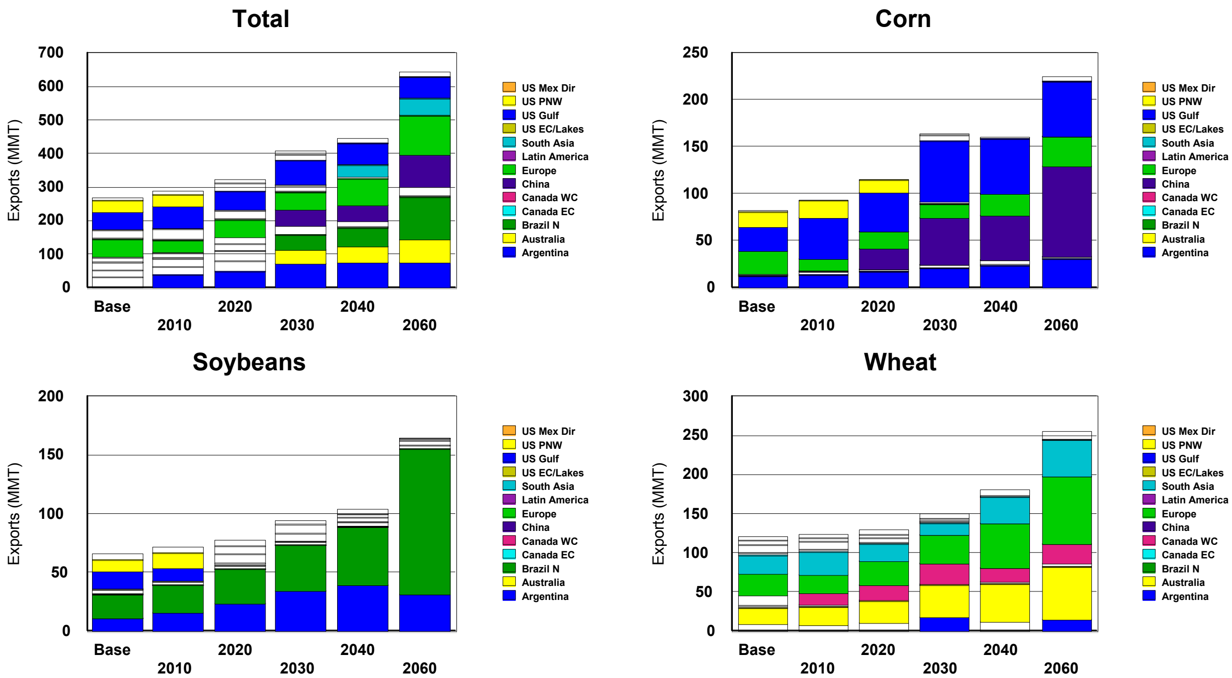

Figure 8.3.2. Export Volume by Crop and Total, Expanded Capacity, Alpha=0.9.

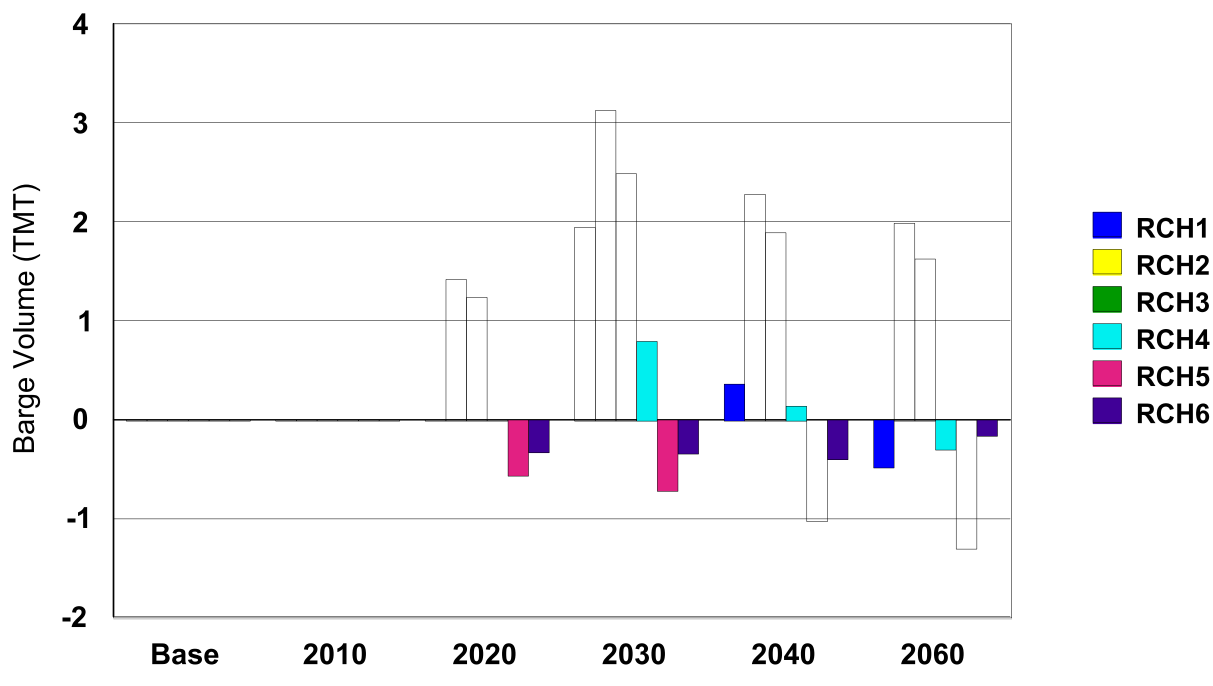

Figure 8.3.3. Change in Barge Volume, Expanded - Current Capacity, Alpha=0.9.

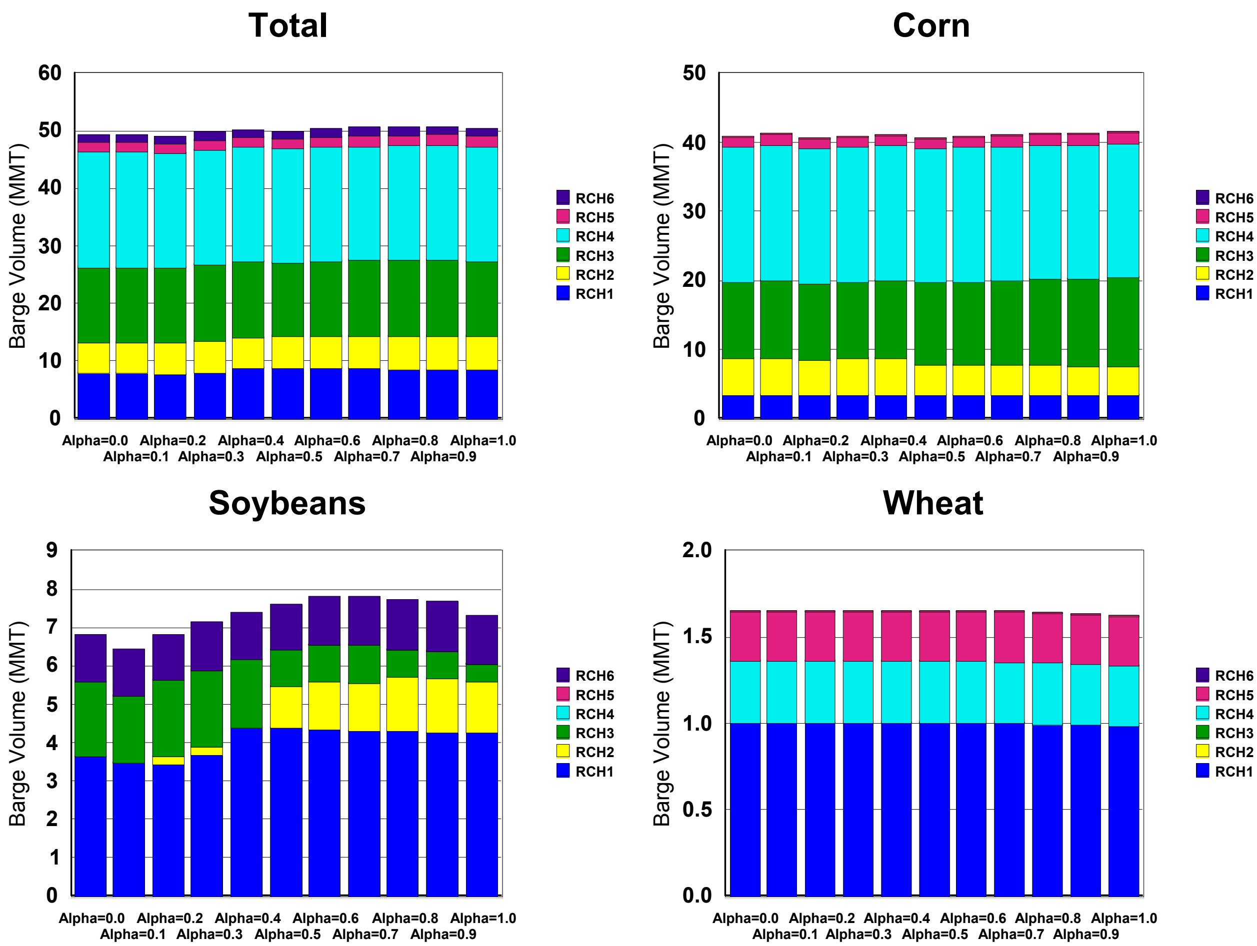

Figure 8.3.4. Barge Volume by Reach, Expanded Capacity for 2010, by Crop, Total and Alpha.

8.4 Ethanol The model was run assuming the high-ethanol scenario described above. To do so the EIA 2006 ethanol estimates were used. Also, to attain an equilibrium, it was necessary to increase the area restrictions the same as for the base case (Table 8.1.1).

Results are shown in Figures 8.4.1-8.4.4.

With α=.9, barge demand increases in 2010, declines in 2020, increases in 2030 and then

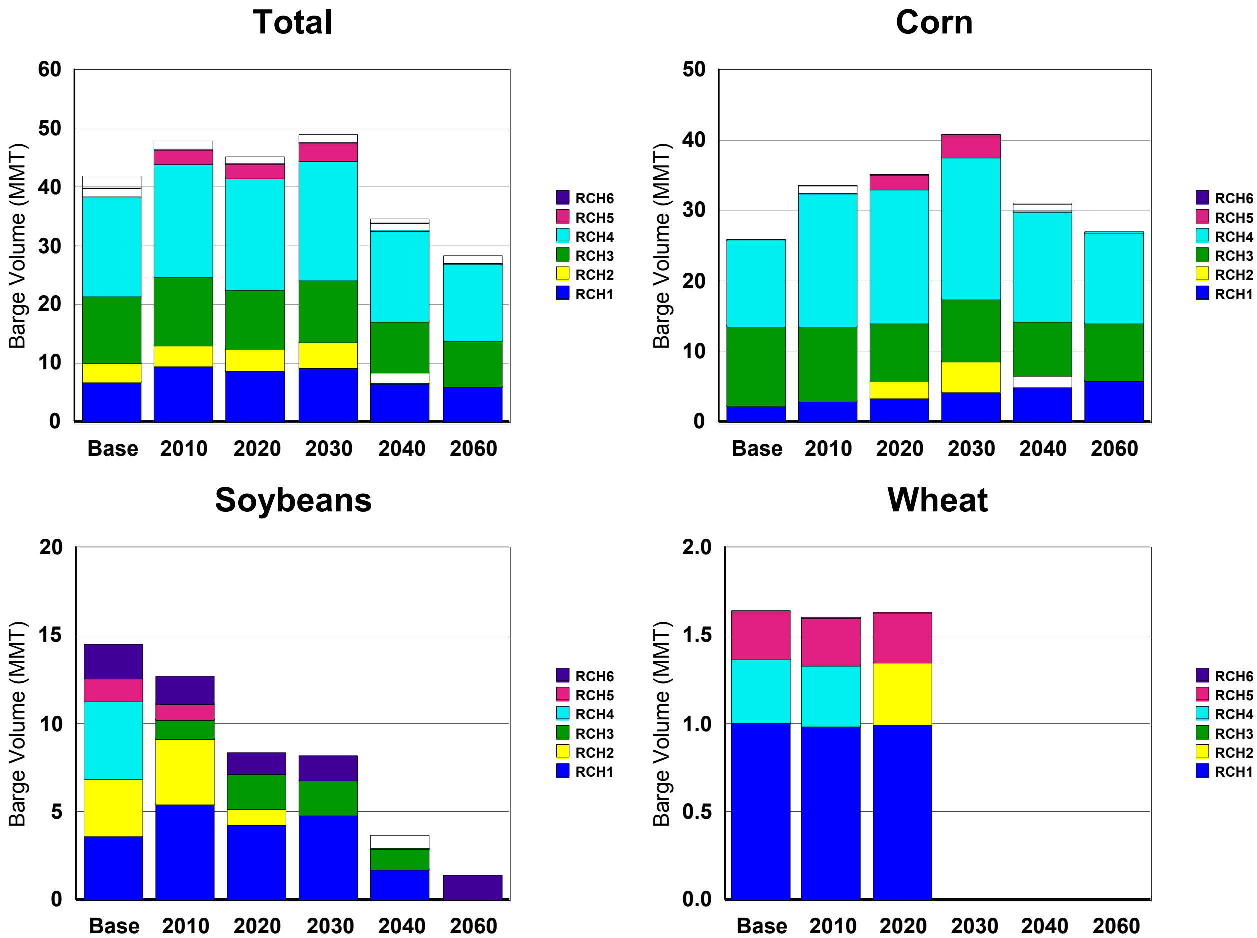

Figure 8.4.1. High Ethanol Demand: Barge Reach Volumes, Alpha=0.9.

declines beyond. Corn demand for barge increases to 41 mmt in 2030 and then declines to 27 mmt in 2060. Soybean and wheat shipments decline to minimal levels with wheat shipments nil on the barge system by 2030.

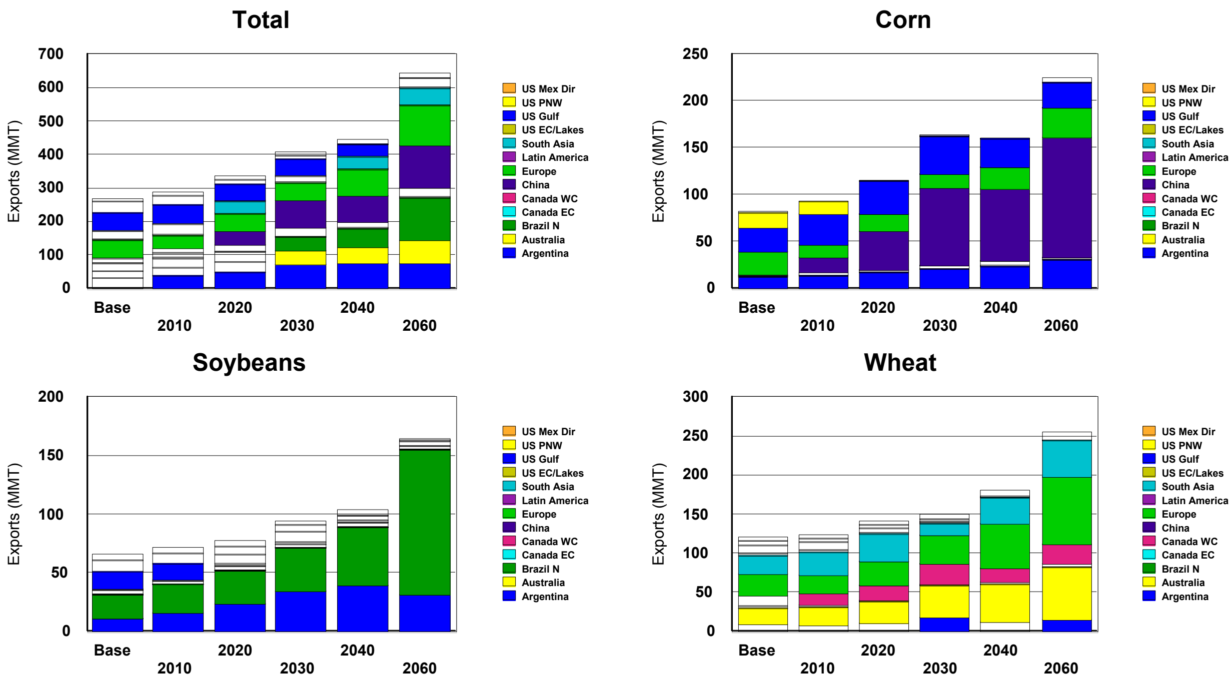

Figure 8.4.2. High Ethanol Demand: Exports, Alpha=0.9.

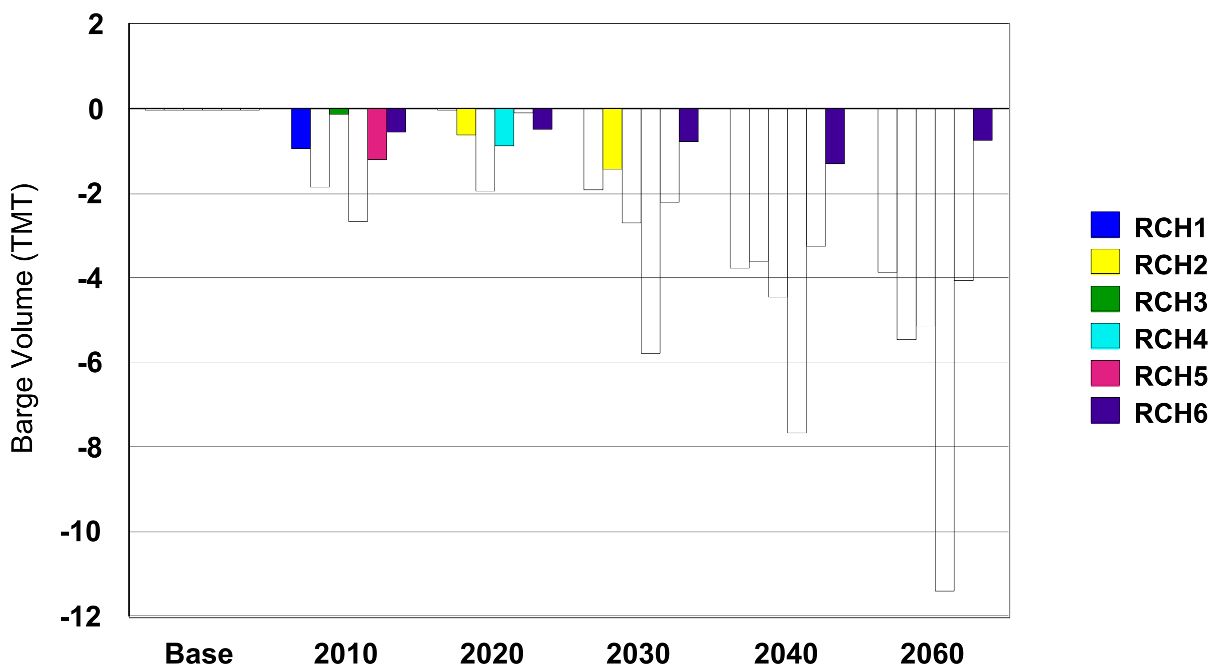

Figure 8.4.3. High Ethanol Demand: Change in Barge Volumes (High Ethanol - Current Capacity), Alpha=0.9.

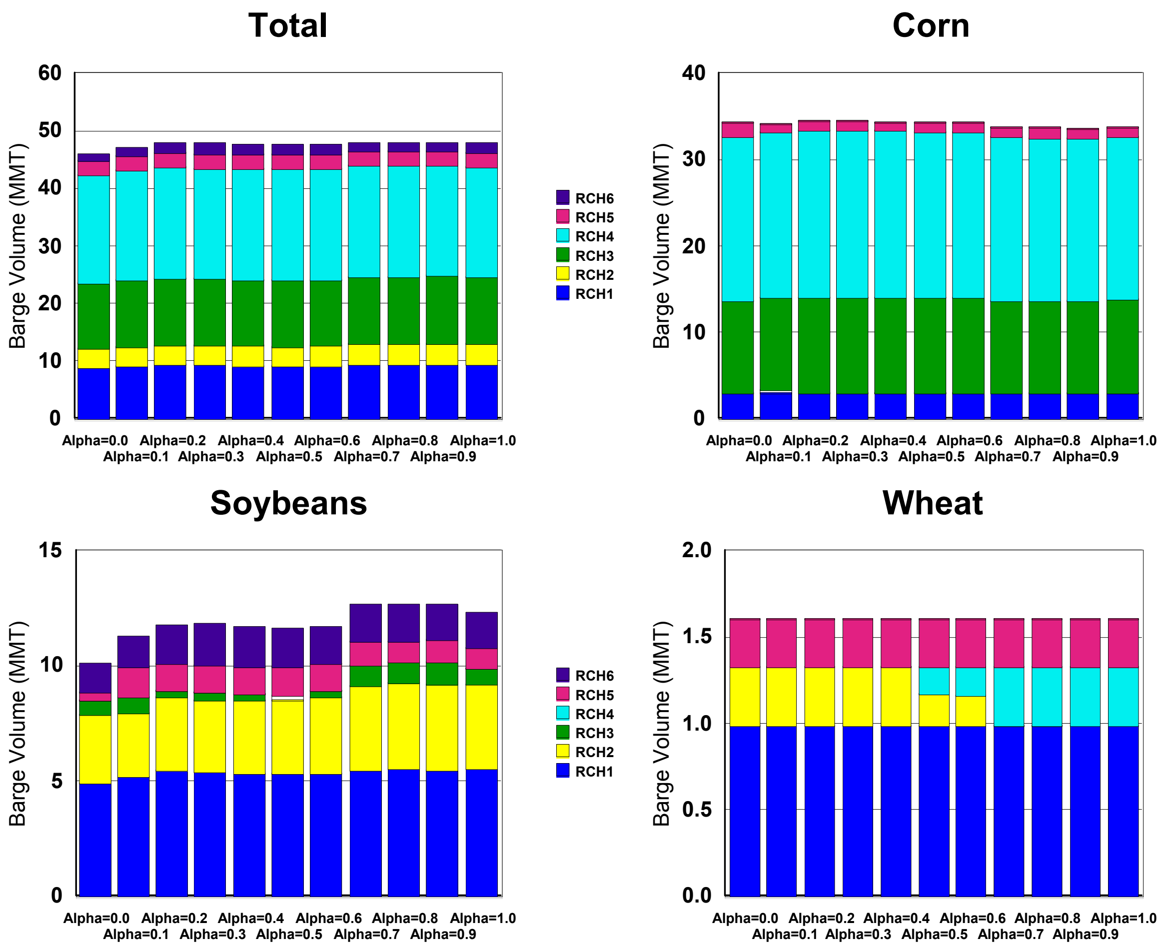

Figure 8.4.4. High Ethanol Demand: Barge Reach Volumes, Effect of Alpha, 2010.

8.5 Risk: The model was used to make projections about the impacts of lock expansions. The approach was to forecast future demands and characterize demand uncertainty are statistically valid. The estimation procedures employ a finite number of historical observations. Demand equations and estimation residuals are then used to extrapolate demand and demand uncertainty for up to 50 years into the future. 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 8.5.1. Strictly, this is the variance across all markets and grains. This increases from about 13 to 27 mmt^2 looking forward from the base period. This variance impacts the variance of barge demand though the latter could not be derived. The coefficient of variation is virtually unchanged.

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 about 20 years out.

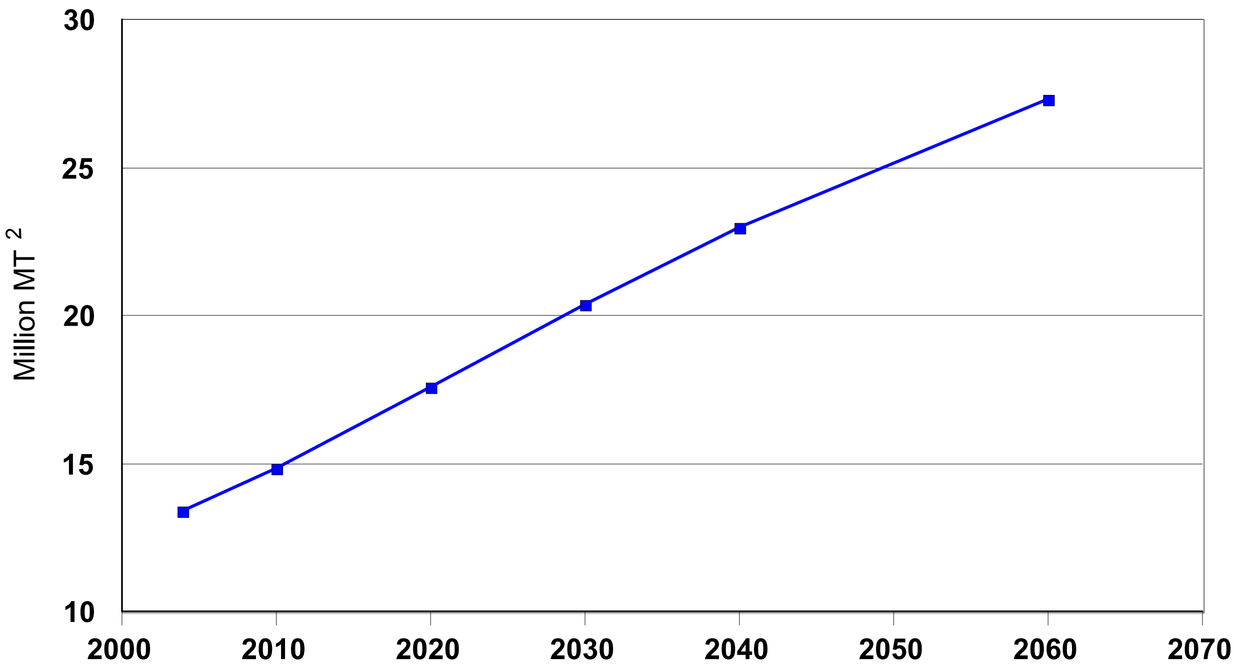

Figure 8.5.1 Total Variance Over Time.

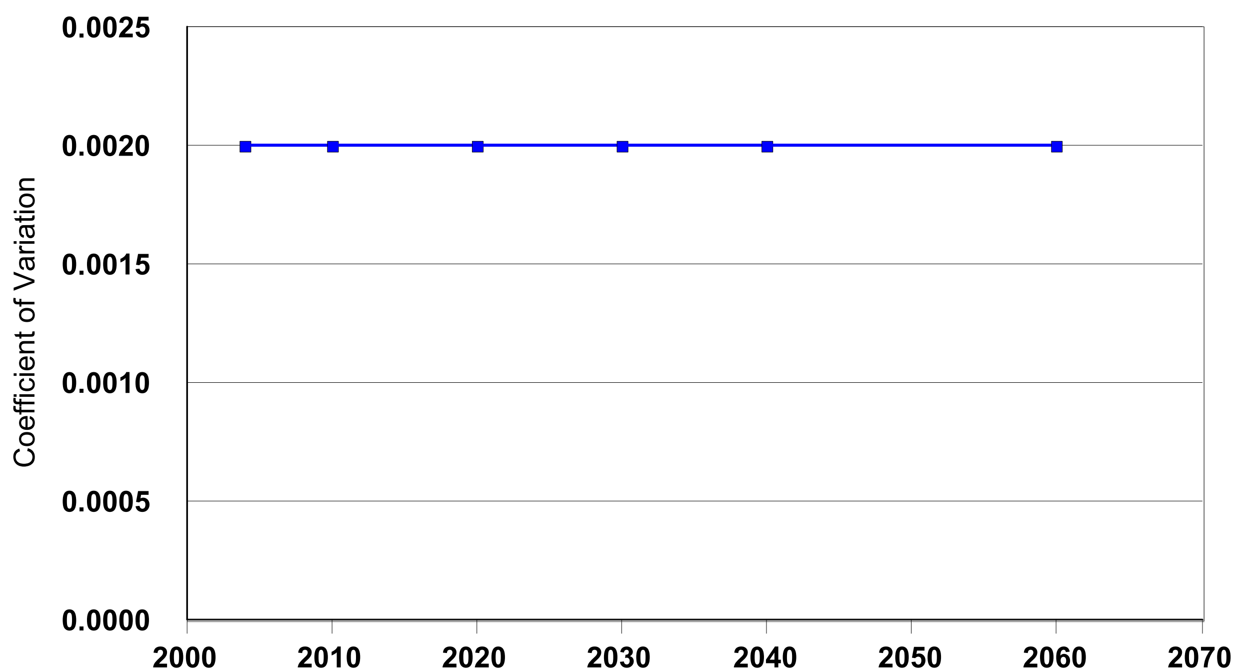

Figure 8.5.2 Coefficient of Variation Over Time.

9. Summary

9.1 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, 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 future flows and considers forecast variability.

The model is a spatial optimization model of the world grain trade. Important parameters are forecasted and used to evaluate changes in flows through specific 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 exporting country and region, and shipping costs and technologies. The model was solved jointly for corn, soybean and wheat. Costs included are production costs for each grain in each exporting region and country, interior shipping and handling costs including delay costs on the River system, and ocean shipping costs.

This model differs from others. It is a longer run model. Consequently, 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 captures the impact of longer-run adjustments. Second, the model has very extensive intermodal competition which affects inter-port, inter-reach and intermodal as well as interregional competition.

9.2 Summary of Underlying Data The results identified a number of important factors that will be impacting barge shipments. These include:

Growth markets: 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 has near nil growth rates.

Corn Used in Ethanol: An important change that is occurring and will have an important impact on the amount of corn available for export is the explosion of the ethanol industry. In concept, the US energy policy will result in increased domestic demand for corn, increased planting of corn to the extent technically possible, reduced plantings of wheat and soybeans in the United States. The latter will result in increased plantings in other countries and reduce exportable supplies from the United States. Corn used in ethanol production is expected to increase from four billion gallons to nearly 10 billion gallons in 2015, and then converge to about 11 billion gallons in 2020 forward. More recent studies have suggested this could be greater and all point toward severely reduced exports

Grain production costs and international competition: These results indicate there are substantial differences in production costs. In particular: 1) the US is the lowest cost producer of corn and soybeans; 2) most US regions' production costs for soybeans are 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 not shared by other wheat producing countries. The cost advantage of the United States diminishes over time and in some of the latter years costs of competing countries decline relative to the United States. These notwithstanding, as illustrated the world supply/demand balance is relatively tight for most grains and as such production from most regions is necessary to satisfy demand requirements.

Intermodal competitiveness: Most important is the close relationship between rail and barge shipments, particularly from the Upper Mississippi River. During the base period, it is critical that rail rates are less than barge shipping costs for some larger origin areas and movements. In addition, in some cases the direct rail cost to the US Gulf is less than barge shipping costs. Finally, the econometric analysis suggests that over time there have been productivity increases in rail, which has resulted in reduced real rail rates.

Delay Costs on the Barge System: Delay costs are the additional costs associated with shipping on the barge system and result from queuing and the added costs for shipments that are delayed. These are an important feature of barge shipping, particularly when shipment volumes are greater. In several of the Reaches grain flows are near the point at which positive delay costs are accrued. At higher volumes, delay costs escalate and ultimately become nearly vertical. The latter is an indicator of capacity, i.e., the level of volume at which the delay costs become perfectly inelastic.

The delay curves would change if the locks were expanded, as proposed. In each case the proposed improvements would have the impact of shifting the delay function rightwards meaning that near-nil delay costs exist for a broader range of shipments. In addition, the value of the negative delay costs for lower volumes are slightly greater than in the previous case.

Ocean Shipping Costs: One of the more important variables is the ocean rate spread between the US Gulf and Asia vs. the PNW and Asia. Typically, this value trades in the range of about $5/mt, though there was quite a bit of volatility in more recent years.

***9.3 Results From the Empirical Analysis*:** Below is a summary of the projections and sensitivities:

Base case projections: The results suggest exports from the United States increase from the base period to 2010 in part due to the assumption that the maximum area for plantings would increase and in part due to that China's corn exports are assumed nil in 2010 and beyond. US corn exports decline the most, with a potential peak of 62 mmt to around 42 mmt. Wheat exports decline substantially, but soybeans increase through 2030. Exports from the United States are concentrated in the US Gulf, which declines to 57 mmt after reaching a peak of 92 mmt in 2010. Exports from the PNW are 25 mmt in the base year and declines in later years. The results illustrate that the United States remains an important exporter of soybeans and this conclusion persists in other scenarios.

Total barge volume increases from the base period at 51 mmt to 65 mmt in 2020. Thereafter, shipments decline to a longer term level at about 57 mmt. The reduced volume comes from limited reductions in corn and soybeans with drastic declines in wheat shipments.

Projections with expanded capacity and delay costs: There are currently delay costs, particularly on Reaches 1 and 4. As volumes increase, costs of shipping by barge increase, some shipments are diverted to different modes and/or routes, and delay costs accrue to shippers. Without the expansion in barge capacity, the delay costs in 2020 would increase on each Reach. Those on Reach 4 would increase to $1.08/mt.

Expansion would result in reduced delay costs on each or Reaches 1, 2 and 4 by about $0.44/mt, 1.04/mt and $1.01/mt respectively. Expanding lock capacity reduces delay costs, increases capacity and shipments by barge. Barge shipments increase by about +4 mmt by 2020. Thereafter, the change in barge shipments would be about +0.9 mmt to +2.5 mmt. There is substantive inter-reach competition and by 2020 shipments on Reach 1, 2 and 4 increase, but shipments on Reach 5 and 6 would decrease.

Delay costs, in aggregate are comprised of the lower delay costs that would occur at current capacity, plus the volume effect. The impact of expansions on delay costs are in the area of $61 million, inclusive of both direct effects. Most of this is accrued on Reach 4, followed by Reach 2 and 1. Expansion results in an increase in barge costs due to the increase in volume, a decrease in rail shipping cost, and a slight increase in ocean shipping costs. In total, the impact of expanding locks is a decrease in costs by about $52 million.

High-Ethanol impacts: The base case assumed EIA 2005 projections of corn use in ethanol demand. The model was revised assuming the EIA 2006 estimates of ethanol produced from corn. Results are drastic. Exports from Argentina, Europe and Eastern Europe, increase and wheat exports from Australia Increase.

Exports from the United States decline from 101 to 78 mmt by 2020, vs. the base case which increased from 101 to 111 mmt. Gulf exports decrease (65 to 51 mmt) and PNW changes only slightly to 14 mmt. Most of the decline is in corn and wheat shipments. Soybeans remain at about 30 mmt. Reach shipments change as well. There is a slight increase through 2010 and thereafter shipments decline to 48 mmt in 2020 and lesser values in years beyond. The decline is greatest for corn, and then wheat. The largest declines for 2030 and beyond are for shipments from Reaches 1, 3, 4, and 5, each declining in the area of 5 to 10 mmt vs. the base case.

In addition, there are major changes in flows within the United States. Most interesting are the increase in shipment to the Eastern and Western corn belts reflecting the increase in domestic demand for ethanol use. Also are the changes in flows from the Northern Plains which had previously exported most of its corn through the PNW. These are now shifted with a significant portion destined for domestic movements. There are also substantial changes in flows from US domestic regions to the Reaches and port areas. Most important are reductions in shipments from Iowa River to Reach 2, Minnesota River to Reach 3, and Illinois North to Reach 4. There are reductions from most regions to New Orleans, but, an increase from Illinois South to New Orleans.

Finally, the model was run assuming more stylized assumptions for some critical variables, mostly impacting the ability of corn production to expand to meet these competing demands. The results suggest the model is fairly robust in capturing these different assumptions. Most striking in making these comparisons are: 1) Corn exports from the United States increase to nearly 83 mmt, as opposed to decline to less than 26 mmt in 2020; 2) Soybean exports from the United States decline to 28 mmt vs. 36 mmt for the 2010 case. Those from Brazil and Argentina each increase sharply vs. our base case solution; 3) Wheat exports increase from each of the competitors and those from the United States decline, but, by not as much as in our unrestricted high-ethanol case; and 4) Reach shipments decline, but not as drastically.

There are important reasons for these differences (which are highlighted in the text). Most important are assumptions about the yield growth, the ability to expand corn acres, and differing assumptions on soybean production and exports from the United States vs. competitor countries.

China policies: One of the most dynamic countries in the world grain market is China and whether China becomes an importer or remains an exporter is highly uncertain. If China becomes an importer, the results depend on the ethanol assumption. Under base case ethanol scenario, shipments on the barge system increase slightly. Under a high-ethanol assumption, barge shipments decline.

The alternative would be for China to export. The results indicate that China competes with Europe. Exports from the US decrease from 122 mmt in 2010 to 92 mmt in 2030, vs. in the base case of 122 to 92 mmt. Most of the change is in exports from the US Gulf. Reach shipments are impacted but only slightly. Under a high ethanol scenario, China's exports increase more which takes away from the growth in exports from Europe and Eastern Europe. The results on Reach shipments are similar With corn exports declining a bit, which is offset by an increase in soybean exports.

South American competitive position. Improved productivity in Brazil and Argentina would increase their relative advantage. Brazil production would increase from 58 mmt in 2010 base case to 61mmt assuming yields increase. This has the impact of increasing their exports from 20 to 23 mmt and reducing those from the United States. Reach shipments decrease, but the change in not radical.

The second change in Brazil relates to interior transportation infrastructual investments. Results suggest that decreasing shipping rates in Brazil North would result in a very slight increase in exports via barges. Production in Brazil North is unchanged. Exports from Brazil to China and North Africa increase and those to Japan decrease. Exports from the United States to China are reduced and exports to Japan increase. The cumulative impacts of these are for a slight increase through the US Gulf. These are offset by a very slight reduction of soybeans from the PNW.

Conservation Reserve Program (CRP): One of the more important US policies in the near term that could impact these results is the administration of the CRP program, particularly true in light of the recent expansion in ethanol. There are 13.8 mill acres in corn, wheat, soybeans that would expire in 2007. USDA indicated there were 12 million acres scheduled to expire between 2008 -2010.

The model was used to evaluate these impacts. Results are reflected in the base case projections since returning 7% of the base area was a maintained assumption. If these CRP acres are not returned, competitor countries would expand production and barge demand would decline by 10 mmt. In either case, this is a critical policy that impacts barge demand.

Barge demand functions: The model was used to trace out a synthetic demand function for barges. These allow for numerous adjustments in the model, including modal shifts, spatial shifts in shipments, spatial shifts in area planted and shifts in shipment patterns, both internationally and domestically. Thus, these should be interpreted as the longer-term elasticity for barge shipping.

Increasing barge rates decreases barge demand, but has a differential impact on Reach shipments. An increase in barge rates by 20% reduces total barge shipments by 5%. Reductions occur in each of Reaches 2-6, with the largest reduction in Reach 6 (-16%). The derived arc elasticity for the total system is -.23 for a 20% increase in barge rates which is much less than some of the previous studies. However, the elasticities varies by Reach. For a 20% increase in rates, elasticities for shipments on Reach 2, 3, and 4 are -.67, -0.28 and -0.16 respectively. These results point that there are substantial inter-reach substitution as barge rates change.

Rail restrictions The results were analyzed assuming a long-term capacity restriction on rail shipping. At least in the shorter-term, such a restriction impacts the ability of rail to compete With barges, even though in some critical cases rail rates are less. Sensitivity analysis shows that increases in rail capacity has an inverse impact on barge shipments. Increases in rail capacity, holding rates and everything else constant, reduce equilibrium barge shipments.

Impact of ocean rate spreads on barge shipments: An important factor impacting barge demand is the ocean spread going to Asia for shipments from the US Gulf versus the PNW. The base case reflects values during the 2000-2004 period. Increases in this spread 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 2 and 3. The reduction in barge shipments is absorbed in part by increased shipments through the

PNW, but the results are somewhat dependent on the assumption on PNW handling capacity and whether this would be short term or long-term.

Panama Canal Expansion: A large amount of the grain exports from the US Gulf transit to the Asian markets using the Panama Canal. Plans are being made to expand the Panama Canal (Kraul) and the 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. The impact of this would effectively reduce the cost of shipping to Asia through the US Gulf. The sensitivities suggest that an expansion of the Panama Canal would increase shipment through the Reaches. Most of the increase would be from Reaches and 4.

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.

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.

9.4 Major Factors Impacting Results: These results are very clear in terms of the direction and size of future barge shipments. Those of greatest importance are ethanol, longer term competitiveness of competitor countries, and competitiveness of rail/road versus barges.

<u>*Ethanol:*</u> The ethanol impact is drastic and has a very important negative impact on barge demand. Simply, increases in ethanol demand results in a shift toward domestic use of corn, reduced exports of corn, shifts from wheat (primarily) into corn which reduces exportable supplies. These are offset by expanded production in competitor countries. Notable amongst these are Brazil and Argentina, Australia, Eastern Europe and China.

The results are very sensitive to underlying assumptions regarding area planted to corn and yields.

<u>*Competitor Countries*</u>: The United States has the advantage of being a low cost producer of corn and soybeans. However, other countries costs per mt are declining relative to those in the United States. This is a subtle conclusion but impacts the results when extrapolated forward. In addition, while some other countries have the ability to expand area, the ability to expand in the Untied States is restricted in part due to the CRP, and in part due to the technical ability to substitute into other crops.

Even though Brazil and Argentina are not lower cost in corn and soybeans, they play a critical role. Though there is strong demand for soybeans internationally and the United States is lower cost, the ability to expand in the United States and simultaneously serve other demands is limited. This is what provides opportunity for these countries.

Rail competition: Rail competition is critical and has a direct impact on barge shipments. There are two aspects of rail competition. One is the level of rail rates relative to barge rates on some specific barge competitive movements. These results show that 1) on some movements, rail rates to US gulf and/or other transit points are lower than by barge; and 2) rail rates have benefitted from productivity increases and lower rates over time. The second is rail capacity which has increased over time due to investment in cars and productivity. These increases in capacity have the impact of reducing demand for barges.

9.5 Extensions 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 model and fundamental issues.

The base case period for our model was for 2000-2004. During this period, and that to follow, 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.

There are several areas that may be worthy of further exploration. These are listed in order relative to how they would potentially impact the results.

Model specifications: Given the size and complexity of this model, there obviously a number of alternative approaches. In rank order, those that would likely have the greatest impact on the results would be to 1) estimate elasticities of substitution amongst modes and include them in the model (data exists to do this, and would allow less extreme shifting amongst modes in response to critical variables); 2) refine the approach to risk (there are numerous alternatives, but the size of the model constrains the ability of some approaches); and 3) incorporate explicit supply and demand functions for underlying commodities (but, this is not inconsequential due to the disaggregated specification of the model). These would be in addition to dealing with issues identified below.

Rail capacity. This is a critical variable which has a very important impact on barge demand. For perspective, rail car loadings for grains (as reported by USDA AMS), have increased from 2002 to 2005. These vary across railroads and the car loadings for some railroads have increased and each of the railroads is pursuing expansions in capacity.

It is not clear how the longer-term adjustment will evolve and there are different ways to measure capacity. What is observed (as referenced above) is loadings, which in concept would be the equilibrium of demand and capacity allocated to grain. Interpretation of rail capacity for grain shipments is further compounded by rail capacity due to other factors (track space, crew, locomotive all of which compete with other commodities), and that though we observe current shipments, more important for this type of analysis is future capacity. Thus, it is essentially important to be assessing the longer-run adjustment curve on the part or railroads.

Irrespective of the complexities, as indicated in this study, capacity has an important impact on barge demand. Thus, measuring changes in longer-term capacity very important to further refined these results.

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. Notably, 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.

There are three important issues. One is that some of these relationships may alternatively be viewed as determined simultaneously. As noted above, the data do not lend themselves to easily estimating the relationships in any form of simultaneous solutions. Second, the implicit assumption here is that the rate relationships are the same in the future as during the base period. These relationships capture the salient variables and spatial relationships to others, but, do not allow for the prospect of alternative or changing marketing structures and pricing behavior. Of course, these would have to be assumed as opposed to being observed in the data. Third, and particularly important is the role and impact of fuels costs. The rate relationships did not find fuel costs to be significant, with exception of ocean rates. Yet, it is well known that fuel surchargers have become important in railroads, as well as other modes. In the case of railroads, the STB reporting with respect to fuel is not clear and is understood to be variable across railroads (and potentially through time). It is not clear how these effects could be unraveled in a way that would be consistent with the structure of the underlying data.

Seasonality and Congestion Given the underlying pressures in the world shipping market, the seasonal features of demand are becoming increasingly more important. The analysis here revolves around the annualization process in supply and demands, delay costs and rate relationships.

In the future, the seasonal demands for shipments from the US and river system will likely be exacerbated and delay costs would likely increase. This is particularly true given the growth in production and exports from southern hemisphere countries. It appears that the demands for capacity expansion are for escalated shipments in an increasingly concentrated shipping season (i.e., following US harvest buy prior to commencing of new-crop Southern hemisphere grains).

An alternative to expanding capacity to facilitate seasonal peakedness in shipping demands, would be to explore alternative peak pricing, congestion pricing and/or allocation and priority mechanisms. Other high fixed cost industries (railroads for shipping grains and other commodities; airlines, etc) have benefitted from these mechanisms. In the case of barges, the demands for dealing with seasonality and congestion will escalate and mechanisms to allocate priorities for shipments within a more compressed window will escalate.

DDG shipping The assumption of this study is that DDGs displace corn demand, and this occurred in the region in which the ethanol was processed.

For the purpose of this model, this is defendable and treating it differently would not likely change the results. Nevertheless, the model could be expanded to explicitly include DDG shipments, and exports. It is unlikely that even if these could be included that the results would change as the major macro factors impacting the result will persist. Thus, these impacts would likely be inconsequential and not necessarily warranted. Further, much is not clear about shipping DDGs (including shipping costs, conversions, equipment, exports etc) nor the technical implications of shipping, consumption by animal types, and export demand and competition for this product.

Biodiesel: The model excluded explicit impacts of soybased biodiesel. Biodiesel, like ethanol, also is a new industry that is just now emerging. It is unlikely that data exists to deal With this directly at this point anyway. Implicitly state level demands are included in our data and analysis which reflects demands for this industry. However, unlike ethanol, the specific impacts of biodiesel are not isolated.

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Appendix: Detailed Model Results

Appendix Table A1a. Base Case Projections: Exports (000MT)

(All)	BaseCase	F2010	F2020	F2030	F2040	F2060
ARGX	28,962	24,197	35,799	50,572	44,026	59,835
AUSX	19,817	22,376	28,701	39,964	33,575	46,568
BRZ1X	11,147	10,385	9,947	9,308	11,337	9,715
BRZ2X	9,904	9,400	16,854	21,965	35,642	91,344
CANEX	512	512	512	1,003	983	888
CANWX	11,912	12,652	11,775	14,166	16,527	19,381
CHIX	8,000	0	0	0	0	0
EURX	44,631	59,570	77,081	108,641	139,491	222,787
LATX	3,696	4,641	4,022	7,608	5,184	5,371
MEXX	0	0	0	0	0	2,861
SAX	24,721	17,025	22,138	25,790	28,553	26,409
USEX	2,554	2,580	2,613	2,147	2,147	4,315
USGX	65,215	91,864	75,889	62,214	63,176	57,078
USPNWX	24,594	18,178	22,639	16,388	16,242	9,292
US Mex Dir	8,234	9,097	9,915	11,074	9,442	5,000
Grand Total	263,899	282,477	317,886	370,838	406,325	560,845
Total US	100,597	121,719	111,056	91,823	91,008	75,686

corn	BaseCase	F2010	F2020	F2030	F2040	F2060
ARGX	11,122	10,172	16,060	21,033	22,818	29,934
AUSX	17	0	131	270	360	706
BRZ1X	0	0	0	0	0	0
BRZ2X	1,432	1,675	1,460	3,822	3,589	3,886
CANEX	0	0	0	0	0	0
CANWX	0	0	0	0	0	0
CHIX	8,000	0	0	0	0	0
EURX	19,000	21,322	36,027	56,105	64,649	101,696
LATX	0	0	0	0	0	0
MEXX	0	0	0	0	0	2,861
SAX	0	0	1,624	5,217	6,793	9,851
USEX	0	0	0	0	0	0
USGX	32,767	53,160	48,485	38,863	42,600	41,606
USPNWX	9,923	8,886	7,111	646	1,589	0
US Mex Dir	1,005	315	0	0	379	0
Grand Total	83,266	95,529	110,897	125,955	142,777	190,539
Total US	43,695	62,361	55,596	39,509	44,568	41,606

soybean	BaseCase	F2010	F2020	F2030	F2040	F2060
ARGX	7,997	5,914	9,710	17,644	19,318	29,901
AUSX	0	0	0	0	4	101
BRZ1X	11,147	10,385	9,947	9,308	11,337	9,715
BRZ2X	8,472	7,725	15,394	18,143	32,053	87,458
CANEX	0	0	0	0	0	0
CANWX	0	0	0	0	0	0
CHIX	0	0	0	0	0	0
EURX	0	0	0	0	0	0
LATX	3,696	4,641	4,022	7,608	5,184	5,371
MEXX	0	0	0	0	0	0
SAX	0	0	0	0	0	0
USEX	0	0	0	0	0	2,168
USGX	19,924	28,524	22,697	23,351	20,577	15,472
USPNWX	6,101	1,670	7,906	8,120	7,031	1,670
US Mex Dir	3,995	4,685	5,000	5,000	4,621	5,000
Grand Total	61,333	63,544	74,676	89,173	100,125	156,856
Total US	30,020	34,879	35,603	36,471	32,229	24,311

wheat	BaseCase	F2010	F2020	F2030	F2040	F2060
ARGX	9,842	8,112	10,029	11,895	1,890	0
AUSX	19,799	22,376	28,570	39,694	33,210	45,762
BRZ1X	0	0	0	0	0	0
BRZ2X	0	0	0	0	0	0
CANEX	512	512	512	1,003	983	888
CANWX	11,912	12,652	11,775	14,166	16,527	19,381
CHIX	0	0	0	0	0	0
EURX	25,630	38,248	41,055	52,536	74,843	121,092
LATX	0	0	0	0	0	0
MEXX	0	0	0	0	0	0
SAX	24,721	17,025	20,514	20,573	21,760	16,557
USEX	2,554	2,580	2,613	2,147	2,147	2,147
USGX	12,524	10,181	4,707	0	0	0
USPNWX	8,570	7,622	7,622	7,622	7,622	7,622
US Mex Dir	3,234	4,097	4,915	6,074	4,442	0
Grand Total	119,299	123,404	132,312	155,711	163,423	213,449
Total US	26,882	24,479	19,858	15,843	14,211	9,769

Appendix Table A1b. Expanded Barge Capacity: Exports (000MT)

	(All) BaseCase	F2010	F2020	F2030	F2040	F2060
ARGX	28,962	24,197	35,799	50,572	44,026	59,835
AUSX	19,817	22,376	28,701	39,964	33,575	46,568
BRZ1X	11,147	10,385	9,947	9,308	11,337	9,715
BRZ2X	9,904	9,400	16,854	21,965	35,580	88,809
CANEX	512	512	512	1,003	983	888
CANWX	11,912	12,652	11,775	14,166	16,527	19,381
CHIX	8,000	0	0	0	0	0
EURX	44,631	59,570	77,081	108,641	139,491	222,787
LATX	3,696	4,641	4,022	7,608	5,184	5,371
MEXX	0	0	0	0	0	2,861
SAX	24,721	17,025	22,138	25,790	28,553	26,409
USEX	2,554	2,580	2,613	2,147	2,147	4,315
USGX	65,215	91,864	77,806	62,860	64,397	59,613
USPNWX	24,594	18,178	20,722	15,742	15,084	9,292
US Mex Dir	8,234	9,097	9,915	11,074	9,442	5,000
Grand Total	263,899	282,477	317,886	370,838	406,325	560,845
Total US	100,597	121,719	111,056	91,823	91,070	78,220

	corn BaseCase	F2010	F2020	F2030	F2040	F2060
ARGX	11,122	10,172	16,060	21,033	22,818	29,934
AUSX	17	0	131	270	360	706
BRZ1X	0	0	0	0	0	0
BRZ2X	1,432	1,675	1,460	3,822	3,589	3,886
CANEX	0	0	0	0	0	0
CANWX	0	0	0	0	0	0
CHIX	8,000	0	0	0	0	0
EURX	19,000	21,322	36,027	56,105	64,649	101,696
LATX	0	0	0	0	0	0
MEXX	0	0	0	0	0	2,861
SAX	0	0	1,624	5,217	6,793	9,851
USEX	0	0	0	0	0	0
USGX	32,767	53,160	49,916	39,509	42,408	41,606
USPNWX	9,923	8,886	5,679	0	1,192	0
US Mex Dir	1,005	315	0	0	968	0
Grand Total	83,266	95,529	110,897	125,955	142,777	190,539
Total US	43,695	62,361	55,596	39,509	44,568	41,606

	soybean BaseCase	F2010	F2020	F2030	F2040	F2060
ARGX	7,997	5,914	9,710	17,644	19,318	29,901
AUSX	0	0	0	0	4	101
BRZ1X	11,147	10,385	9,947	9,308	11,337	9,715
BRZ2X	8,472	7,725	15,394	18,143	31,991	84,923
CANEX	0	0	0	0	0	0
CANWX	0	0	0	0	0	0
CHIX	0	0	0	0	0	0
EURX	0	0	0	0	0	0
LATX	3,696	4,641	4,022	7,608	5,184	5,371
MEXX	0	0	0	0	0	0
SAX	0	0	0	0	0	0
USEX	0	0	0	0	0	2,168
USGX	19,924	28,524	23,183	23,351	21,989	18,007
USPNWX	6,101	1,670	7,420	8,120	6,270	1,670
US Mex Dir	3,995	4,685	5,000	5,000	4,032	5,000
Grand Total	61,333	63,544	74,676	89,173	100,125	156,856
Total US	30,020	34,879	35,603	36,471	32,290	26,846

	wheat BaseCase	F2010	F2020	F2030	F2040	F2060
ARGX	9,842	8,112	10,029	11,895	1,890	0
AUSX	19,799	22,376	28,570	39,694	33,210	45,762
BRZ1X	0	0	0	0	0	0
BRZ2X	0	0	0	0	0	0
CANEX	512	512	512	1,003	983	888
CANWX	11,912	12,652	11,775	14,166	16,527	19,381
CHIX	0	0	0	0	0	0
EURX	25,630	38,248	41,055	52,536	74,843	121,092
LATX	0	0	0	0	0	0
MEXX	0	0	0	0	0	0
SAX	24,721	17,025	20,514	20,573	21,760	16,557
USEX	2,554	2,580	2,613	2,147	2,147	2,147
USGX	12,524	10,181	4,707	0	0	0
USPNWX	8,570	7,622	7,622	7,622	7,622	7,622
US Mex Dir	3,234	4,097	4,915	6,074	4,442	0
Grand Total	119,299	123,404	132,312	155,711	163,423	213,449
Total US	26,882	24,479	19,858	15,843	14,211	9,769

Appendix Table A1c. High Ethanol Demand: Exports (000MT)

	(All) BaseCase	F2010	F2020	F2030	F2040	F2060
ARGX	28,962	28,052	38,191	40,079	46,109	63,667
AUSX	19,817	23,250	32,411	45,189	33,693	46,715
BRZ1X	11,147	8,833	10,977	12,178	14,151	10,774
BRZ2X	9,904	9,906	17,921	26,541	37,141	81,258
CANEX	512	512	512	1,003	983	888
CANWX	11,912	10,698	11,935	14,379	16,415	19,381
CHIX	8,000	0	0	0	0	0
EURX	44,631	70,355	77,686	122,258	156,078	238,788
LATX	3,696	4,325	4,022	6,294	5,184	5,371
MEXX	0	0	0	2,854	5,180	9,337
SAX	24,721	10,331	23,919	26,090	28,960	23,121
USEX	2,554	2,580	2,613	2,147	2,147	5,269
USGX	65,215	79,066	50,956	23,711	19,316	18,029
USPNWX	24,594	12,279	14,560	14,966	9,292	9,292
US Mex Dir	8,234	9,097	9,915	11,074	7,510	5,000
Grand Total	263,899	269,284	295,620	348,763	382,159	536,889
Total US	100,597	103,022	78,044	51,898	38,266	37,589

	corn BaseCase	F2010	F2020	F2030	F2040	F2060
ARGX	11,122	14,027	18,453	24,294	26,791	33,767
AUSX	17	83	194	361	478	832
BRZ1X	0	0	1,030	2,870	2,814	1,058
BRZ2X	1,432	2,181	4,790	8,398	9,202	9,348
CANEX	0	0	0	0	0	0
CANWX	0	0	0	0	0	0
CHIX	8,000	0	0	0	0	0
EURX	19,000	29,209	46,005	69,722	81,235	117,696
LATX	0	0	0	0	0	0
MEXX	0	0	0	2,854	5,180	9,337
SAX	0	877	4,164	8,915	11,574	14,977
USEX	0	0	0	0	0	0
USGX	32,767	38,903	26,370	0	0	0
USPNWX	9,923	1,056	0	0	0	0
US Mex Dir	1,005	2,246	0	0	0	0
Grand Total	83,266	88,583	101,006	117,414	137,275	187,017
Total US	43,695	42,206	26,370	0	0	0

	soybean BaseCase	F2010	F2020	F2030	F2040	F2060
ARGX	7,997	5,914	9,710	11,757	19,318	29,901
AUSX	0	0	0	0	4	121
BRZ1X	11,147	8,833	9,947	9,308	11,337	9,715
BRZ2X	8,472	7,725	13,131	18,143	27,939	71,909
CANEX	0	0	0	0	0	0
CANWX	0	0	0	0	0	0
CHIX	0	0	0	0	0	0
EURX	0	0	0	0	0	0
LATX	3,696	4,325	4,022	6,294	5,184	5,371
MEXX	0	0	0	0	0	0
SAX	0	0	0	0	0	0
USEX	0	0	0	0	0	3,122
USGX	19,924	29,484	20,989	23,711	19,316	18,029
USPNWX	6,101	3,601	6,938	7,344	1,670	1,670
US Mex Dir	3,995	2,754	5,000	5,000	5,000	5,000
Grand Total	61,333	62,636	69,736	81,557	89,769	144,838
Total US	30,020	35,839	32,926	36,055	25,986	27,820

	wheat BaseCase	F2010	F2020	F2030	F2040	F2060
ARGX	9,842	8,112	10,029	4,028	0	0
AUSX	19,799	23,167	32,217	44,828	33,210	45,762
BRZ1X	0	0	0	0	0	0
BRZ2X	0	0	0	0	0	0
CANEX	512	512	512	1,003	983	888
CANWX	11,912	10,698	11,935	14,379	16,415	19,381
CHIX	0	0	0	0	0	0
EURX	25,630	41,145	31,681	52,536	74,843	121,092
LATX	0	0	0	0	0	0
MEXX	0	0	0	0	0	0
SAX	24,721	9,454	19,755	17,175	17,386	8,144
USEX	2,554	2,580	2,613	2,147	2,147	2,147
USGX	12,524	10,679	3,597	0	0	0
USPNWX	8,570	7,622	7,622	7,622	7,622	7,622
US Mex Dir	3,234	4,097	4,915	6,074	2,510	0
Grand Total	119,299	118,065	124,877	149,792	155,115	205,035
Total US	26,882	24,978	18,748	15,843	12,279	9,769

Appendix Table A2a Base Case Projections Reach Flows by Grain (000MT)

Total	Base	2010	2020	2030	2040	2060
RCH1	7,154	7,057	7,314	7,192	7,412	1,143
RCH2	3,781	6,273	6,541	5,797	6,087	8,804
RCH3	12,235	12,091	12,235	11,287	11,931	12,235
RCH4	21,771	25,466	26,932	25,988	26,725	24,953
RCH5	4,184	5,938	7,013	6,112	6,742	5,285
RCH6	2,050	4,288	5,461	3,489	4,281	4,659
Total	51,175	61,114	65,496	59,865	63,176	57,078

Corn	Base	2010	2020	2030	2040	2060
RCH1	2,834	2,874	3,340	3,814	4,254	830
RCH2	3,781	5,018	4,743	3,368	3,890	5,442
RCH3	8,657	9,974	9,830	8,618	9,035	9,419
RCH4	14,463	17,149	18,473	17,150	18,484	19,183
RCH5	2,625	4,173	4,965	4,307	4,912	4,661
RCH6	408	1,294	1,709	1,606	2,024	2,071
Total	32,767	40,482	43,061	38,863	42,600	41,606

Soybeans	Base	2010	2020	2030	2040	2060
RCH1	2,556	3,222	3,007	3,378	3,158	312
RCH2	0	1,255	1,797	2,429	2,196	3,362
RCH3	3,578	2,117	2,405	2,669	2,896	2,816
RCH4	6,945	8,052	8,122	8,837	8,240	5,770
RCH5	1,283	1,543	1,771	1,805	1,829	624
RCH6	804	1,521	1,937	1,884	2,257	2,587
Total	15,166	17,709	19,039	21,002	20,577	15,472

Wheat	Base	2010	2020	2030	2040	2060
RCH1	1,764	962	967	0	0	0
RCH2	0	0	0	0	0	0
RCH3	0	0	0	0	0	0
RCH4	364	265	337	0	0	0
RCH5	276	221	276	0	0	0
RCH6	838	1,473	1,816	0	0	0
Total	3,242	2,922	3,396	0	0	0

Appendix Table A2b. Expanded Capacity Reach Flows by Grain (000MT)

Total

	Base	2010	2020	2030	2040	2060
RCH1	7,154	7,057	9,332	6,332	6,849	0
RCH2	3,781	6,273	8,185	6,958	7,426	11,991
RCH3	12,235	12,091	12,235	11,714	12,235	12,235
RCH4	21,771	25,466	30,079	28,406	29,811	27,514
RCH5	4,184	5,938	5,797	4,129	4,537	3,708
RCH6	2,050	4,288	3,896	3,282	3,449	4,165
Total	51,175	61,114	69,523	60,821	64,308	59,613

Corn

	Base	2010	2020	2030	2040	2060
RCH1	2,834	2,874	4,139	3,814	4,254	0
RCH2	3,781	5,018	5,432	3,894	4,579	6,766
RCH3	8,657	9,974	9,830	9,046	9,339	9,419
RCH4	14,463	17,149	20,559	18,187	19,112	20,136
RCH5	2,625	4,173	3,986	3,170	3,535	3,708
RCH6	408	1,294	1,208	1,398	1,590	1,578
Total	32,767	40,482	45,154	39,509	42,408	41,606

Soybeans

	Base	2010	2020	2030	2040	2060
RCH1	2,556	3,222	3,661	2,518	2,595	0
RCH2	0	1,255	2,753	3,064	2,847	5,225
RCH3	3,578	2,117	2,405	2,669	2,896	2,816
RCH4	6,945	8,052	9,183	10,219	10,700	7,378
RCH5	1,283	1,543	1,536	959	1,003	0
RCH6	804	1,521	1,437	1,884	1,859	2,587
Total	15,166	17,709	20,974	21,313	21,900	18,007

Wheat

	Base	2010	2020	2030	2040	2060
RCH1	1,764	962	1,532	0	0	0
RCH2	0	0	0	0	0	0
RCH3	0	0	0	0	0	0
RCH4	364	265	337	0	0	0
RCH5	276	221	276	0	0	0
RCH6	838	1,473	1,250	0	0	0
Total	3,242	2,922	3,396	0	0	0

Appendix Table A2c High Ethanol Sensitivity Reach Flows by Grain (000MT)

Total	Base	2010	2020	2030	2040	2060
RCH1	7,154	9,420	8,400	2,626	2,088	0
RCH2	3,781	3,520	2,233	2,564	0	5,225
RCH3	12,235	8,866	8,421	2,663	2,393	2,816
RCH4	21,771	22,976	22,529	10,196	11,176	7,400
RCH5	4,184	4,629	4,193	1,102	837	0
RCH6	2,050	2,257	1,933	1,408	1,181	2,587
Total	51,175	51,668	47,709	20,560	17,676	18,029

Corn	Base	2,010	2,020	2,030	2,040	2,060
RCH1	2,834	3,663	3,349	0	0	0
RCH2	3,781	2,368	1,377	0	0	0
RCH3	8,657	6,708	6,011	0	0	0
RCH4	14,463	14,461	12,984	0	0	0
RCH5	2,625	2,824	2,299	0	0	0
RCH6	408	590	351	0	0	0
Total	32,767	30,615	26,370	0	0	0

Soybeans	Base	2,010	2,020	2,030	2,040	2,060
RCH1	2,556	3,845	3,559	2,626	2,088	0
RCH2	0	1,152	856	2,564	0	5,225
RCH3	3,578	2,158	2,411	2,663	2,393	2,816
RCH4	6,945	8,193	9,206	10,196	11,176	7,400
RCH5	1,283	1,543	1,618	1,102	837	0
RCH6	804	819	854	1,408	1,181	2,587
Total	15,166	17,709	18,504	20,560	17,676	18,029

Wheat	Base	2,010	2,020	2,030	2,040	2,060
RCH1	1,764	1,912	1,493	0	0	0
RCH2	0	0	0	0	0	0
RCH3	0	0	0	0	0	0
RCH4	364	322	338	0	0	0
RCH5	276	262	277	0	0	0
RCH6	838	848	727	0	0	0
Total	3,242	3,345	2,835	0	0	0

Appendix Table A3a Base Projections: Harvested Area by Production Region (Total, 000 Hectares).

Total	Base	2010	2020	2030	2040	2060
ARG	22,887	20,357	21,930	24,754	24,344	26,752
AUS	13,894	14,044	14,729	16,988	13,050	13,985
BRZ N	20,787	19,932	22,232	23,990	26,248	36,713
BRZ S	16,977	16,368	15,785	16,553	16,531	17,270
CAL	2,828	2,785	2,285	2,258	2,230	2,174
CBC	35	34	28	28	27	27
CHI	61,507	59,210	57,942	56,711	57,733	61,727
CMB	1,636	1,354	1,341	1,339	1,322	1,286
CON	2,550	2,665	2,813	3,264	3,212	3,702
CSK	6,049	5,956	4,884	4,823	4,763	4,641
EUR	40,018	39,672	36,927	36,759	36,127	36,742
FSU-ME	71,417	70,483	70,611	76,865	71,765	66,892
JAP	376	305	280	256	231	182
KOR	104	111	116	133	133	149
LAT	8,397	8,185	8,754	11,063	10,020	11,523
MEX	8,253	7,364	9,163	10,498	10,659	12,143
NAF	8,923	9,107	9,732	11,424	11,620	13,668
SA	56,452	54,321	56,650	63,525	67,394	78,798
SAF	26,824	25,616	29,644	35,120	36,479	44,216
SEA	9,990	9,874	9,676	10,448	9,806	9,853
USCP	7,654	8,406	7,595	7,623	7,619	7,709
USCPR	4,976	4,961	5,203	5,409	5,566	5,390
USD	3,180	3,472	3,170	3,843	3,441	3,720
USIAR	2,507	2,900	3,047	3,173	3,271	3,244
USIAW	6,632	7,655	8,053	8,396	8,664	8,539
USILN	5,221	5,999	6,298	6,554	6,752	6,695
USILS	3,848	4,336	4,550	4,733	4,874	4,765
USINN	3,666	4,263	4,482	4,670	4,816	5,195
USINR	986	1,097	1,151	1,197	1,233	1,278
USMI	1,838	2,142	2,238	2,318	2,377	2,324
USMN	3,447	2,556	2,644	2,713	2,570	2,685
USMNR	2,921	1,997	2,089	2,172	2,235	2,234
USMOR	816	928	976	1,018	1,051	1,011
USMOW	2,734	3,097	3,255	3,391	3,130	3,357
USNE	1,634	1,838	1,917	1,982	1,896	2,012
USNP	9,540	9,863	10,039	10,227	9,662	9,953
USOH	3,409	3,962	4,157	4,322	4,021	4,300
USPNW	1,874	1,643	1,608	1,573	1,537	1,467
USSE	4,421	4,854	5,079	5,269	4,902	5,218
USSP	4,453	4,320	3,950	3,924	4,073	4,369
USW	345	371	370	328	312	350
USWIS	1,278	954	994	1,027	1,051	1,057
USWIW	495	355	371	384	374	399
USWNP	2,118	1,897	1,853	1,809	1,765	1,677
Total	459,895	451,608	460,612	494,855	490,887	531,392
Total US	79,992	83,864	85,091	88,056	87,194	88,948

Appendix Table A3a (Continued) Harvested Area by Production Region (Corn, 000 Hectares).

Corn	Base	2010	2020	2030	2040	2060
ARG	2,434	2,134	2,577	2,846	2,731	2,880
AUS	80	74	93	109	110	130
BRZ N	7,707	7,691	7,658	8,480	8,160	8,652
BRZ S	5,385	5,358	5,303	5,837	5,582	5,844
CAL	7	8	8	9	9	9
CBC	0	0	0	0	0	0
CHI	28,350	25,431	24,247	25,605	26,963	29,680
CMB	87	88	90	103	103	98
CON	1,117	1,134	1,168	1,336	1,327	1,496
CSK	0	0	0	0	0	0
EUR	11,381	11,086	11,939	13,190	12,662	13,362
FSU-ME	4,915	5,041	5,294	6,169	6,233	7,248
JAP	1	1	1	1	1	0
KOR	18	19	22	27	29	37
LAT	5,026	4,540	5,387	6,512	6,210	7,606
MEX	7,548	6,780	8,580	9,915	9,942	11,404
NAF	1,108	1,090	1,053	1,130	1,052	1,041
SA	9,238	9,188	9,844	11,398	11,450	13,176
SAF	24,034	22,556	25,876	30,272	31,009	36,897
SEA	8,261	8,018	7,532	7,836	7,050	6,423
USCP	2,533	2,396	2,463	2,535	2,584	2,729
USCPR	2,273	1,947	2,001	2,059	2,099	2,217
USD	468	552	568	584	596	629
USIAR	1,455	1,701	1,748	1,799	1,834	1,937
USIAW	3,566	4,165	4,281	4,406	4,491	4,743
USILN	2,945	3,484	3,581	3,686	3,757	3,968
USILS	1,751	2,038	2,095	2,156	2,198	2,321
USINN	1,776	2,135	2,195	2,259	2,303	2,432
USINR	463	525	540	556	567	598
USMI	777	953	979	1,008	1,028	1,085
USMN	1,231	941	968	996	1,015	1,072
USMNR	1,623	1,245	1,280	1,317	1,343	1,418
USMOR	284	336	345	355	362	382
USMOW	882	1,045	1,074	1,105	1,127	1,190
USNE	874	992	1,019	1,049	1,069	1,129
USNP	2,146	2,469	2,538	2,612	2,663	2,812
USOH	1,259	1,505	1,547	1,592	1,623	1,714
USPNW	84	83	86	88	90	95
USSE	1,481	1,705	1,752	1,803	1,838	1,941
USSP	785	955	981	1,010	1,029	1,087
USW	77	81	83	86	87	92
USWIS	731	615	632	651	664	701
USWIW	322	255	262	269	275	290
USWNP	26	32	32	33	34	36
Total	146,507	142,393	149,722	164,788	165,298	182,603
Total US	29,810	32,156	33,052	34,013	34,675	36,621

Appendix Table A3a (Continued) Harvested Area by Production Region (Soybeans, 000 Hectares).

Soybeans	Base	2010	2020	2030	2040	2060
ARG	14,534	13,335	14,426	16,942	16,608	18,790
AUS	35	36	37	36	34	52
BRZ N	11,587	11,020	13,366	14,314	16,905	26,903
BRZ S	10,367	9,728	9,334	9,475	9,616	9,905
CAL	0	0	0	0	0	0
CBC	0	0	0	0	0	0
CHI	9,501	10,524	11,239	13,296	13,618	16,210
CMB	0	0	0	0	0	0
CON	1,129	1,229	1,347	1,600	1,646	1,973
CSK	0	0	0	0	0	0
EUR	692	708	740	858	864	998
FSU-ME	1,032	858	1,066	1,210	1,194	1,328
JAP	146	127	123	120	116	109
KOR	83	89	90	102	99	108
LAT	2,319	2,596	2,323	3,397	2,700	3,077
MEX	76	78	100	122	144	188
NAF	14	16	20	27	31	42
SA	6,108	7,360	9,165	12,201	13,731	18,836
SAF	710	733	951	1,168	1,386	1,821
SEA	1,632	1,776	2,065	2,533	2,676	3,351
USCP	821	951	1,008	1,066	1,115	1,232
USCPR	2,200	2,580	2,733	2,891	3,023	2,750
USD	2,340	2,623	2,313	2,975	2,572	2,830
USIAR	1,047	1,196	1,295	1,370	1,433	1,303
USIAW	3,062	3,487	3,769	3,987	4,169	3,792
USILN	2,191	2,455	2,646	2,800	2,928	2,663
USILS	1,817	2,081	2,204	2,332	2,439	2,218
USINN	1,785	2,040	2,183	2,310	2,415	2,670
USINR	450	516	547	578	605	621
USMI	802	919	995	1,053	1,101	1,001
USMN	1,581	924	979	1,036	895	985
USMNR	1,273	730	788	834	872	793
USMOR	463	541	573	606	634	576
USMOW	1,546	1,807	1,914	2,025	1,750	1,926
USNE	575	643	699	740	639	704
USNP	3,113	3,418	3,620	3,829	3,310	3,642
USOH	1,790	2,106	2,231	2,360	2,040	2,245
USPNW	0	0	0	0	0	0
USSE	2,234	2,459	2,653	2,807	2,426	2,670
USSP	227	259	226	238	251	276
USW	0	0	0	0	0	0
USWIS	459	268	284	300	314	286
USWIW	169	96	105	111	96	105
USWNP	0	0	0	0	0	0
Total	89,908	92,312	100,157	113,648	116,393	138,980
Total US	29,943	32,099	33,764	36,248	35,026	35,289

Appendix Table A3a (Continued) Harvested Area by Production Region (Wheat, 000 Hectares).

Wheat	Base	2010	2020	2030	2040	2060
ARG	5,920	4,888	4,927	4,966	5,004	5,082
AUS	13,779	13,933	14,598	16,843	12,905	13,803
BRZ N	1,493	1,221	1,209	1,196	1,184	1,159
BRZ S	1,225	1,282	1,147	1,241	1,334	1,520
CAL	2,821	2,777	2,278	2,249	2,221	2,165
CBC	35	34	28	28	27	27
CHI	23,656	23,256	22,456	17,810	17,152	15,837
CMB	1,549	1,266	1,251	1,235	1,220	1,189
CON	304	302	298	328	239	233
CSK	6,049	5,956	4,884	4,823	4,763	4,641
EUR	27,945	27,879	24,248	22,710	22,601	22,383
FSU-ME	65,470	64,584	64,252	69,486	64,338	58,316
JAP	228	177	157	136	115	73
KOR	3	3	3	4	4	4
LAT	1,052	1,049	1,044	1,154	1,109	840
MEX	628	506	483	461	574	551
NAF	7,801	8,001	8,659	10,267	10,537	12,586
SA	41,106	37,773	37,640	39,927	42,213	46,786
SAF	2,081	2,326	2,818	3,680	4,084	5,498
SEA	97	79	79	79	79	79
USCP	4,300	5,059	4,124	4,023	3,921	3,748
USCPR	503	434	469	458	444	423
USD	373	297	290	283	274	261
USIAR	5	4	4	4	4	4
USIAW	4	3	4	4	3	3
USILN	85	59	71	69	67	64
USILS	279	216	251	245	238	226
USINN	105	88	104	101	98	94
USINR	73	56	65	63	61	58
USMI	259	270	263	257	249	237
USMN	635	691	697	682	660	628
USMNR	25	21	21	20	20	23
USMOR	69	51	59	57	55	53
USMOW	307	245	267	261	253	241
USNE	185	203	198	194	188	179
USNP	4,281	3,977	3,881	3,785	3,690	3,498
USOH	360	351	379	370	358	341
USPNW	1,790	1,560	1,522	1,485	1,447	1,372
USSE	707	690	674	658	637	607
USSP	3,441	3,106	2,743	2,676	2,793	3,005
USW	269	290	287	243	225	258
USWIS	89	71	78	76	74	70
USWIW	5	4	5	4	4	4
USWNP	2,092	1,866	1,821	1,776	1,731	1,641
Total	223,480	216,903	210,734	216,419	209,197	209,809
Total US	20,239	19,609	18,275	17,795	17,493	17,039

Appendix Table A3b High Ethanol Sensitivity: Harvested Area by Production Region (Total, 000 Hectares).

Total	Base	2010	2020	2030	2040	2060
ARG	22,887	20,867	22,195	23,640	24,676	27,010
AUS	13,894	14,441	16,239	18,840	13,063	14,002
BRZ N	20,787	20,076	22,321	24,917	26,298	34,649
BRZ S	16,977	15,706	16,330	17,190	17,211	17,792
CAL	2,828	2,314	2,286	2,259	2,231	2,174
CBC	35	35	28	28	27	27
CHI	61,507	59,842	57,008	58,163	59,391	63,176
CMB	1,636	1,356	1,350	1,350	1,329	1,286
CON	2,550	2,741	3,102	3,620	3,574	4,012
CSK	6,049	5,613	4,884	4,823	4,763	4,641
EUR	40,018	41,363	36,801	38,294	37,774	38,027
FSU-ME	71,417	72,478	77,870	77,671	72,669	67,659
JAP	376	305	280	256	231	182
KOR	104	114	128	147	147	162
LAT	8,397	8,256	8,556	10,789	10,508	11,141
MEX	8,253	8,982	10,045	11,581	11,939	13,212
NAF	8,923	9,365	10,733	12,672	13,034	14,891
SA	56,452	52,384	58,604	66,103	70,459	81,661
SAF	26,824	25,659	29,934	35,522	36,977	44,707
SEA	9,990	10,134	10,663	11,581	10,990	10,727
USCP	7,654	8,483	7,604	7,615	7,636	7,706
USCPR	4,976	5,006	5,216	5,397	4,974	5,391
USD	3,180	3,503	3,173	3,807	3,445	3,721
USIAR	2,507	2,927	3,055	3,166	3,286	3,245
USIAW	6,632	7,724	8,074	8,377	8,130	8,542
USILN	5,221	6,053	6,314	6,540	6,783	7,273
USILS	3,848	4,375	4,517	4,723	4,420	4,767
USINN	3,666	4,302	4,493	4,659	4,838	5,199
USINR	986	1,107	1,154	1,195	1,130	1,326
USMI	1,838	2,161	2,243	2,313	2,192	2,325
USMN	3,447	2,579	2,474	2,707	2,460	2,687
USMNR	2,921	2,015	2,094	2,167	2,090	2,235
USMOR	816	936	968	1,016	933	1,012
USMOW	2,734	3,125	3,182	3,384	3,091	3,358
USNE	1,634	1,854	1,922	1,978	1,902	2,013
USNP	9,540	9,862	9,403	9,912	9,674	9,955
USOH	3,409	3,998	4,167	4,313	4,030	4,302
USPNW	1,874	1,643	1,608	1,573	1,538	1,467
USSE	4,421	4,899	4,493	5,257	4,799	5,220
USSP	4,453	4,024	3,953	3,922	3,893	4,372
USW	345	375	319	335	312	351
USWIS	1,278	963	997	1,025	1,000	1,057
USWIW	495	358	372	384	376	399
USWNP	2,118	1,897	1,853	1,809	1,765	1,677
Total	459,895	456,201	473,005	507,018	501,989	540,738
Total US	79,992	84,171	83,648	87,571	84,697	89,598

Appendix Table A3b (Continued) High Ethanol Sensitivity: Harvested Area by Production Region (Corn, 000 Hectares).

Corn	Base	2010	2020	2030	2040	2060
ARG	2,434	2,643	2,842	3,157	3,064	3,137
AUS	80	89	102	121	124	141
BRZ N	7,707	7,835	8,445	9,406	9,153	9,425
BRZ S	5,385	5,458	5,848	6,474	6,261	6,367
CAL	7	8	9	10	10	9
CBC	0	0	0	0	0	0
CHI	28,350	25,431	24,247	25,605	26,963	29,680
CMB	87	89	100	115	109	98
CON	1,117	1,155	1,288	1,482	1,488	1,630
CSK	0	0	0	0	0	0
EUR	11,381	12,242	13,166	14,631	14,204	14,557
FSU-ME	4,915	5,135	5,838	6,843	6,992	7,897
JAP	1	1	1	1	1	0
KOR	18	19	24	30	33	40
LAT	5,026	4,709	5,082	6,458	6,564	7,224
MEX	7,548	8,398	9,462	10,998	11,152	12,424
NAF	1,108	1,110	1,161	1,253	1,180	1,134
SA	9,238	9,616	10,856	12,643	12,844	14,355
SAF	24,034	22,556	25,876	30,272	31,009	36,897
SEA	8,261	8,168	8,306	8,692	7,909	6,997
USCP	2,533	2,395	2,469	2,529	2,596	2,731
USCPR	2,273	1,946	2,006	2,055	2,109	2,219
USD	468	552	569	583	598	629
USIAR	1,455	1,700	1,753	1,795	1,842	1,938
USIAW	3,566	4,164	4,292	4,396	4,512	4,746
USILN	2,945	3,483	3,591	3,677	3,774	3,971
USILS	1,751	2,038	2,100	2,151	2,208	2,323
USINN	1,776	2,135	2,200	2,254	2,313	2,433
USINR	463	525	541	555	569	599
USMI	777	953	982	1,006	1,032	1,086
USMN	1,231	941	970	993	1,020	1,073
USMNR	1,623	1,245	1,283	1,314	1,349	1,419
USMOR	284	336	346	354	364	383
USMOW	882	1,045	1,077	1,103	1,132	1,191
USNE	874	991	1,022	1,047	1,074	1,130
USNP	2,146	2,468	2,544	2,606	2,675	2,814
USOH	1,259	1,505	1,551	1,589	1,630	1,715
USPNW	84	83	86	88	90	95
USSE	1,481	1,704	1,756	1,799	1,846	1,942
USSP	785	954	984	1,008	1,034	1,088
USW	77	81	84	86	88	92
USWIS	731	615	634	649	667	701
USWIW	322	255	262	269	276	290
USWNP	26	32	33	33	34	36
Total	146,507	146,810	155,788	172,129	173,892	188,658
Total US	29,810	32,146	33,136	33,938	34,832	36,645

Appendix Table A3b (Continued) High Ethanol Sensitivity: Harvested Area by Production Region (Soybeans, 000 Hectares).

Soybeans	Base	2010	2020	2030	2040	2060
ARG	14,534	13,335	14,426	15,517	16,608	18,790
AUS	35	37	37	36	34	57
BRZ N	11,587	11,020	12,667	14,314	15,961	24,065
BRZ S	10,367	9,193	9,334	9,475	9,616	9,905
CAL	0	0	0	0	0	0
CBC	0	0	0	0	0	0
CHI	9,501	10,721	12,395	14,748	15,275	17,659
CMB	0	0	0	0	0	0
CON	1,129	1,278	1,485	1,775	1,846	2,149
CSK	0	0	0	0	0	0
EUR	692	721	816	952	969	1,087
FSU-ME	1,032	1,063	1,175	1,342	1,339	1,447
JAP	146	127	123	120	116	109
KOR	83	91	100	113	111	118
LAT	2,319	2,478	2,323	3,050	2,700	3,077
MEX	76	78	100	122	144	188
NAF	14	16	22	30	34	46
SA	6,108	7,414	10,107	13,533	15,402	20,521
SAF	710	733	951	1,168	1,386	1,821
SEA	1,632	1,887	2,277	2,810	3,002	3,651
USCP	821	951	1,010	1,064	1,120	1,233
USCPR	2,200	2,579	2,740	2,884	2,498	2,750
USD	2,340	2,655	2,313	2,942	2,572	2,830
USIAR	1,047	1,222	1,298	1,367	1,439	1,303
USIAW	3,062	3,557	3,778	3,978	3,616	3,792
USILN	2,191	2,498	2,653	2,793	2,941	3,239
USILS	1,817	2,080	2,210	2,327	2,015	2,218
USINN	1,785	2,061	2,189	2,304	2,426	2,672
USINR	450	516	548	577	500	669
USMI	802	939	998	1,050	910	1,001
USMN	1,581	924	805	1,033	895	985
USMNR	1,273	744	790	832	721	793
USMOR	463	541	574	604	524	576
USMOW	1,546	1,807	1,885	2,020	1,750	1,926
USNE	575	660	701	738	639	704
USNP	3,113	3,416	2,977	3,520	3,310	3,642
USOH	1,790	2,106	2,237	2,355	2,040	2,245
USPNW	0	0	0	0	0	0
USSE	2,234	2,504	2,182	2,801	2,426	2,670
USSP	227	259	226	238	251	276
USW	0	0	0	0	0	0
USWIS	459	268	285	300	260	286
USWIW	169	99	105	110	96	105
USWNP	0	0	0	0	0	0
Total	89,908	92,577	100,843	114,946	117,493	140,605
Total US	29,943	32,385	32,503	35,840	32,948	35,915

Appendix Table A3b (Continued) High Ethanol Sensitivity: Harvested Area by Production Region (Wheat, 000 Hectares).

Wheat	Base	2010	2020	2030	2040	2060
ARG	5,920	4,888	4,927	4,966	5,004	5,082
AUS	13,779	14,315	16,099	18,683	12,905	13,803
BRZ N	1,493	1,221	1,209	1,196	1,184	1,159
BRZ S	1,225	1,054	1,147	1,241	1,334	1,520
CAL	2,821	2,306	2,278	2,249	2,221	2,165
CBC	35	35	28	28	27	27
CHI	23,656	23,691	20,367	17,810	17,152	15,837
CMB	1,549	1,266	1,251	1,235	1,220	1,189
CON	304	308	329	363	239	233
CSK	6,049	5,613	4,884	4,823	4,763	4,641
EUR	27,945	28,400	22,819	22,710	22,601	22,383
FSU-ME	65,470	66,280	70,857	69,486	64,338	58,316
JAP	228	177	157	136	115	73
KOR	3	3	4	5	3	4
LAT	1,052	1,069	1,151	1,280	1,244	840
MEX	628	506	483	461	643	600
NAF	7,801	8,238	9,550	11,389	11,820	13,711
SA	41,106	35,354	37,640	39,927	42,213	46,786
SAF	2,081	2,370	3,107	4,082	4,581	5,990
SEA	97	79	79	79	79	79
USCP	4,300	5,137	4,124	4,023	3,921	3,743
USCPR	503	481	470	457	367	423
USD	373	297	290	282	275	261
USIAR	5	4	4	4	4	4
USIAW	4	4	4	4	3	3
USILN	85	72	71	69	67	64
USILS	279	257	206	245	196	226
USINN	105	106	104	101	99	94
USINR	73	66	65	63	61	58
USMI	259	270	264	257	250	237
USMN	635	714	699	680	545	629
USMNR	25	26	21	20	20	23
USMOR	69	60	48	57	46	53
USMOW	307	274	220	261	209	241
USNE	185	203	199	193	189	179
USNP	4,281	3,977	3,881	3,785	3,690	3,498
USOH	360	388	380	369	360	341
USPNW	1,790	1,560	1,522	1,485	1,447	1,372
USSE	707	690	554	657	527	608
USSP	3,441	2,811	2,743	2,676	2,608	3,007
USW	269	293	236	249	224	258
USWIS	89	80	78	76	74	70
USWIW	5	5	5	4	4	4
USWNP	2,092	1,866	1,821	1,776	1,731	1,641
Total	223,480	216,813	216,374	219,943	210,604	211,475
Total US	20,239	19,639	18,009	17,793	16,916	17,038

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

Appendix

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 appendix provides all the background data, manipulations and description of the methodology. provides the summary for this study and the major results. An accompanying report titled *Longer-Term Forecasting of Commodity Flows on the Mississippi River: Application to Grains and World Trade* provides a summary of the problem, the results and implications.

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1. Review of Studies

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, 2003, etc.) caution about the use of these types of models for infrastructure planning.

Some studies have forecast trade flows, either internal or seaborne, utilizing past relationships for flows. Studies that have focused on Mississippi river traffic include Babcock and Xiaohua; Jack Faucett Associates 1997, 2000; and Tang. Others include Veenstra and Haralambides who focused on major seaborne trade flows. Babcock and Xiaohua 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. They indicate results for the models produced long-term seaborne trade flow estimates that had relatively small forecast errors.

Several studies have focused specifically on transport infrastructure and trade flows.[1] 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. The model examined the effects of a proposal to increase barge fuel taxes from $0.20/gallon to $1.20/gallon on agricultural exports of corn and soybeans. Barge costs were estimated utilizing a barge costing model from Reebie Associates. 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. They found increases in barge fuel taxes would divert 10.6 mmt from inland waterways, of which 70% of diversions would be from the upper Mississippi/Illinois river system. Producers in Minnesota, Illinois and Iowa would incur 75% of expected decline in producer revenues (151 Million). Total exports of soybeans are nearly unchanged, while corn exports declined 2.2%.

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

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[1] These are not exhaustive. Others, as examples, include Tolliver (2000), Yu, Bessler and Fuller (2005), Yu and Fuller (2005), Fellin, Fuller, Grant and Smotck (2001), Fuller, Fellin, Grant and Bertels (1999), Fuller and Fellin (1997), Fuller and Grant (1993), Fuller and Yu (June 2004), Fuller and Yu (July 2004), Yu and Fuller (September 2003), Gervais, Misawa, McVey and Baumel (2001), Hauser (1986) and Hauser and Grover (1986).

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. 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.

Fuller et al. (2000) used a similar model to evaluate effects of updating the Panama canal and subsequent increase in toll charges on trade flows focusing on barge flows along the Mississippi. They found change in the toll from $1.50/MT to $3.50/MT introduced significant changes in trade flows represented by shifts in corn and soybean exports from gulf ports to Northern Pacific ports and shift from gulf soybean shipments to Asia via the canal to shipments around Africa’s Cape of Good Hope to Asia.

Supply and Demand Elasticities for Transportation Modes.

Some studies have examined supply and demand elasticities for modes of transportation. Oum et al. reviewed recent estimates of price elasticities for different modes of transportation. Reviews of more than 70 studies that report elasticities of demand for several modes of transit and market situations 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 and wheat of -0.52 to -1.18 (3 studies), truck for corn and wheat of -.73 to .99 (2 studies), inland waterways for grain of -.64 to -1.62 (2 studies), and ocean shipping for dry bulk shipments of -.06 to -.25 (1 study). In a subsequent study Oum, Waters and Young (1992) qualified this observation and indicated that “across-the-board generalizations about transport demand are impossible.”

Dager, et al. (2004), reviewed the assumptions on USACE models for Ohio and Upper Mississippi/Illinois river systems. The UMR-IWW group relates maximum willingness to pay as: 1) shift in mode, 2) geographical shift in destination, 3) geographical shift in origin, and 4) a no long-haul transportation alternative. The paper provides evidence to indicate that axioms 2-4 are less likely to occur than axiom 1 and therefore the minimum of alternatives is most likely modal shifts.

They also reviews study by Yu and Fuller that econometrically estimated elasticity of grain barge shipments on the UMR-IWW. Yu and Fuller found elasticities were inelastic for (-.2 for Illinois river, -.6 for reach 3 (Mpls to IA)). Dager al., estimated elasticities for barge shipment as -.7, -.3, -.42 and -.57 for lower Mississippi, middle Mississippi, Illinois and Upper Mississippi river waterways. The inelastic nature of grain barge shipments along UMR-IWW may be due to shifts that have occurred in rail equipment (larger cars and locomotives) that have resulted in fewer movement options, rise in direct shipment from growers to barge loading facilities rather than shipment to local elevator and truck/rail shipment to barge facilities. These shifts have resulted in more production areas along rivers being left with fewer alternatives to changes in barge rates. This they argue, reduces potential for axioms 2-4 occurring and argues that only axiom of concern is the shift in mode. However, this study focuses only on barge elasticities of demand.

Two studies analyzed short term supply and demand for rail and barge shipments to the US Gulf and PNW. One analyzed pricing by railroads and estimated a system of structural equations to analyze the dynamic nature of arbitrage (Miljkovic, 2001). Monthly data was used and results indicatd the railroad industry is noncompetitive and rates converge at a different speed in different regions. 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 also significant and important and were inversely related to rail rates. Monthly dummy variables were important as well. In Miljkovic et al, the competition between barge and rail were analyzed using monthly data. 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 traditional ACE economic model estimates 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. Flatter real demand curves for water transportation (the more own-price elastic), the greater the divergence between benefits between traditional ACE predictions and elasticity of demand predictions.

Three prior surveys of journal articles examined elasticities for transportation (Waters, 1984, 1989 and Oum 1990). Conclusions on surveys and recent studies on transportation elasticities indicate 1) Barge own-price elasticities appear greater in absolute value than rail own-price elasticities which are larger than truck own-price elasticities. 2) Absolute long-run rail own price elasticities are slightly greater than 1 and truck are slightly less or near one; Freight elasticities increase as the share of transportation costs in the total production cost increases. 3) Limited results for cross-price elasticities, those that exist are relatively low in absolute value, and 4) Freight own-price elasticities appear to be greater absolute value in markets that have some degree of modal competition and in the case of water transportation.

2. Empirical Model of Spatial Grain Flows

A large number of factors impact the distribution of world grain trade. These include supply and demand in individual countries and regions, production costs, trade and agricultural policies, interior shipping and handling costs and ocean shipping costs. To analyze these factors, a spatial optimization model of world trade in grains was developed. Crops included in the model were corn, soybeans and wheat. Sixteen producing countries and 16 consuming countries and 31 regions were defined and used. Within North America there were 27 producing regions and 15 consuming regions, conforming with traditional production/consumption regions.

This section provides an overview of the procedures and the specification of the analytical model. Agronomic and consumption were estimated econometrically and are described first. Then we describe the spatial optimization model and data sources. There are a large number of variables in this model and the sections that follow provide details on data sources, variable transformations and relationships as well as the historical behavior. These are referred from this section by section numbers that follow.

2.1 Harvested Area, Yields Domestic and Import Demand

Harvested area was used as a constraint in the model as described below. Harvested area was obtained for each of the 3 crops in 44 countries/regions and 27 within North America. This was specified as a function of a trend which represents longer term changes in arable land for each grain in individual countries and regions. Changes in arable land are due to changes in economic conditions, policies and availability of water for agricultural production and trade environments. Harvested area is specified as:

$$HA_{ci} = \gamma_{0ci} + \gamma_{1ci}Trend + e_{cit}$$

where HA is harvested area, Trend is time trend commencing from 1980, c = 1 to 44 and represents producing regions, and i = 1 to 3 and represents crop. The model is estimated with time series data of HA from 1980 to 2004 and the estimated model is used to forecast HA for the projection period. The estimated value was posed as a maximum available land for crop production in each country and region.

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

$$\ln YLD_{cit} = \gamma_{0cit} + \gamma_{1ci}\ln Trend + e_{cit}$$

where YLD is the yield in mt/ha, Trend is time trend commencing from 1980, c = 1 to 44, i = 1 to 3, trend = 1980 to 2004. Annual data for harvested area (HA) and yield (YLD) for the years 1980- 2004 were obtained from USDA PS&D data base (U.S. Department of Agriculture, Foreign Agriculture Service). The estimated model was used to forecast yields of each crop for the projection period.

Consumption functions were estimated for the 3 crops in the 9 countries and 7 multi-country regions. These procedures and results were described in Section 3. Import demand (MD) for each crop in the countries/regions were defined as $MD_{cit} = DD_{cit} - DP_{cit}$ where DP is total production and DD is domestic consumption. The model determines the level of import demand. If MD is positive, country c is an importing country, while country c is an exporting country if MD is negative.

2.2 Spatial Optimization Model

The objective of the model is to minimize production costs of grain and oilseeds in major producing countries and marketing costs from producing regions to consuming regions, subject to meeting import 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. In addition, the model includes agricultural production and export subsidies commonly used as production enhancements means in exporting countries, import tariffs as trade impediments in importing countries and other trade relations that may affect international competition.

The logic to the objective function is that it reflects what would be considered a longer-term competitive equilibrium whereby spatial flows are determined by costs, technical restrictions and other relationships. Under these conditions, trade flows of agricultural commodities would be determined by demand, production costs in producing countries, marketing costs from exporting countries and trade interventions. In addition, yields in producing regions are included to measure efficiency in crop and oilseed production. Demand is projected and the least cost means of meeting that demand is derived. This differs from econometric models that use functional relationships to project equilibrium trade levels, but generally are incapable of capturing spatial elements of competition. Given our objective is to make longer-term forecasts with greater emphasis on spatial and modal distributions, a model based on longer-term competitive equilibrium was developed.

The model is solved jointly for each of the 3 grains. Costs included in the model are direct production costs for each grain in each exporting country and region less production subsidies, interior shipping and handling cost for each grain in each exporting region less export subsidies and ocean shipping costs plus import tariffs.

The model contains 16 exporting countries and 16 importing countries with each type of grain and oilseed having different sets of exporting and importing countries. Some exporting countries are further divided into producing and consuming regions to capture the interdependency between the transportation system and agricultural production.

Transportation modes include truck, rail and barges for inland transportation and ocean vessel for ocean transportation. The model includes six reaches in the United States defined in Section 7. Barge rates are represented as a supply function.[2] Four of the six reaches have delay functions described in Section 8 which reflect the possible river congestion costs which could delay flows and increase costs. The function is a nonlinear exponential function which is near flat until flows increase to a critical level. At the point the delay costs increase sharply which forces the model to shift shipments to either other reaches or downriver to export ports. The rail system is subjected to a car loading capacity constraint, applied globally to all origins. Details of these relationships are described in Section 8.

The objective of the model is to minimize production costs in producing regions in exporting countries and shipping costs from producing regions in exporting countries to importing countries. This objective function is defined as

$$
\begin{aligned}
W = {} & \sum_c \sum_i (PC_{ci} - S_i) A_{ci} + \sum_c \sum_i \sum_j t_{cij} Q^t{}_{cij} \\
& + \sum_c \sum_i \sum_w t^R{}_{cij} Q^R{}_{cij} + \sum_c \sum_i \sum_w t^t{}_{ciw} Q^t{}_{ciw} \\
& \sum_c \sum_i \sum_p t_{cip} Q^R{}_{cip} + \sum \sum \sum (t_{cwp} + B_p) Q^B_{cwp} \\
& + \sum_c \sum_p \sum_q (t_{cpq} + r_q) Q_{cpq}
\end{aligned}
$$

where
i=index for producing regions,
j=index for consuming regions,
p=index for ports in exporting countries,
q=index for ports in importing countries,
w=index for river access point on the Mississippi River system,
B=barge,
R=rail,
T=truck,
PC_{ci}=production cost of crop c in producing region i,
A_{ci}=area used to produce crop c in producing region i,
t=transportation cost per ton,
Q=quantity of grains and oilseed shipped,
S=production subsidies in the exporting country;
r=import tariffs in the importing country;
B=delay costs associated with barge shipments on each of four reaches on the Mississippi river.

The first term on the right-hand side represents production costs in producing regions in

[2]It was not possible to specify rail supply functions due to the market structure of that industry.

exporting countries; the next two terms represent transportation costs for shipping agricultural goods from producing regions to domestic consuming regions for domestic consumption and river access points for exports. The fourth and fifth terms represent transportation cost for producing regions and river access points to ports for exports, respectively. The last term represents ocean shipping from ports in exporting countries to ports in importing countries. Production and export subsidies (S_i) were deducted from production costs and import tariffs (r_q) were added to ocean shipping costs, and to rail shipping costs in the case of Mexico.

The objective function is optimized subject to a set of constraints. Some of these are arable land constraints in exporting countries, demand constraints for each type of grain and oilseed in consuming regions in both exporting and importing countries. This objective function is optimized subject to the following constraints:

1) $$Y_{ci}\ A_{ci} \geq \sum_j Q_{cij} + \sum_p Q_{cip}$$

2) $$\sum_c A_{ci} \leq TA_i$$

3) $$A_{ci} \geq MA_{ci}$$

4) $$\sum_i Q_{cij} \geq D_{cj}$$

5) $$\sum_p Q_{cpq} \geq MD_{cq}$$

6) $$\sum_c \sum_i Q_{ciw} \leq LD_w$$

7) $$\sum_c \sum_i \sum_p Q^R_{cip} + \sum_c \sum_i \sum_j Q^R_{cij} + \sum_c \sum_i \sum_w Q^R_{ciw} \leq MR^{US}$$

8) $$\sum_i Q^R_{cip} + \sum_w Q^W_{cwp} = \sum_q Q_{cpq}$$

where

y=yield per hectare in each country,
TA=total arable land in each producing regions,
MA=minimum land used for each crop in each producing region,
D=Forecasted domestic demand in consuming regions,
MD=forecasted import demand in importing countries,
LD_w throughput capacity for grains and oilseeds at river access point W,
Q^R is quantity shipped by direct rail, and
Q^B is quantity shipped by barge.

Equation 1 indicates that total grains and oilseeds produced in each producing region in exporting countries should be equal or larger than the quantities of grains and oilseeds shipped to domestic consuming regions and export ports. It is assumed that a country exports grains and oilseeds after satisfying its domestic consumption. Under this assumption, exportable surplus is total domestic production of each type of grain and oilseed minus domestic consumption of the individual crops. Equation 2 is the physical constraint of arable land in each producing region. Since total arable land is fixed in each producing region, production activities are optimized within the physical constraint of arable land. The next constraint (Equation 3) represents characteristics of production activities in each producing region in exporting countries. In general, producers in a region tend to produce certain crops due to their experience in production practices and that certain segments of land are more suited to producing one crop over others, and switching to other crops raises costs. To incorporate this characteristic, Equation 3 provides the minimum production constraint for each grain or oilseed.

The demand for grains and oilseeds is estimated to 2060 using econometric techniques and the estimated demands for grains and oilseeds in each consuming region in importing and exporting countries are introduced into the model. Equation 4 represents the domestic demand constraints in consuming regions in exporting countries. The total quantity of grains and oilseeds shipped from producing regions to consuming regions should be larger than or equal to the total quantities needed. Equation 5 represents import demand constraints in importing countries. Equation 6 represents is the handling capacity at river access points in the United States. Equation 7 represents rail capacity constraints, indicating that grains and oilseeds shipped to port, domestic consuming regions and river access points by rail should be less than or equal to the total quantity the U.S. can ship at different capacity levels. The last constraint (Equation 8) is for inventory clearing at ports in exporting countries. Ports in exporting countries are not allowed to carry inventories and are transhipment points for exporting grains and oilseeds. Excess supply of a grain is calculated by subtracting domestic consumption from production under an assumption that carry-over stocks remain constant over time.

Additional Restrictions: The model was calibrated to reflect the flows that occurred during the early 2000's. In addition to the restrictions implied above, some selected restrictions were imposed on the model to calibrate it to current world trade patterns and to US domestic flows.

To calibrate the model to world trade, US shipments to Cuba and North Korea were not allowed. The other was that China would retain its policy of exporting a minimal amount of corn (8 mmt) subject to export subsidies determined annually (see section 8 for details). However, this was relaxed in the sensitivities.

Others are summarized in Table 2.1 and all pertain to wheat. These were applied in order to capture some of the peculiarities associated with world grain shipments. These primarily relate to costs and quality differences between suppliers and importers. The purpose the restrictions are due in part that there are numerous suppliers that are lower cost than North America. However, some importers have product demands and product requirements that require purchasing and imports from these regions, despite that they are higher cost. Australia and Argentina are lower cost producers than North America to many regions. To capture these, we imposed restrictions of varying types to calibrate historical trade flows.

Table 2.1 Constraints Imposed on Model: Market and Trade Policy Restrictions

Exporter	Importer	Restriction	Reason	Impact
US exports	Cuba and N. Korea	Not allowed	Trade policies	Shift trade to other origins
Trade policies impacting wheat				
Canada	United States	3 mmt	Flows in recent years	Negligible
US/Canada East Coast	EU	Only allowed HRS from T. Bay and Duluth based on historical shares	Quality requirements	Disallows Gulf shipments
US/Canada West Coast	Japan ,Korea, Philippines, Singapore, Thailand	Only allowed from HRS and White Wheat regions. Based on historical shares	Quality requirements	Disallows Gulf to these Asian markets at lower cost

Results from the model were also reviewed and experimented with to calibrate it with respect to domestic grain flows over the base period. These were identified generally by comparing model results relative to domestic grain flows and assessing reasons for differences. In doing this, some important observations were related to the below:

Soybeans by barge: The model generated larger flows of soybeans entering the barge system than observed.

Hard wheat shipments by barge: Observed wheat shipments from the hard wheat areas have evolved now to be mostly by direct rail shipment. These were also observed in field work (Dager, 2007). The reason for this is largely due to the needs for blending which is critical for hard wheats. The only places where blending can occur now is at Savage and/or at the Texas Gulf. Thus, the model was restricted as such. Soft wheat from the eastern regions can enter the river system without this restriction as blending is not needed.

Iowa River:[3] This origin has extremely low rail rates relative to other origins and to most destinations. As a result this origin was the lowest cost origin to serve Western Corn belt demands and/or the Southeast. This is despite the common perception that corn from this region is nearly all destined to the River.

In examining the STB data, this is an incorrect common perception in that the amount of corn being shipped from Iowa River to the Western Corn belt by rail is an important movement and its volume has increased from near nil to nearly 500,000 mt in 2004. And, the volume from Iowa West to the Western Corn Belt from 2000 to 2004 has been decreasing over time (from over 1.5 mmt to less than 1 mmt). By fixing other errant domestic flows resulted in flows originating from IAR to barges.

[3]Regional defintions are defined in detail in Sections 6.2 and 7.1.

Southeast and Northeast demand. Initial solutions had these demands being largely served from regions west of the river. These were notably from Iowa (as above) as well as some areas of the Northern Plains, Minnesota River etc. Yet, the STB data suggests that while rates for these movements are observed and lower than for major domestic movements, these flows are virtually nil. These are particularly important given the size of the Southeast market which if unrestricted had the impact of drawing large volumes from some of these regions.

Ohio shipments of grain. Initial solutions had flows from Ohio going largely to the eastern corn belt and no river flows. STB data on flows show Ohio supplying the southeast, northeast and river.

PNW rail shipments. Initial solutions showed to little corn and soybeans being shipped to the PNW for export.

In response to these, a series of adjustments were made to the model in order to more accurately reflect these flows. These are summarized in Table 2.2.

Table 2.2 Changes to Model Specifications to Calibrate Domestic Flows

Region	Change	Effect
Wheat from western regions (NP, MN, MNR, MOW, MOR, CP, CPR, IAR, IAW)	Restricted export wheat shipments from Western origins to be by direct rail	Increases direct rail shipments of wheat to Gulf/PNW and increases barge flows of corn
Corn shipments from Iowa River, Minnesota, Minnesota River and Northern Plains to the Southeast	Restrict domestic rail/truck flows to nil	Increases flows available for the river and/or for the PNW export markets
Corn shipment from Iowa west, Minnesota, Minnesota River, Missouri River and Missouri West to the Northeast	Restrict domestic rail/truck flows to nil	Increases flows available for the river and/or for the PNW export markets
Corn from Minnesota to the Central Plains	Restrict domestic rail flows to nil	Increases flows available for the river and/or for the PNW export markets
Soybeans from the Northern Plains to the Southeast	Restrict domestic rail flows to nil	Increases flows available for the river and/or for the PNW export markets
All grain shipments from Ohio to Eastern Corn Belt	Restrict domestic truck/rail flows to nil	Forces Ohio to ship to NE, SE (normal flows) adds wheat from OH to barge system.

2.3 Base Case Definition, Projection Methodology and Sensitivities

A base case is defined and used for comparison with results from the scenarios. The base case is interpreted as that reflecting the most likely (current) scenario. The base case uses data for the period 2000-2004. The model was used to make projections. To do so, the following logic was used and applied and summarized as:

- Demand is projected for each country and region based on income and population projections from Global Insights;
- Yield and production costs for each producing region are derived;
- Production potential is determined in each country/region subject to the area restriction;

- US modal rates were derived for the period 2000-2004 and it was assumed that their spatial relationship was the same during the projection period.

- Ocean shipping costs were projected based on oil, trend etc.

Using these, the model was solved for each year in the projection horizon which was defined in 10 year increments for 50 years.

Table 2.3 define the major assumptions for the base period and projection period. The model was estimated assuming base case conditions at 2000-2004 values. It was estimated with and without expansion of the barge system. Restrictions were imposed on rail car loading capacity. Modal rates were assumed at 2000-2004 average values, and barge rates were represented as a supply relation and subject to delay costs. Area to these crops in the United States was restricted to 100% of the historical area harvested and yields were based on longer-term trends. These were retained in the projection period, but, both were relaxed as sensitivities. Ethanol use of corn in the United States was assumed at the EIA 2005 (Energy Information Agency) projections. These were revised in 2006 and a sensitivity allowed for this increased demand for corn for ethanol production.

Table 2.3 Base Case Assumptions

Model Assumption	Base Period 2000-2004	Projection Period	Sensitivities during projection period
Barge system capacity	Existing	Existing and expanded capacity	
Non-Grain Barge Traffic	2000-2004 average levels	Assumed same as in base case	
US rail capacity	Restricted capacity to recent maximum shipments		Relaxed
Modal rates	Rail from 2000-2004 average; barge rates represented as supply functions by reach; ocean rates derived from a regression	Retained as in base case	
US Area restrictions	3 restrictions imposed: minimum total area=100% of recent 3 year average; maximum total area=100% of base; maximum area that can be switched among crops was 7% from the base period.	Maximum changed to 107% in 2010 forward	Relaxed to allow expanded area to reach a solution
Rest of World (ROW) area restrictions	3 restrictions imposed: minimum total area=100% of recent 3 year average; maximum total area=107% of base; maximum area that can be switched among crops was 7% from the base period.	Maximum changed to 107% in 2010 forward	Relaxed to allow expanded area to reach a solution
Ethanol production	EIA 2005 projections	EIA 2005 projections	EIA 2006 Projections.
Other Trade policies	Retained	Retained	

Sensitivities and Calibration In calibrating the model, we experimented with numerous variables. Just to mention a few, these included: 1) restricting rail capacities geographically; 2) not restricting US area planted; 3) a revision to allow for adjustments to stocks; 4) and, allowing for rail rates to be related to barge rates; among others. The impacts of these were generally mixed and/or would not be defendable, and were not included in the final model

The model was used to conduct a number of sensitivities. These include:

Ethanol: The base case assumed EIA 2005 projections of corn use in ethanol demand, 100% of US base area and longer-term yield growth rates. The sensitivities involved using EIA 2006 projections, expanding US area base by 7% (approximately the amount of CRP acres), and a more aggressive growth rate in yields.

Rail capacity: The base case assumes a limit on rail capacity. In the longer term rails can and have expanded capacity. In a sensitivity the rail restriction was imposed to show its impact on barge flows.

Alternative China policy: The base case was taken to represent the period 2000-2004. This was a period of transition in China in part due to their joining the WTO. During this period China evolved to be an exporter of corn from Northern China under export subsidies. To execute these shipments, export permits were required.

A sensitivity was performed whereby China's exports were suspended with and without expanded US ethanol production.

South American competitive position: With the rapid growth in South American soybeans, a number of sensitivities were evaluated. One was an increase yield productivity. The other was for reduced shipping costs due to the adoption and development of interior transportation infrastructure.

Panama Canal expansion: There are likely 3 important impacts of the Panama Canal expansion. These are not exactly clear with current available information, but can be inferred for illustrations.

One is for an increase in tolls by $1/mt for construction period (expected to be about 8 years).[4] The second is that an expanded canal would allow for Panamax vessels to be more fully loaded out of the US Gulf (comparable to the PNW). The impact of this is to effectively increase the volume in a ship by about 6000 mt beginning in year 10 which would reduce shipping cost by about $4/mt net of the toll impact.[5] Each of these impacts was assumed in this sensitivity. The third impact may be for the adoption of larger vessels. This impact is highly speculative and would otherwise impact all ports and thus, was not included in the sensitivity.

US Gulf-PNW Ocean spread: An important factor impacting barge demand is the ocean spread going to Asia for shipments from the US Gulf versus the PNW. The base case reflects values

[4]The Canal has suggested that to proceed a national vote must approve the project. This is expected in mid-2006. To proceed, their intent would be to charge a toll increase during the construction period to finance the project. It is not clear of the value of this, so we used the values above for illustration.

[5]This value was derived using empirical data and an economic engineering model of ocean shipping costs.

during the 2000-2004 period. Sensitivities were conducted to evaluate how changes in the spread impacts demand for barge shipments.

2.3 Solution Methodology. The model determines the quantity produced in each country and region, import demand, and trade flows from origins to destinations. The latter are derived for US domestic origins, as well as all international trade flow. The model is nonlinear with numerous restrictions. Hence it was solved using the MINOS algorithm in GAMS. The model has 21,301 variables and 761 restrictions.

3. Consumption Functions and Import Demand

3.1 World Historical Consumption: Wheat, Corn and Soybeans

World consumption on wheat, corn, and soybeans has grown substantially since 1960 Figures 3.1.1-3.1.3). Data used in Sections 3 and 4 were from USDA-FAS PS&D (various years). Separate and more detailed derivations were made for U.S. consumption regions and the impact of ethanol. These are reported in Section 6.

Wheat consumption leveled off during the 1990's, while corn consumption is growing at a steady rate. Soybean consumption is increasing at an increasing rate. Figures 3.1.4 -3.1.6 show the percentage change in wheat, corn and soybean consumption in the major countries/regions of the world. Wheat consumption in South East Asia (SEA) has grown by 157% since 1980 followed by South Africa (99.7%), South Asia (92.8%), and North Africa (80.6%). The world consumption of wheat has grown by 33.5% since 1980. The world consumption of corn has grown by 60% since 1980, Figure 3.1.5. The largest growth is in South Korea (268%) followed by North Africa (191%) and Australia (180%). World soybean consumption has grown by 188% since 1980. The largest growth is in South Asia (1440%) followed by Latin America (1096%) and North Africa (766%).

The largest consumer of wheat for importing countries is China, at around 100 to 110 million metric tons, Figure 3.1.7. The next largest consumer is North Africa (30 million metric tons) followed by SEA (18 million metric tons). South East Asia is the largest corn consuming region among importers at about 30 million metric tons Figure 3.1.8. Mexico (26 million metric tons) is followed by Latin America (18 million metric tons) and Japan (16 million metric tons). China is the largest consuming importing country for soybeans (37 million metric tons) Figure 3.1.9). China is followed by the European Union (19 million metric tons) and SEA (8 million metric tons). China's consumption has increased 330% since 1991.

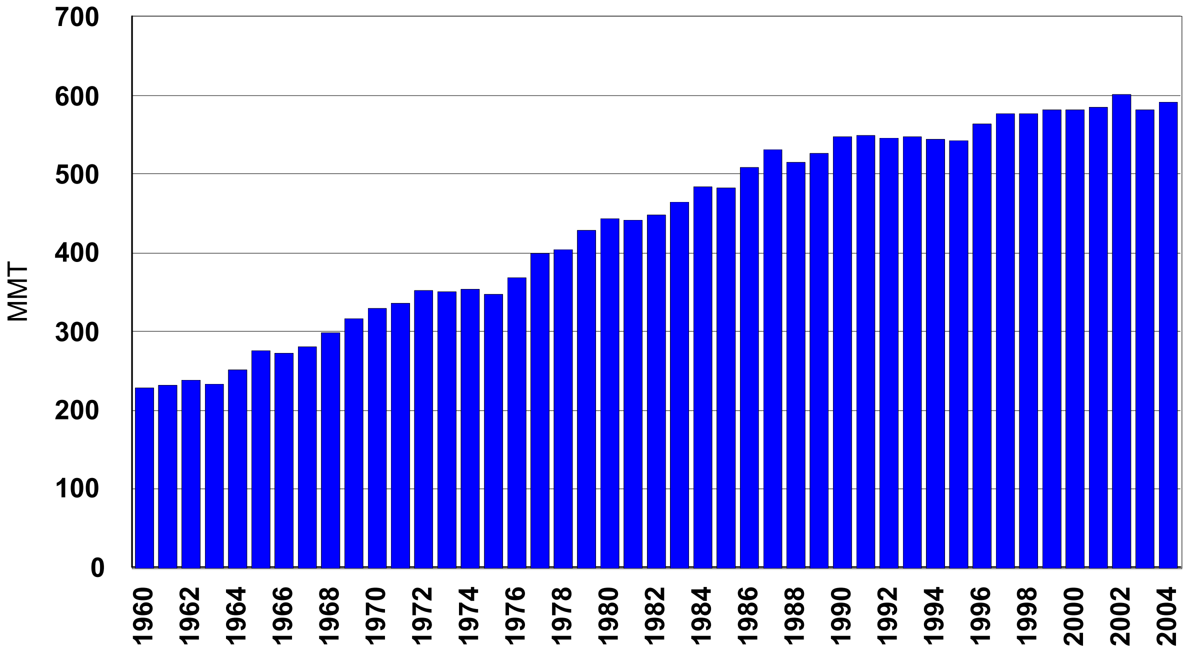

Figure 3.1.1 World Wheat Consumption, 1960-2004.

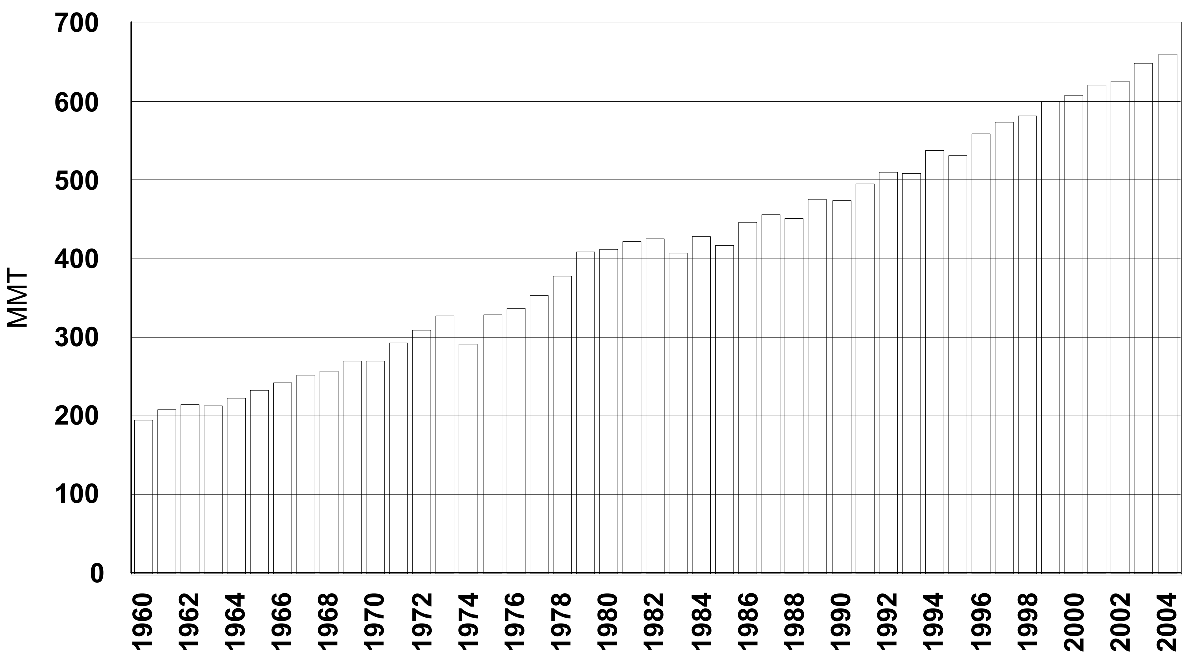

Figure 3.1.2 World Corn Consumption, 1960-2004.

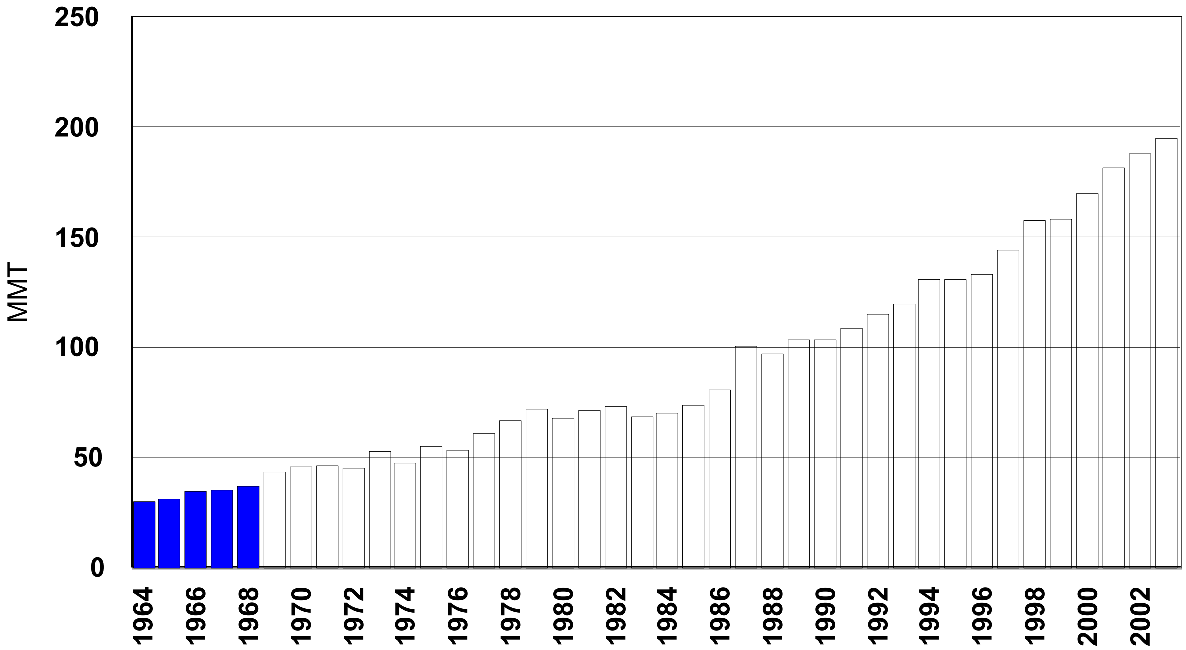

Figure 3.1.3 World Soybean Consumption, 1964-2003.

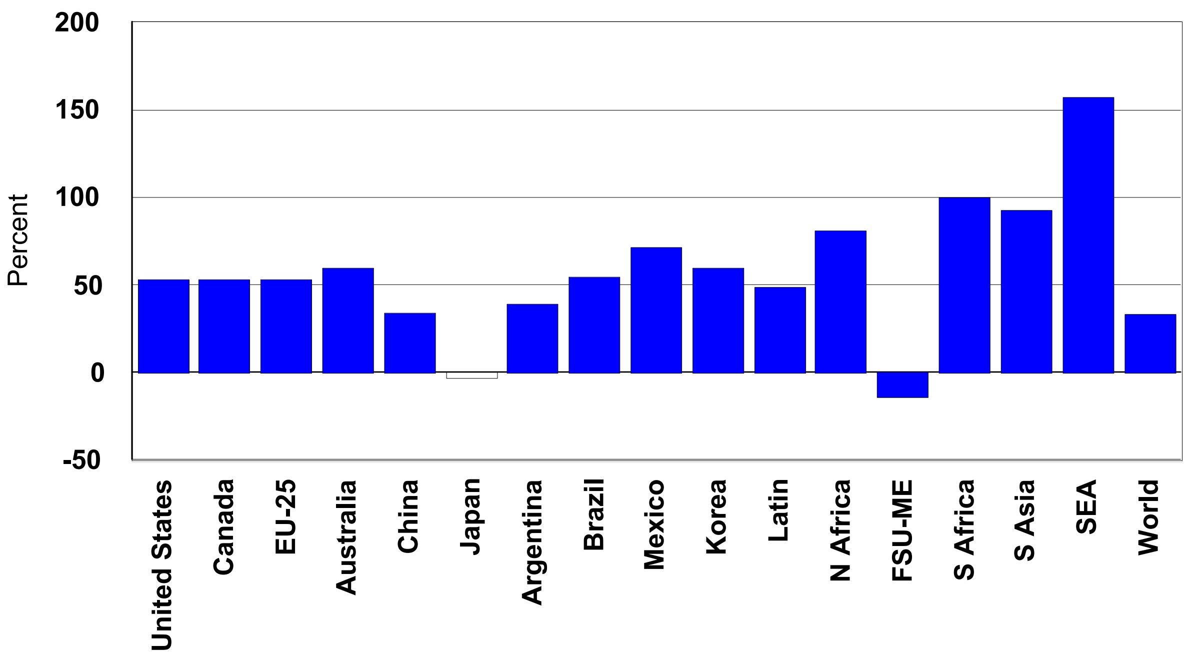

Figure 3.1.4 Change in World Wheat Consumption, 1980-2004.

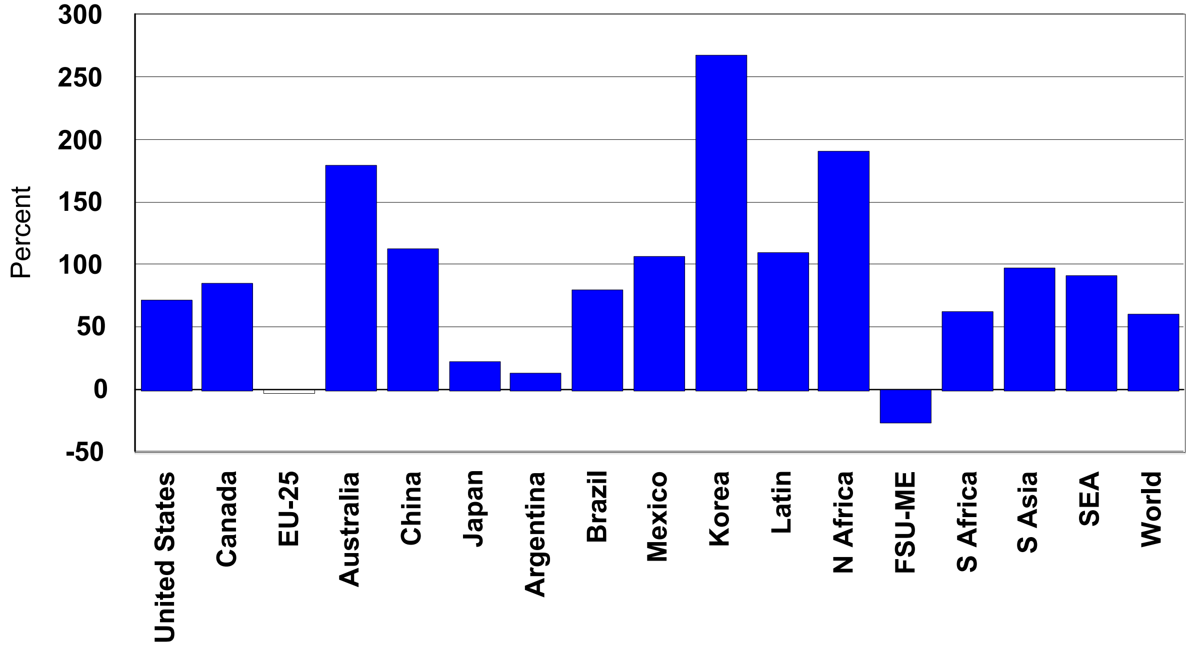

Figure 3.1.5 Change in World Corn Consumption, 1980-2004.

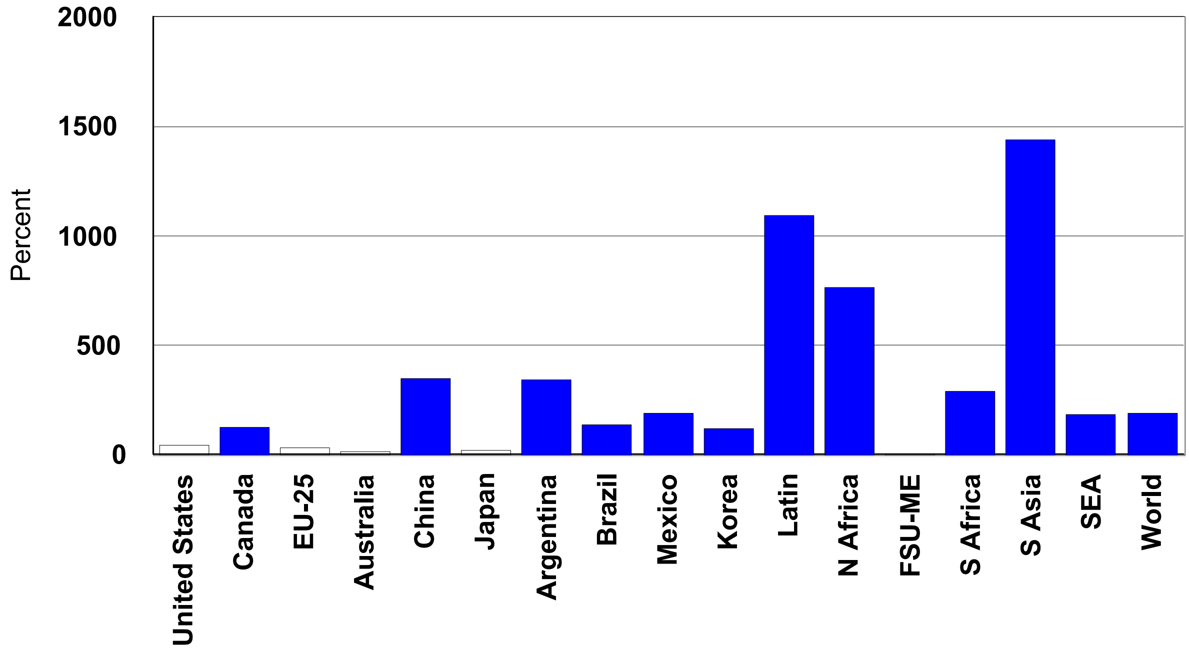

Figure 3.1.6 Change in World Soybean Consumption, 1980-2003.

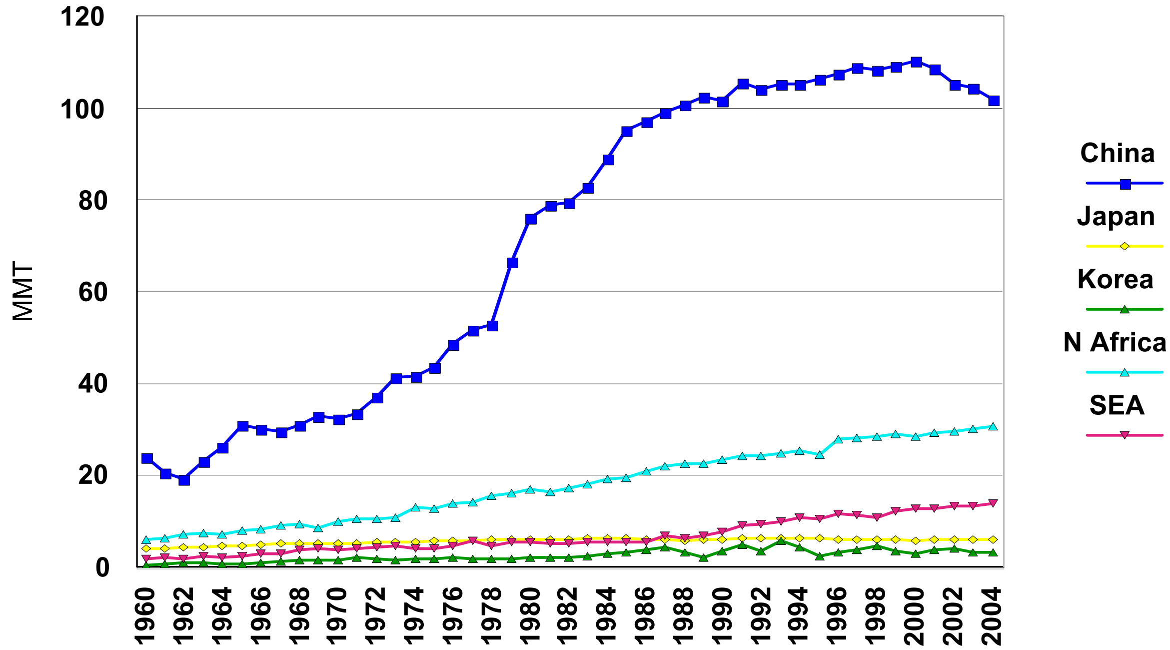

Figure 3.1.7 Wheat Consumption for Selected Importers, 1960-2004.

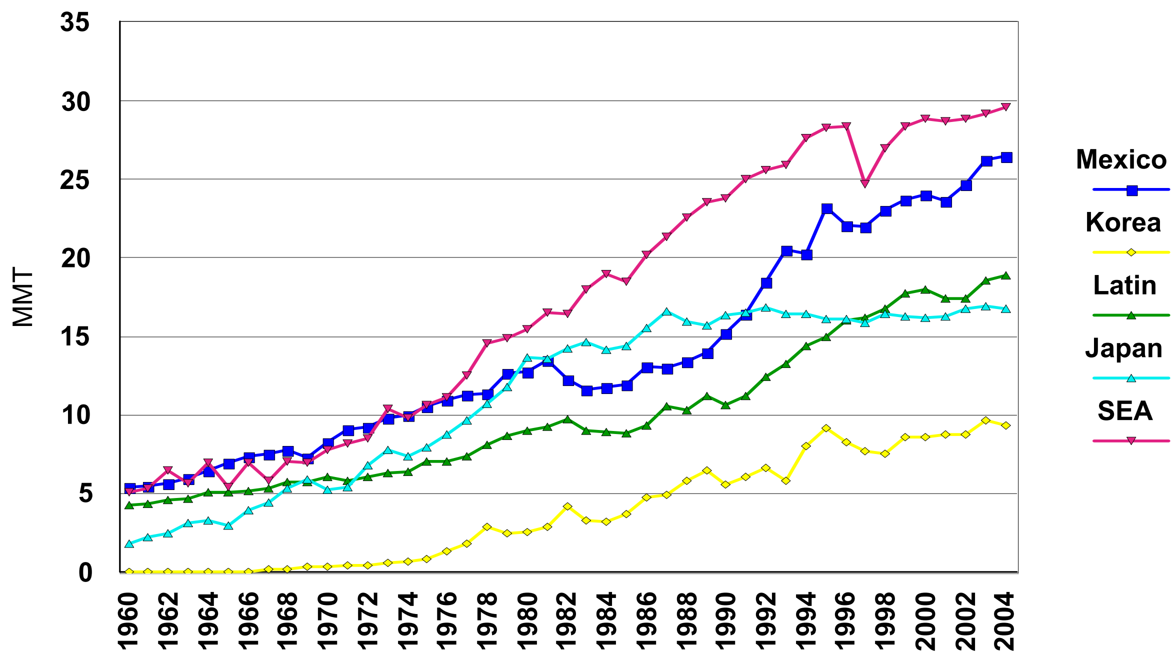

Figure 3.1.8 Corn Consumption for Selected Importers, 1960-2004.

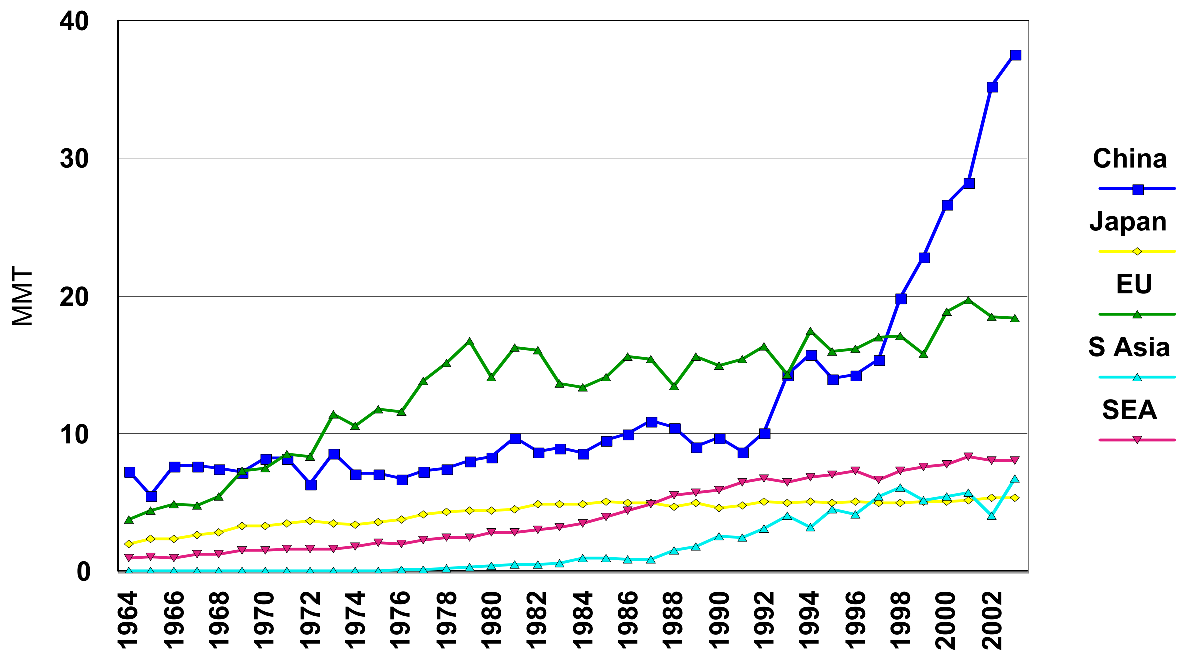

Figure 3.1.9 Soybean Consumption for Selected Importers, 1964-2003.

3.2 Estimation of Consumption Functions.

Consumption functions were estimated for the 3 crops in 16 countries and 11 multi-country regions. Data were taken from USDA-FAS PS&D for consumption and income was obtained from Global Insights. These were estimated using data covering the period 1990 to 2004. Regions and definitions are contained in Table 7.1 of the project's report.

A double log functional form was used because of the nonlinear relationship between income and consumption. However that method assumes that the income elasticity remains constant over time. With a forecast period of 50 years, per capita income increases substantially, especially in developing countries. With the increasing per capita incomes, income elasticities should decrease.

To capture this, the income elasticities for 54 countries were estimated for the three crops using a two-step procedure. First, a consumption function was estimated for each country where:

$$C=f(Y)$$

for each crop where C is per capita consumption and Y is income measured in constant US dollars (from Global Insight). The results generated an income elasticity for each country and crop, E_{ci}.

The second step was to estimate the relationship between the elasticity and the per capita income. The notion here is that as incomes increase, there would be a tendency for the income elasticity to decline. Thus, as a countries' income changes, there is a shift in consumption to be similar to other countries at similar stages in development. An equation was estimated to determine the rate of change in income elasticities as per capita income increases.

$$E_{ci} = C_{ci} - A_{ci}(Y_{ci})^{.5}$$

where

c=country and i=crop. That estimated elasticity was used to generate the consumption response to changes in per capita income.

Table 3.2.1 show the estimated income elasticities for the countries/regions used in the study for the three crops. The three equations are shown in Table 3.2.2. The R^2 are between 0.85 and 0.86 and both the constant term and coefficients are similar. Income elasticities for developed countries, United States, Japan, and Australia are much lower than developing countries like Mexico, China, and Brazil. Figures 3.2.1 -3.2.3 shows the relationship between the estimated income elasticity and per capita income. The data points move from high per capita income and low elasticity to low per capita income and high elasticity.

Table 3.2.1. Income Elasticities for Exporting and Importing Regions/Countries

	Wheat	Corn	Soybean
S Asia	0.51	0.78	0.53
FSU-ME	0.39	0.64	0.41
SEA	0.24	0.48	0.27
Europe	0.16	0.34	0.19
Latin	0.41	0.67	0.44
S Africa	0.60	0.83	0.61
N Africa	0.41	0.66	0.44
Argentina	0.25	0.55	0.29
Australia	0.14	0.32	0.17
Brazil	0.40	0.66	0.43
Canada	0.16	0.30	0.17
Korea	0.19	0.48	0.23
Mexico	0.36	0.63	0.39
United States	0.05	0.11	0.06
Japan	0.16	0.31	0.18
China	0.44	0.73	0.47

Table 3.2.2. Regression Results for the Income Elasticity Equations

	Constant	Coefficient	R^2
Wheat	0.551	-0.078	0.846
	(9.525)	(-23.183)	
Corn	0.836	-0.096	0.862
	(12.438)	(-24.735)	
Soybean	0.574	-0.077	0.856
	(10.424)	(-24.130)	

*t ratios are in ( ).

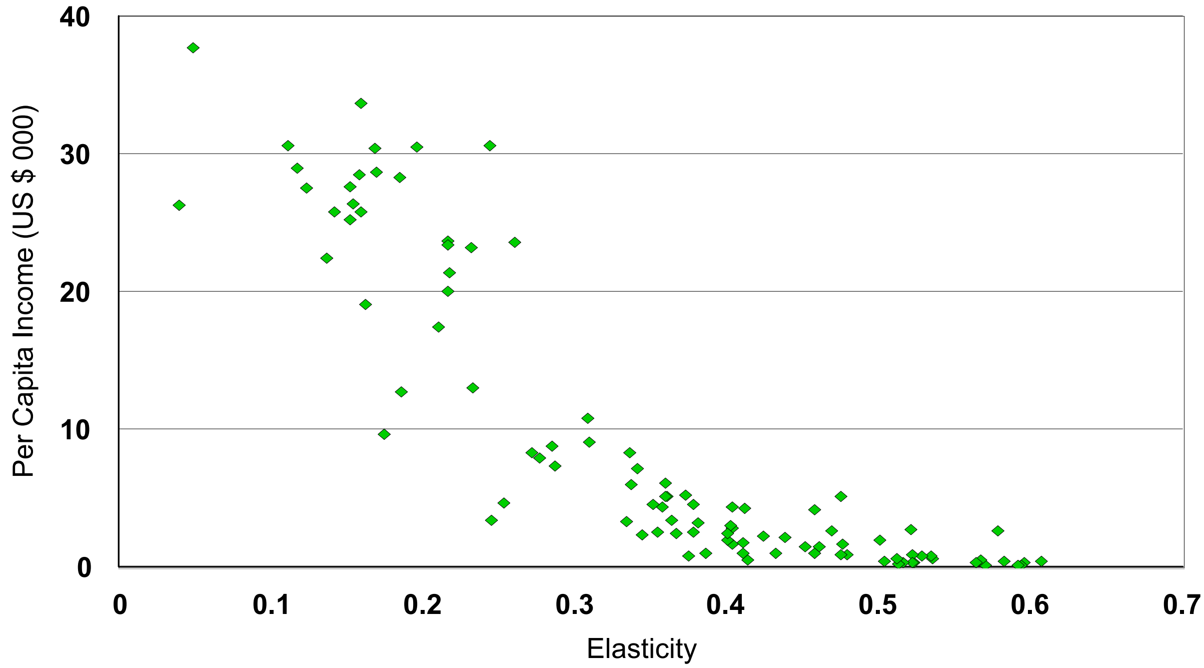

Figure 3.2.1 Income Elasticity for Wheat.

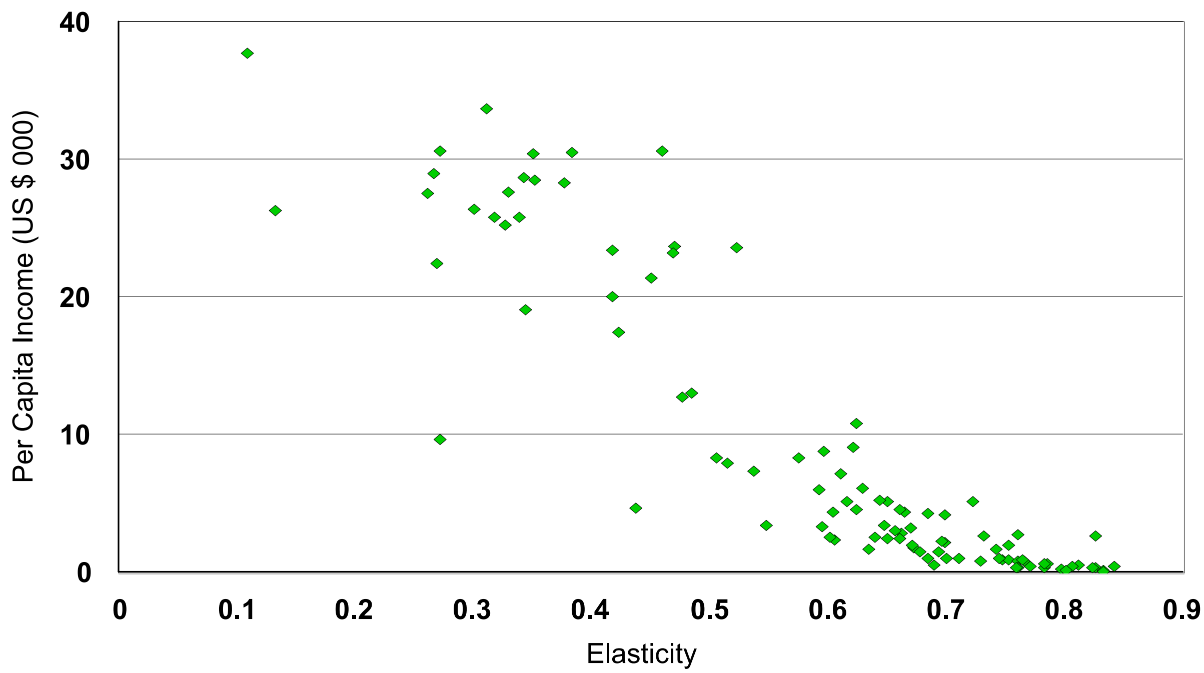

Figure 3.2.2. Income Elasticity for Corn.

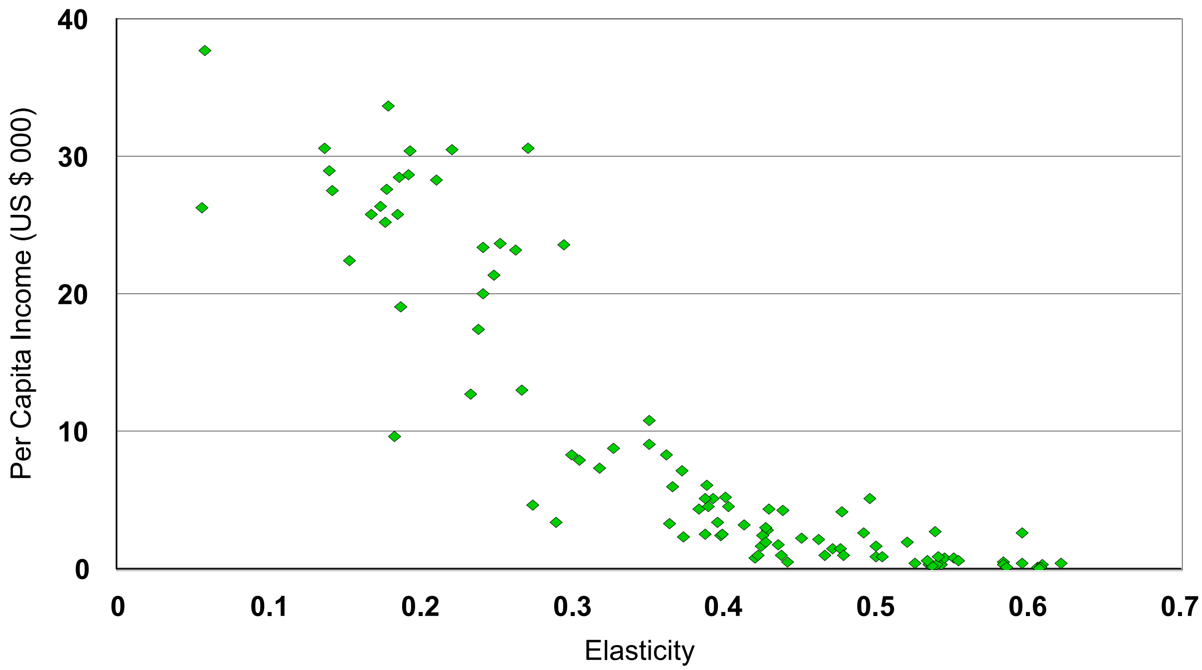

Figure 3.2.3. Income Elasticity for Soybeans.

Table 3.2.3 shows the estimated income elasticities for the countries/regions in the study for the selected years between 2003 and 2025. Income elasticities fall from 2003 to 2025. For example, for China soybeans the elasticity falls from 0.47 to 0.40. Regions which are not projected to have substantial income growth, like South Africa the elasticities fall very little.

Table 3.2.3. Estimated Income Elasticities For Selected Regions/countries

	----------------Wheat-------------				--------------Corn--------------				-----------Soybeans----------			
	2004	2010	2015	2025	2004	2010	2015	2025	2004	2010	2015	2025
U. S.	0.05	0.01	-0.02	-0.08	0.11	0.06	0.02	-0.05	0.06	0.02	-0.01	-0.07
Canada	0.16	0.12	0.10	0.07	0.30	0.26	0.24	0.20	0.17	0.14	0.12	0.09
EU	0.16	0.13	0.11	0.07	0.34	0.31	0.29	0.23	0.19	0.16	0.14	0.10
Australia	0.14	0.12	0.10	0.05	0.32	0.28	0.26	0.21	0.17	0.14	0.12	0.08
China	0.44	0.42	0.41	0.37	0.73	0.71	0.69	0.64	0.47	0.45	0.44	0.40
Japan	0.16	0.12	0.10	0.04	0.31	0.26	0.23	0.16	0.18	0.14	0.11	0.06
Argentina	0.25	0.23	0.21	0.18	0.55	0.53	0.51	0.47	0.29	0.27	0.26	0.22
Brazil	0.40	0.39	0.38	0.35	0.66	0.65	0.63	0.60	0.43	0.42	0.40	0.38
Mexico	0.36	0.34	0.33	0.29	0.63	0.61	0.59	0.54	0.39	0.37	0.36	0.32
S. Korea	0.19	0.14	0.10	0.05	0.48	0.41	0.38	0.31	0.23	0.18	0.15	0.10
Latin	0.41	0.39	0.37	0.33	0.67	0.65	0.63	0.58	0.43	0.42	0.40	0.36
N Africa	0.41	0.40	0.39	0.37	0.66	0.64	0.63	0.60	0.44	0.42	0.41	0.39
FSU-ME	0.39	0.37	0.36	0.34	0.64	0.61	0.60	0.57	0.41	0.40	0.38	0.36
S Africa	0.60	0.59	0.59	0.58	0.83	0.82	0.82	0.81	0.61	0.60	0.60	0.59
S Asia	0.51	0.50	0.49	0.48	0.79	0.78	0.77	0.75	0.53	0.52	0.52	0.50
SEA	0.24	0.23	0.22	0.19	0.48	0.46	0.45	0.42	0.27	0.26	0.25	0.22

Using these estimated income elasticities, per capita consumption was calculated. The equation was specified by:

$$PCC_{cit} = (PCC_{cit-1} + (\text{Percent change in } PCI_{cit})(E_{cit})$$

where c= country, 1 to 16, i= crop, 1 to 3, and t=year, 2004 to 2060. From these results, we derived the total domestic demand for each grain in each country or region by multiplying by the population estimate for that year and country. The estimated percent change (to 2025 for illustration) are summarized in Table 3.2.4 and in Figure 3.2.4 for selected countries and regions.

Table 3.2.4. 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

Import demand (MD) for each crop in the countries/regions were defined as $MD_{cit} = DD_{cit} - DP_{cit}$ where total production (DP) and domestic consumption (DD). If MD is positive, country c is an importing country, while country c is an exporting country if MD is negative.

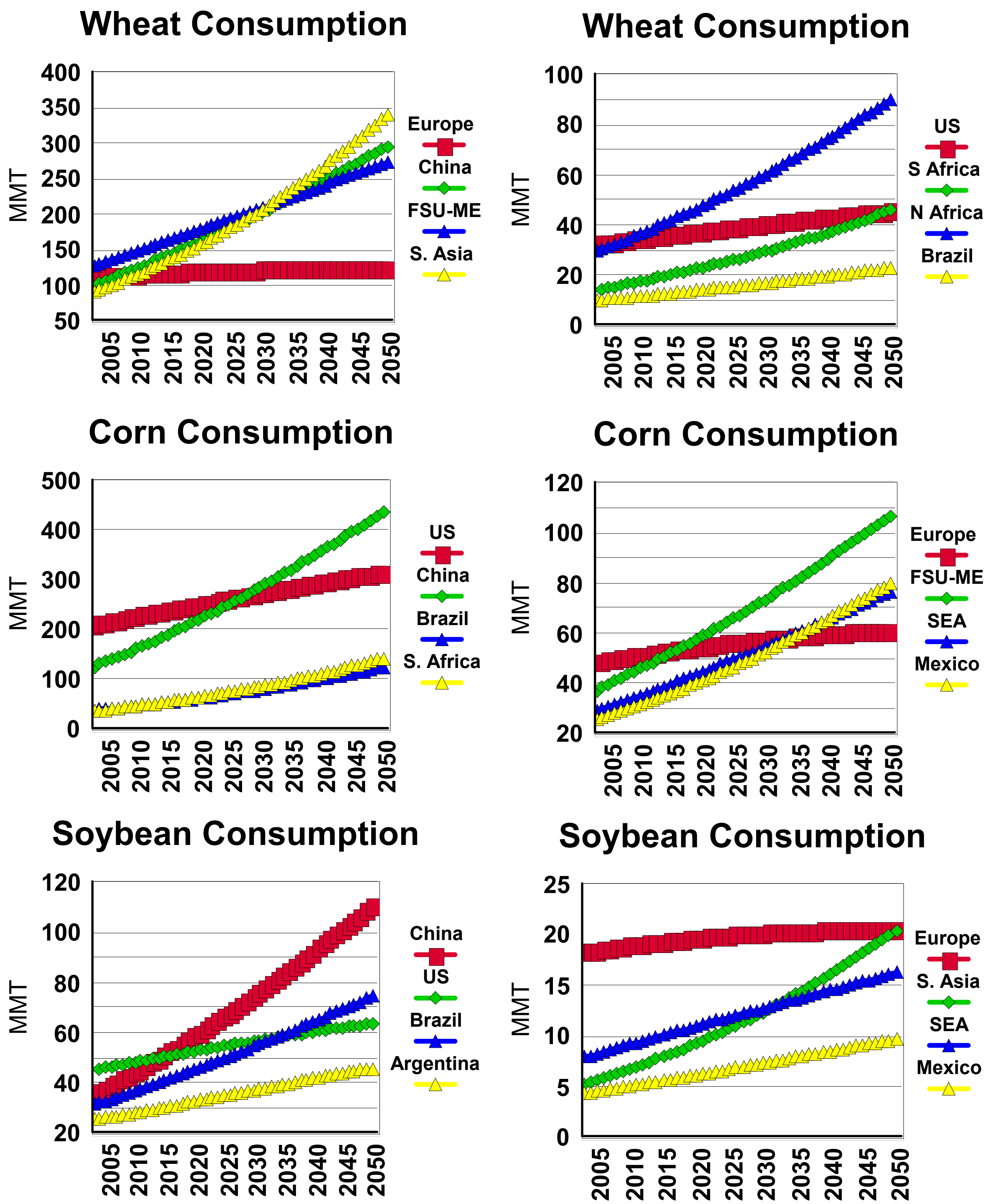

Figure 3.2.4 Forecast Consumption for Selected Importing Countries/Regions 2005-2050.

4. World Production: Area and Yield Projections

4.1 Historical Yields: Wheat, Corn, and Soybeans Table 4.1 shows the historical yields for wheat in major producing countries. Europe has the highest yield followed by the United States. Wheat yields in Australia and Argentina have increased the greatest since 1980, 69% and 63% respectively. Yields in the Canada and the United States have increased the least, 13% and 19% respectively. The percentage change in these tables is calculated from 1980-81 to 2001-02 years.

Table 4.2 show the corn yields for major corn producing countries. The yield for the United States is substantially higher than either China or Mexico, but yields for both are increasing at a faster rate.

Soybean yields are similar in the major producing countries/regions. However, yields in the United States are slightly higher than areas in South America.

Table 4.1. Wheat Yields for Major Exporting Countries/Regions

	United States	Canada	Argentina	Europe	FSU ME	Australia
			MT/HA			
1980	2.25	1.74	1.55	3.80	1.44	0.96
1985	2.52	1.77	1.61	4.28	1.42	1.38
1990	2.66	2.28	1.91	4.81	1.99	1.63
1995	2.41	2.25	1.91	4.68	1.47	1.79
2000	2.83	2.44	2.58	4.98	1.56	1.83
2002	2.75	2.28	2.50	4.95	1.74	2.03
% Change: 1980-2002	22	31	61	30	21	111

Table 4.2 Corn Yields for Major Producing Countries

	United States	Mexico	China
		MT/Acre	
1980	5.71	1.28	3.08
1985	7.41	1.69	3.61
1990	7.44	2.14	4.52
1995	7.12	2.28	4.92
2000	8.59	2.36	4.60
2002	8.64	2.65	5.30
% Change: 1980-2002	51	107	72

Table 4.3. Soybean Yields for Major Exporting Countries/Regions

	United States	Argentina	Brazil	Latin
		MT/HA		
1980	1.78	2.01	1.79	1.54
1985	2.29	2.20	1.49	1.34
1990	2.29	2.42	1.62	1.63
1995	2.38	2.08	2.20	2.12
2000	2.56	2.65	2.79	2.47
2002	2.72	2.51	2.52	2.43
% Change: 1980-2002	53	25	41	58

4.2 Area Harvested: Wheat, Corn, and Soybeans Many of the major exporting countries/regions have decreased the harvested areas of wheat since 1980 (Table 4.4). United States has decreased wheat area about 31% during the time period. FSU-ME area has fallen about 19% during the same time period but that was during the breakup to the Soviet Union which may be the cause of the reduced area. Argentina has increased wheat area by 35% and Australia at 11%. Total harvested wheat area has increased 2.9% since 1980.

World harvested area for corn has fallen 8.9% since 1980. Harvested area for the United States has fallen 5% while corn area in China has increased 15% during the time period.

The world soybean area increased 53.7% since 1980. In 1980, 49 million hectares were planted to soybeans. By 2003, 78 million hectares were harvested. The main increases were in South America, mainly Argentina, Brazil, and Uruguay. Harvest area increased 477% from 1.7 million hectares in 1980 to 11.1 hectares in 2002. Brazil increased harvested area from 8.5 million hectares in 1980 to 15.9 million hectares in 2002. United States increased harvested area 8% during the time period.

Table 4.4. Wheat Harvest Area for Major Exporting Countries/Region (000Hectarwa)

	United States	Canada	Argentina	Europe	FSU ME	Australia
			HA (000)			
1980	28,773	11,098	5,023	25,997	79,345	11,283
1985	26,185	13,729	5,270	26,195	68,606	11,736
1990	27,965	14,098	5,700	27,085	66,752	9,218
1995	24,668	11,141	4,500	25,859	65,008	9,221
2000	21,502	10,962	6,392	26,817	61,306	13,002
2002	19,689	11,000	6,800	26,517	64,357	12,500
% Change: 1980-2002	-32	0	35	2	-19	11

Table 4.5. Corn Harvest Area for Major Producing Countries

	United States	Mexico	China
		HA (000)	
1980	29,526	8,100	20,353
1985	30,436	6,200	17,694
1990	27,095	6,600	21,402
1995	26,390	7,800	22,767
2000	29,316	7,510	23,056
2002	27,846	7,870	23,500
%Change: 1980-2002	-5	-3	15

Table 4.6. Soybean Harvest Area for Major Exporting Countries/Regions

	United States	Argentina	Brazil	Latin
		HA (000)		
1980	27,443	1,740	8,501	492
1985	24,929	3,316	9,450	727
1990	22,870	4,750	9,750	1,257
1995	24,906	5,980	10,950	1,680
2000	29,303	10,380	13,970	1,959
2002	29,542	11,100	15,900	2,057
% Change: 1980-2002	8	538	87	318

4.3 Estimated Crop Yields Production and production potential were derived for each country and region as follows. Yield functions were estimated as a function of a trend where:

$$Y=f(\text{trend})$$

where Y is the yield for each of the crops and data were used from 1980 to 2004. These were estimated as a logarithmic function to allow for nonlinear relationship and were derived for each country and crop.

Forecasted yields for each of the countries are shown in Table 4.7-4.9 for each of the major producing countries. Results show that yields in Argentina and Australia are growing relative to those in North America and Europe and by 2025 will converge toward values in those countries.

Table 4.7. Estimated Wheat Yields for Major Exporting Countries/regions

	United States	Canada	Argentina	Europe	FSU ME	Australia
			MT/HA			
2003	2.77	2.30	2.53	4.99	1.75	2.07
2010	2.90	2.46	2.78	5.32	1.85	2.34
2015	3.00	2.57	2.96	5.55	1.91	2.53
2020	3.09	2.68	3.14	5.78	1.98	2.72
2025	3.19	2.79	3.32	6.02	2.05	2.92

Table 4.8. Estimated Corn Yields for Major Producing Countries

	United States	Mexico	China
	MT/HA		
2003	8.64	2.65	5.30
2010	9.44	3.08	5.94
2015	10.01	3.38	6.40
2020	10.58	3.69	6.86
2025	11.15	3.99	7.32

Table 4.9. Estimated Soybean yields for Major Exporting Countries/regions

	United States	Argentina	Brazil	Latin
		MT/HA		
2003	2.76	2.54	2.57	2.48
2010	3.03	2.71	2.87	2.81
2015	3.21	2.83	3.09	3.05
2020	3.40	2.95	3.30	3.28
2025	3.59	3.07	3.52	3.52

4.4. US Yield Growth Rates and Projections A critical issue in the evaluation of ethanol policies on the US corn sector is the prospects about yield growth rates. Varying opinions have been claimed about these as described below and in the text of the report.

In this section we analyze these statistically using the data described above. Trend line regressions are shown in Tables 4.10-4.14 and Figures 4.1-4.3. For each region a simple regression was estimated as in section 2.1 (p.4) where:

$$ln\text{YLD}_{cit} = \gamma_{0cit} + \gamma_{1ci} ln\text{Trend} + \epsilon_{cit}$$

Results indicate that in all cases there are positive yield growth rates and the R^2 indicates the percent of variability explained by trend alone. Projections based on these regressions are shown in Figures 4.1-4.3 for each of the 3 commodities by region.

To evalute the impact of a prospective shift in productivity in corn following the period of introduction of GM traits, we re-ran the regression including a binary intercept dummy for the period containing the most recent ten years (GM10). The functional form of this regression is:

$$ln\text{YLD}_{cit} = \gamma_{0cit} + \gamma_{1ci} ln\text{Trend} + \gamma_{2cit}\text{GM10} + \epsilon_{cit}$$

Results are in Table 6.5.4. These are very critical. In all cases the binary variables are not significant. Strictly, this means that there has been a constant rate of growth over time, but, at least statistically there has not been a shift in yield productivity in the most recent 10 years.

An alternative was also estimated where a binary slope adjustment was incorporated for the last 10 years. The functional form of this regression is:

$$ln\text{YLD}_{cit} = \gamma_{0cit} + \gamma_{1ci} ln\text{Trend} + \gamma_{2cit}\text{GM10} \bullet ln\text{Trend} + \epsilon_{cit}$$

Results for all production regions for the binary slope adjustment were statistically insignificant.[6] This indicates there has not been a statistically significant change in corn yields in the last ten

[6] Results are not reported for the slope change, but are available from the authors.

years from that occurring from 1980-2004.

There are a number of potential reasons for these results. One is that the introduction of GM technology in the case of corn has not been adopted universally in all regions. Second, it may be that the GM technology does not impact yield as much as it impacts cost savings.

While others have pointed to rapid growth in the past 10 years those comparisons should be qualified. First, comparison to the crop years inclusive of 1992-1995 may be an inappropriate measure of the impact of GM technology. The reason for this is that GM was not introduced until 1996. Further, and more important, the crop years 1991-1996 were characterized by several years with much below trend line yield in several corn production regions and for total U.S. corn yields. Thus, estimates of trend yields using this shorter period as a base more likely reflect the lower than normal yields in the early years of the data, than any shift in longer term trends. Others have made comparisons across regions and through time, but, in no case do these provide statistical evidence that there has been a significant shift as a result of the introduction of GM technology. Finally, looking forward, these results do not refute claims of others in reference to future growth rates. However, it should be recognized that realization of these gains requires 1) the GM trait being technically successful and commercialized; and 2) these traits being widely adopted which is highly dependent on technology efficiency and pricing relative to alternatives, geography and technology in competing crops.

Table 4.10 Corn: Estimated Parameters for Yield/Harvested Area = F(Ln Trend)			
Production Region	Intercept[1]	Ln Trend[1]	R2
Central Plains	1.09 (4.67)	.305 (4.54)	.47
Central Plains River	.29 (0.70)	.488 (4.17)	.43
Delta	-.52 (-0.90)	.679 (4.17)	.49
Illinois North	.19 (0.34)	.552 (3.46)	.34
Illinois South	.12 (0.22)	.548 (3.45)	.34
Indiana North	.32 (0.67)	.499 (3.61)	.36
Indiana River	.27 (0.45)	.496 (2.88)	.27
Iowa River	.20 (0.31)	.537 (2.81)	.26
Iowa West	.28 (0.60)	.519 (3.85)	.39
Michigan	.53 (1.51)	.396 (3.94)	.40
Minnesota	-.26 (-0.42)	.637 (3.54)	.35
Minnesota River	.21 (0.41)	.533 (3.67)	.37
Missouri River	-.55 (-0.69)	.685 (3.00)	.28
Missouri West	-.69 (-1.09)	.741 (4.05)	.42
Northeast	.66 (1.36)	.340 (2.45)	.21
Northern Plains	-.89 (-3.24)	.736 (8.81)	.70
Ohio	.65 (1.31)	.392 (2.75)	.25
PNW	.81 (5.56)	.430 (10.25)	.82
Southeast	-.84 (-1.79)	.744 (5.53)	.57
Southern Plains	.73 (2.71)	.355 (4.60)	.48
West	.87 (7.50)	.403 (12.09)	.86
Wisconsin South	.60 (1.44)	.403 (3.38)	.33
Wisconsin West	.37 (0.74)	.446 (3.05)	.29
Western N. Plains	.59 (2.12)	.394 (4.88)	.51

[1] t values are in ( )

Table 4.11 Wheat: Estimated Parameters for Yield/Harvested Area = F(Ln Trend)			
Production Region	Intercept[1]	Ln Trend[1]	R2
Central Plains	.29 (0.59)	.168 (1.18)	.06
Central Plains River	-.44 (-0.80)	.381 (2.38)	.20
Delta	-.67 (-1.21)	.491 (3.09)	.29
Illinois North	-.05 (-0.09)	.393 (2.50)	.21
Illinois South	.36 (0.72)	.241 (1.68)	.11
Indiana North	-.32 (-0.70)	.471 (3.60)	.36
Indiana River	-.27 (-0.53)	.419 (2.83)	.26
Iowa River	-.54 (-0.84)	.463 (2.52)	.22
Iowa West	-.68 (-1.18)	.462 (2.79)	.25
Michigan	-.37 (-0.78)	.475 (3.48)	.34
Minnesota	.29 (0.41)	.195 (0.96)	.04
Minnesota River	.46 (0.91)	.145 (1.00)	.04
Missouri River	.04 (0.09)	.307 (2.27)	.18
Missouri West	-.44 (-1.04)	.432 (3.57)	.36
Northeast	-.45 (-1.49)	.473 (5.48)	.57
Northern Plains	-.70 (-1.08)	.402 (2.17)	.17
Ohio	-.44 (-1.33)	.504 (4.51)	.47
PNW	.76 (2.73)	.185 (2.31)	.19
Southeast	-.88 (-2.32)	.554 (5.11)	.53
Southern Plains	.28 (0.68)	.120 (1.02)	.04
West	1.25 (9.48)	.093 (2.45)	.21
Wisconsin South	-.05 (-0.10)	.374 (2.96)	.28
Wisconsin West	1.27 (-3.56)	.640 (6.22)	.63
Western N. Plains	-.06 (-0.08)	.198 (0.92)	.04

[1] t values are in ( )

Table 4.12 Soybeans: Estimated Parameters for Yield/Harvested Area = F(Ln Trend)			
Production Region	Intercept[1]	Ln Trend[1]	R2
Central Plains	-.69 (-2.17)	.463 (5.10)	.53
Central Plains River	-.88 (-1.69)	.473 (3.19)	.31
Delta	-1.73 (-4.05)	.660 (5.39)	.56
Illinois North	-.07 (-0.18)	.320 (2.95)	.27
Illinois South	-.59 (-1.51)	.425 (3.79)	.38
Indiana North	-.32 (-0.88)	.380 (3.60)	.36
Indiana River	-.69 (-1.85)	.454 (4.22)	.44
Iowa River	-.10 (-0.21)	.322 (2.48)	.21
Iowa West	-.00 (-0.01)	.289 (2.55)	.22
Michigan	.10 (0.28)	.209 (1.99)	.15
Minnesota	.06 (0.11)	.215 (1.49)	.09
Minnesota River	-.11 (-0.27)	.299 (2.51)	.21
Missouri River	-1.38 (-2.38)	.616 (3.70)	.37
Missouri West	-.84 (1.81)	.453 (3.41)	.34
Northeast	-.86 (-1.93)	.461 (3.62)	.36
Northern Plains	-.42 (0.99)	.315 (2.57)	.22
Ohio	-.02 (-0.04)	.269 (2.47)	.21
PNW	NA	NA	NA
Southeast	-1.53 (-3.66)	.611 (5.07)	.53
Southern Plains	-.28 (-0.64)	.223 (1.78)	.12
West	NA	NA	NA
Wisconsin South	-.05 (-0.11)	.282 (2.15)	.17
Wisconsin West	-.50 (-0.85)	.369 (2.18)	.17
Western N. Plains	NA	NA	NA

[1] t values are in ( )

NA - Not Applicable - No Soybeans Planted in these areas.

Table 4.13. Corn Estimated Parameters for Yield/Harvested Area = F(Ln Trend, Dummy for last 10 years)

Production Region	Intercept[1]	Ln Trend[1]	Binary Variable for Last 10 Years[1]	R2
Central Plains	.69 (1.81)	.428 (3.70)	-.07 (-1.30)	.51
Central Plains River	-.16 (-0.24)	.627 (3.05)	-.08 (-0.82)	.45
Delta	-2.81 (-2.86)	1.344 (4.55)	-.16 (-1.21)	.65
Illinois North	.28 (0.30)	.524 (1.84)	.02 (0.12)	.34
Illinois South	-.80 (-0.88)	.833 (3.04)	-.16 (-1.27)	.39
Indiana North	-.13 (-0.16)	.637 (2.61)	-.08 (-.069)	.37
Indiana River	-.38 (-0.38)	.696 (2.30)	-.11 (-.081)	.29
Iowa River	1.45 (1.34)	.153 (0.47)	.22 (1.43)	.32
Iowa West	.88 (1.12)	.337 (1.43)	.10 (0.94)	.42
Michigan	.54 (0.90)	.393 (2.19)	.00 (0.02)	.40
Minnesota	.97 (0.96)	.257 (0.84)	.21 (1.52)	.41
Minnesota River	1.09 (1.31)	.261 (1.05)	.15 (1.33)	.42
Missouri River	-.90 (-0.67)	.794 (1.95)	-.06 (-0.33)	.29
Missouri West	-1.19 (-1.11)	.895 (2.76)	-.09 (-0.58)	.42
Northeast	.49 (0.60)	.390 (1.58)	-.03 (-0.25)	.21
Northern Plains	-.58 (-0.75)	.629 (2.72)	.14 (1.34)	.68
Ohio	.66 (0.78)	.390 (1.53)	.00 (0.01)	.25
PNW	.57 (2.35)	.507 (7.00)	-.04 (-1.28)	.83
Southeast	-.97 (-1.22)	.785 (3.27)	-.02 (-0.21)	.57
Southern Plains	.88 (1.94)	.307 (2.24)	.03 (0.43)	.48
West	.46 (2.78)	.530 (10.71)	-.07 (-3.13)	.91
Wisconsin South	1.20 (1.74)	.218 (1.05)	.10 (1.09)	.37
Wisconsin West	1.28 (1.54)	.167 (0.67)	.16 (1.36)	.34
Western N. Plains	1.12 (2.44)	.233 (1.69)	.09 (1.43)	.55

[1] t values are in ( )

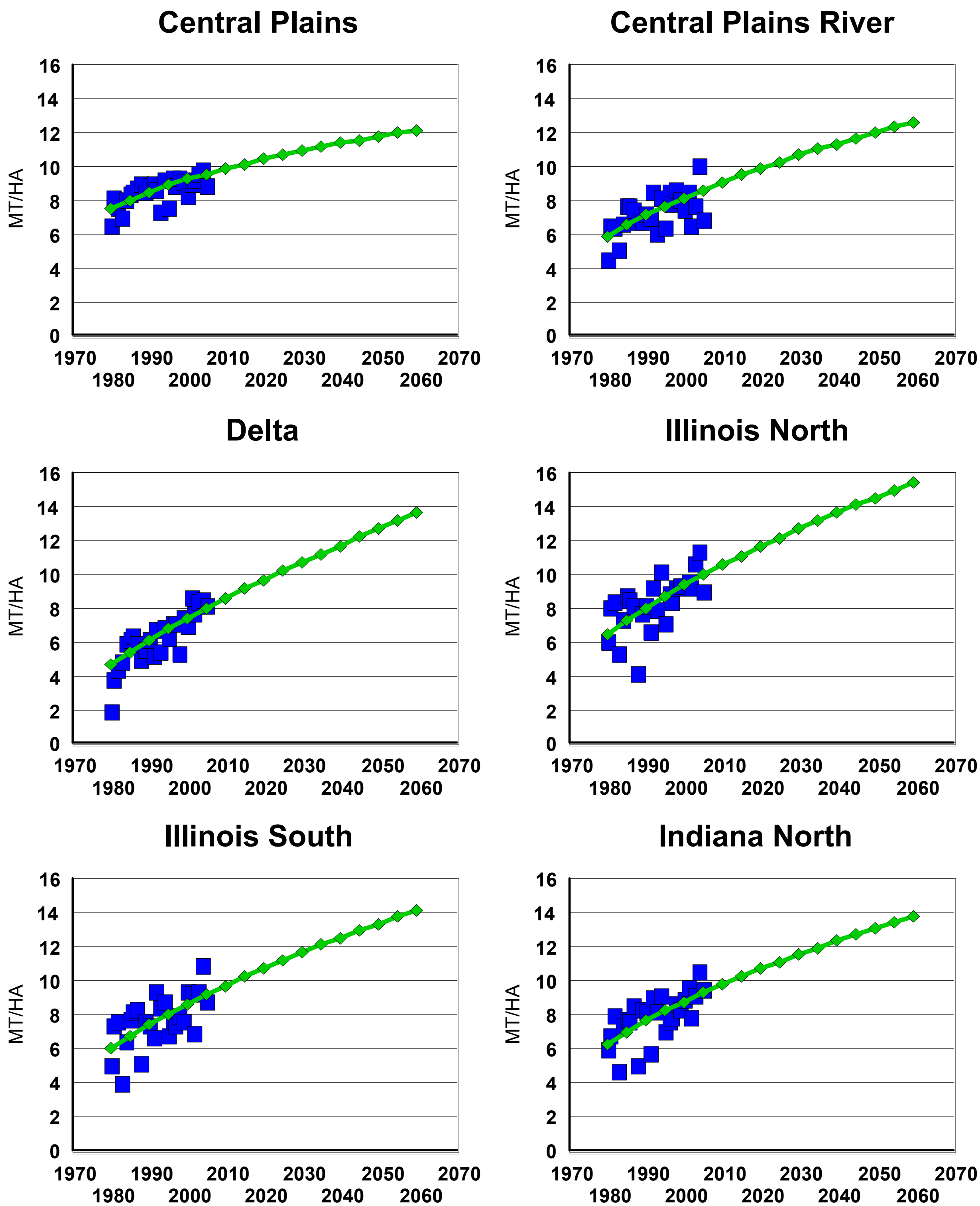

Figure 4.1. Corn: Actual and Forecast Yields by Production Region (mt/ha)

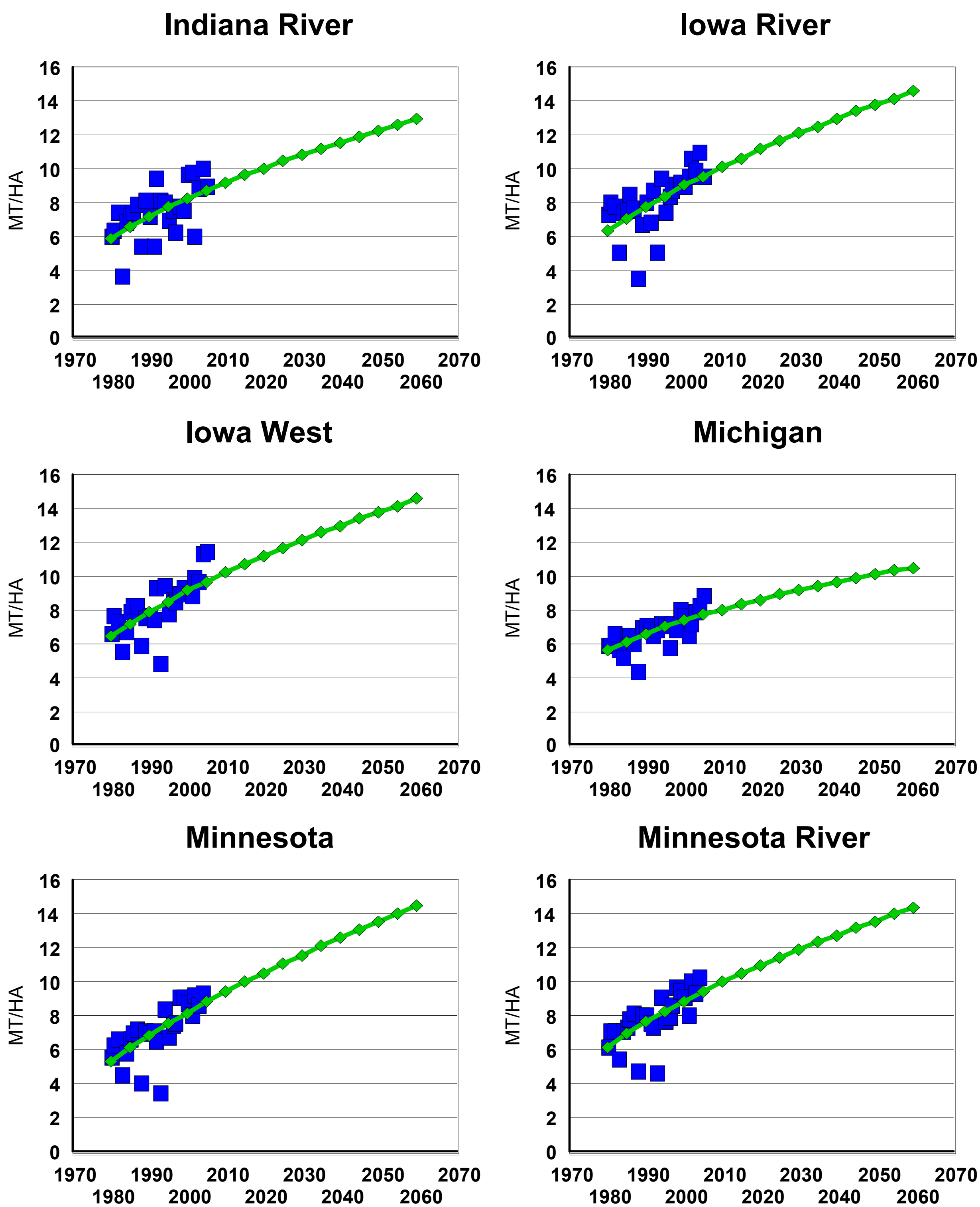

Figure 4.1(cont.) Corn: Actual and Forecast Yields by Production Region (mt./ha)

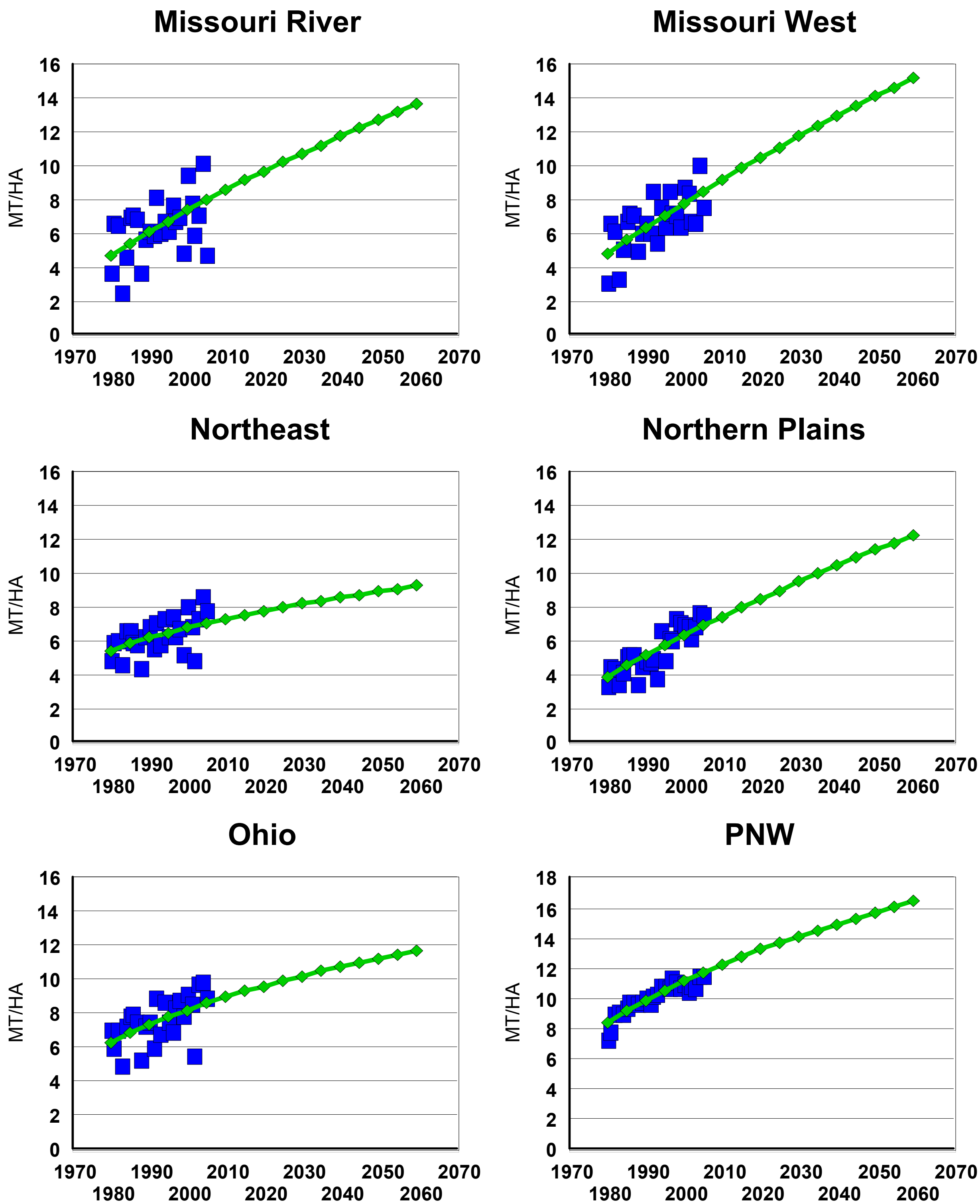

Figure 6.5.1(cont.) Corn: Actual and Forecast Yields by Production Region (mt/ha)

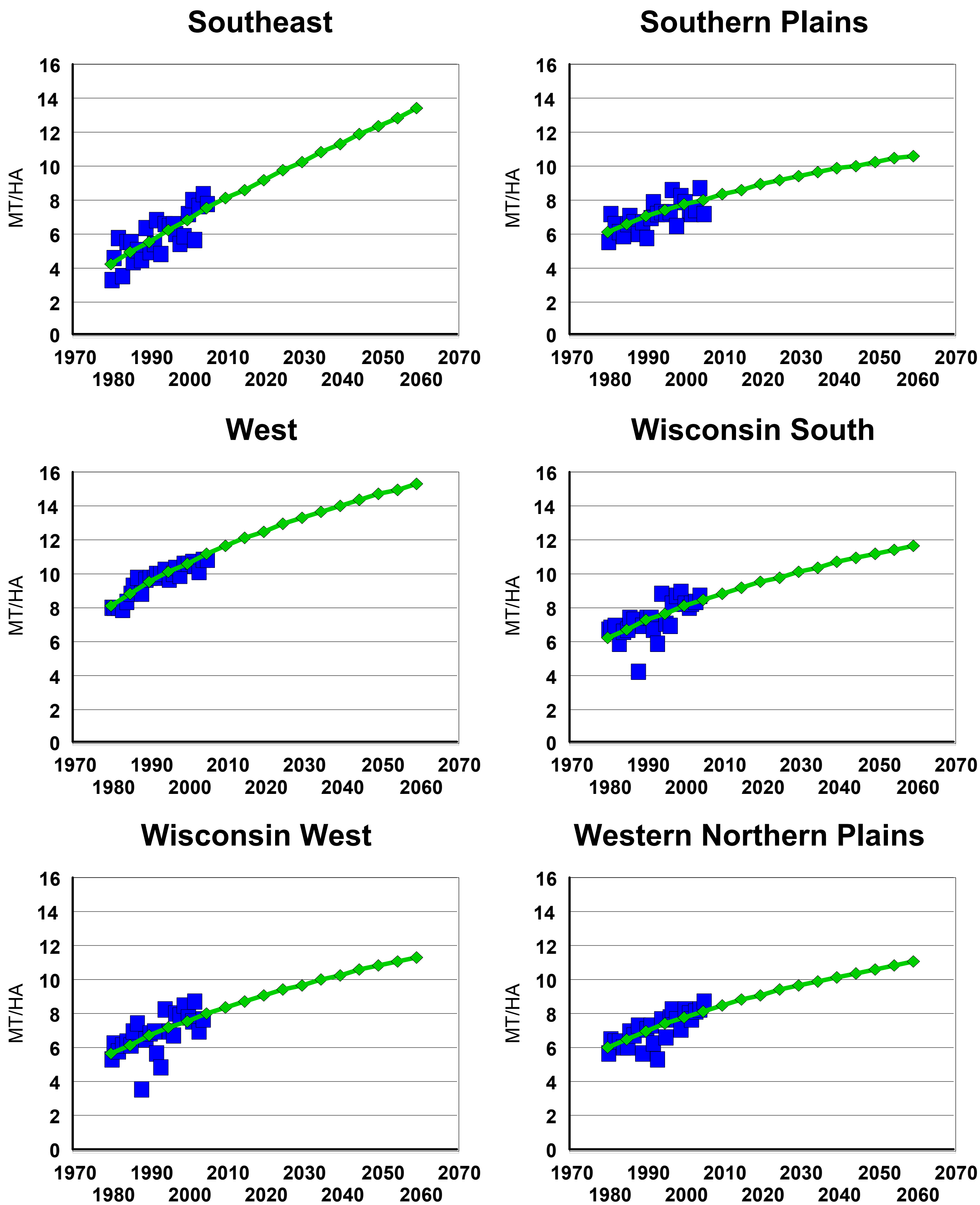

Figure 4.1.(cont.) Actual and Forecast Corn Yields by Production Region (mt/ha)

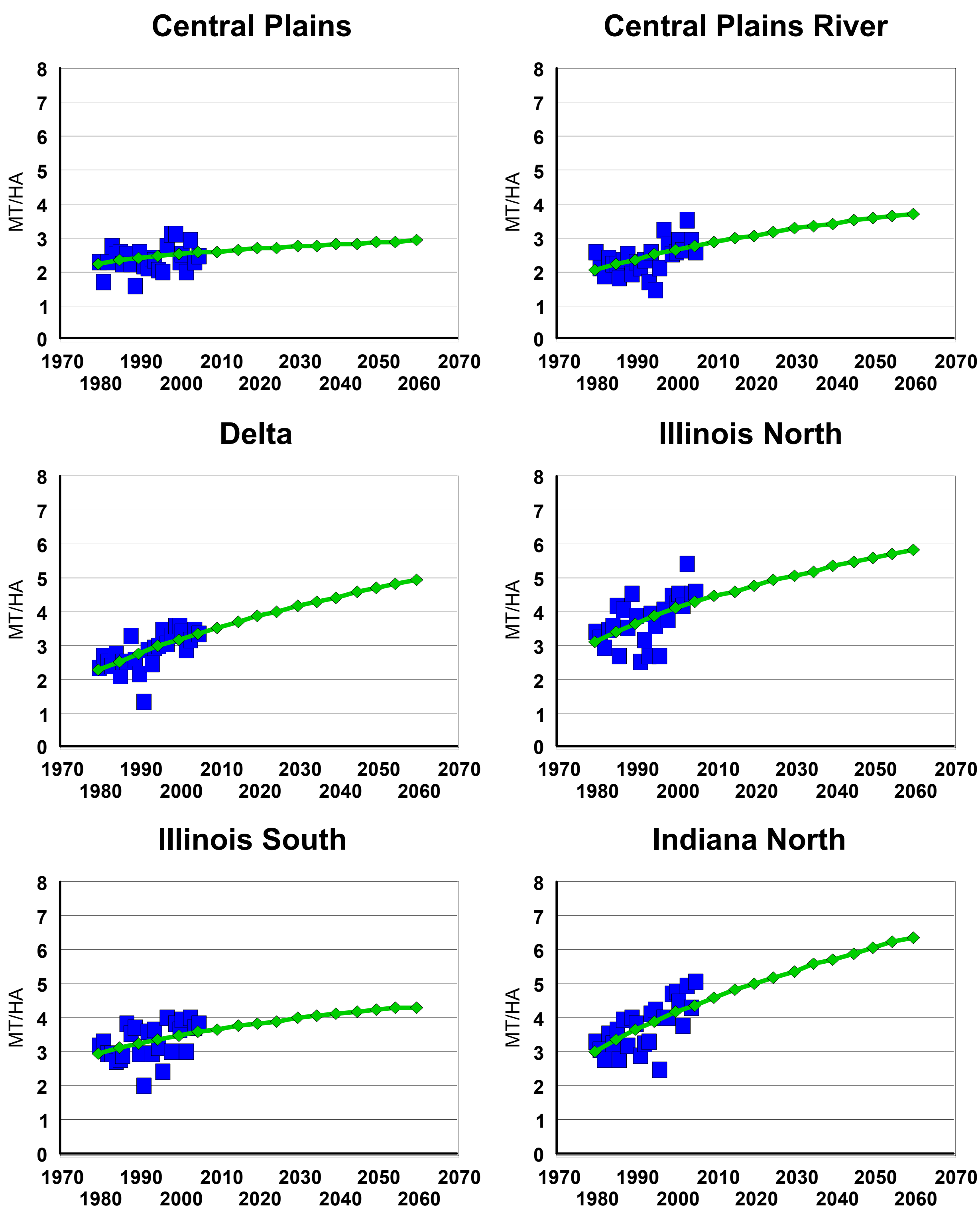

Figure 4.2. Wheat: Actual and Forecast Yields by Production Region (mt/ha)

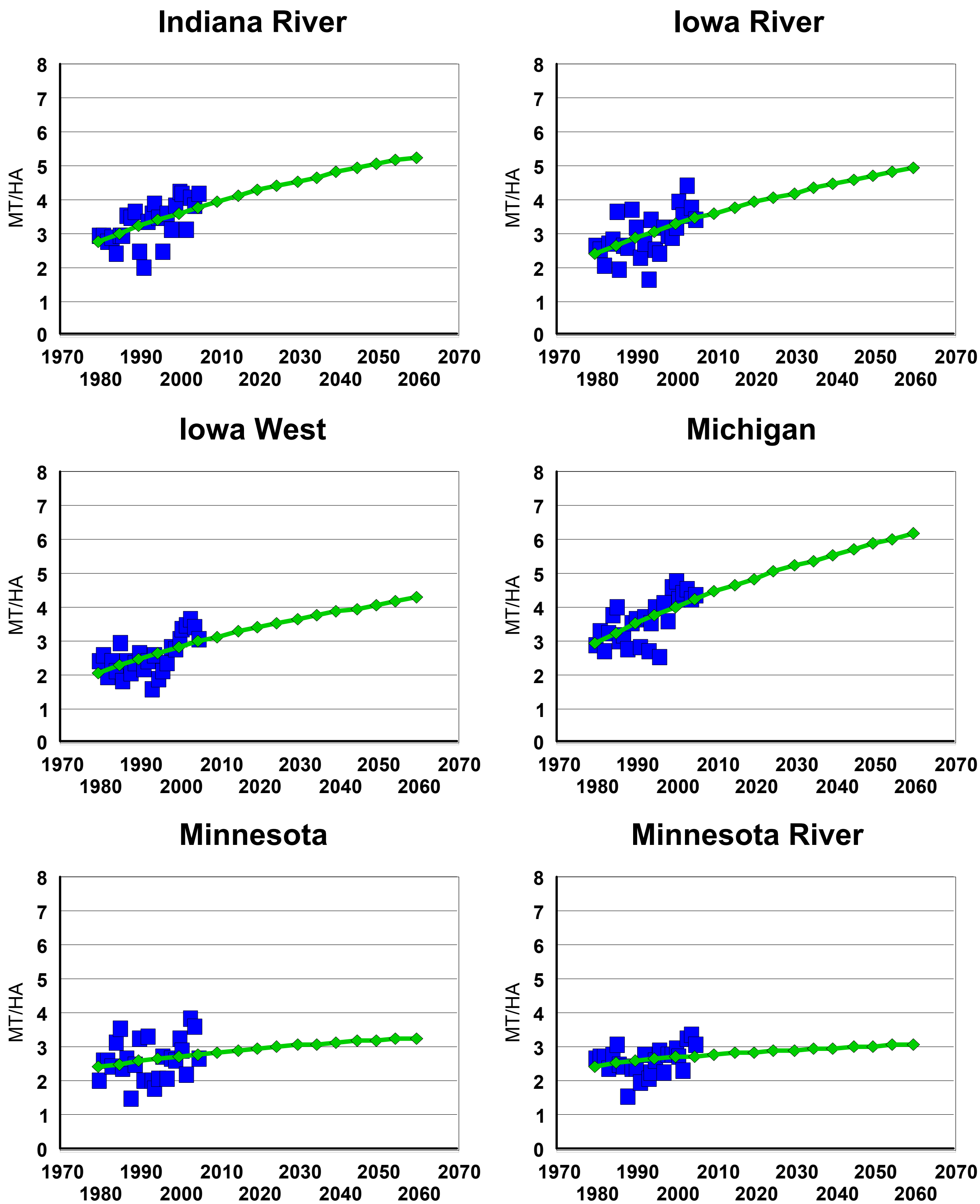

Figure 4.2 (cont.) Wheat: Actual and Forecast Yields by Production Region (mt/ha)

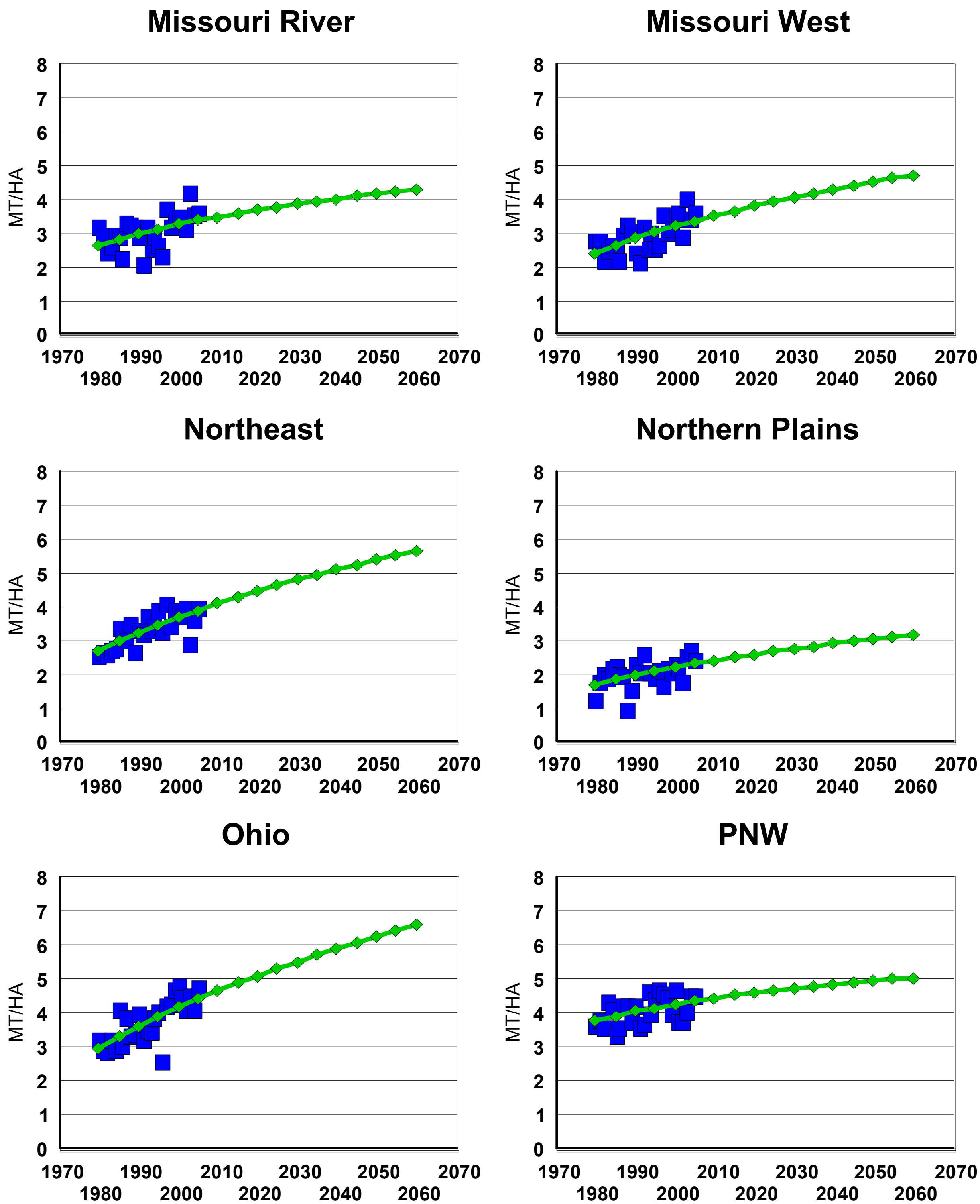

Figure 4.2 (cont.) Wheat: Actual and Forecast Yields by Production Region (mt/ha)

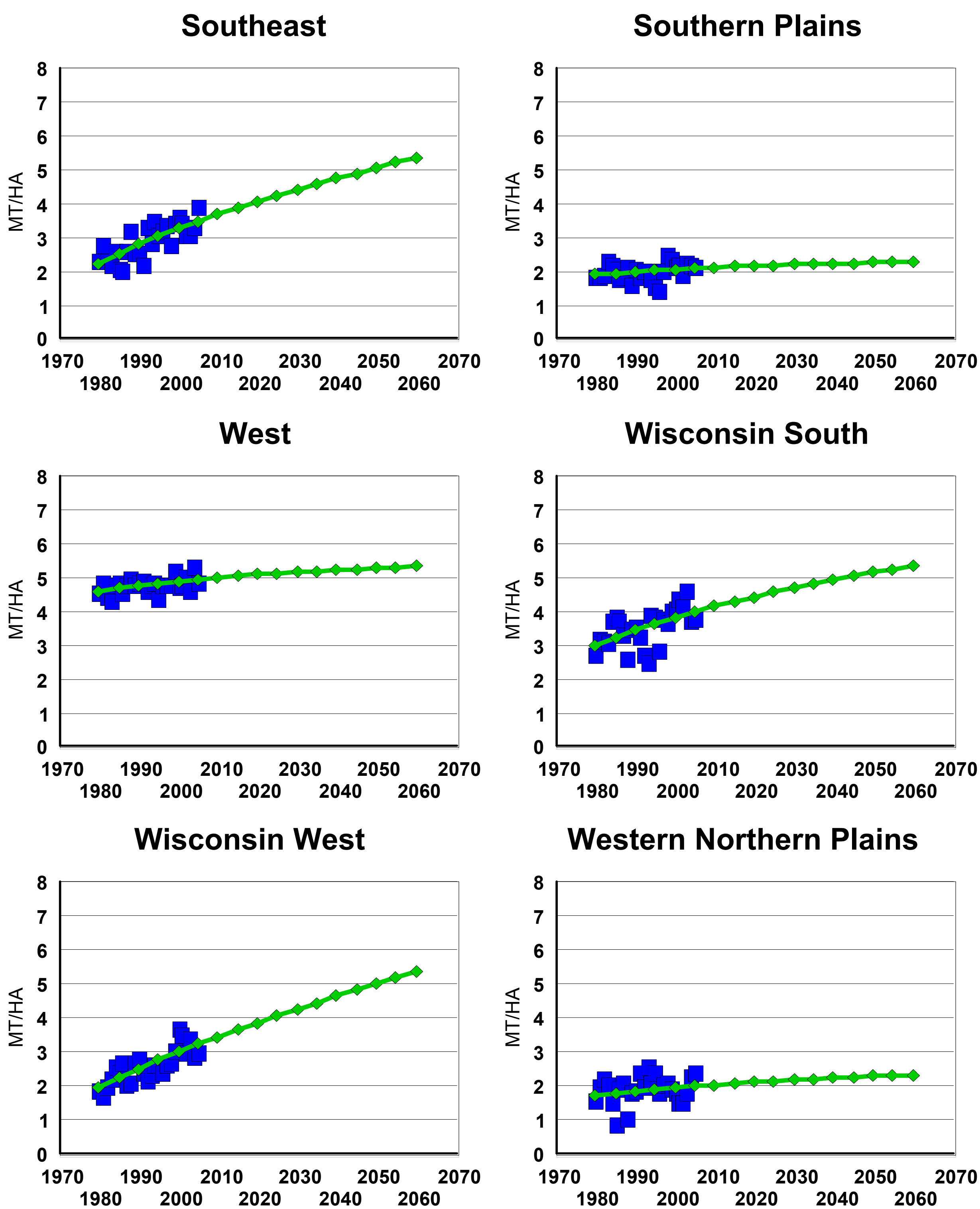

Figure 4.2. (Cont.) Wheat: Actual and Forecast Yields by Production Region (MT/HA).

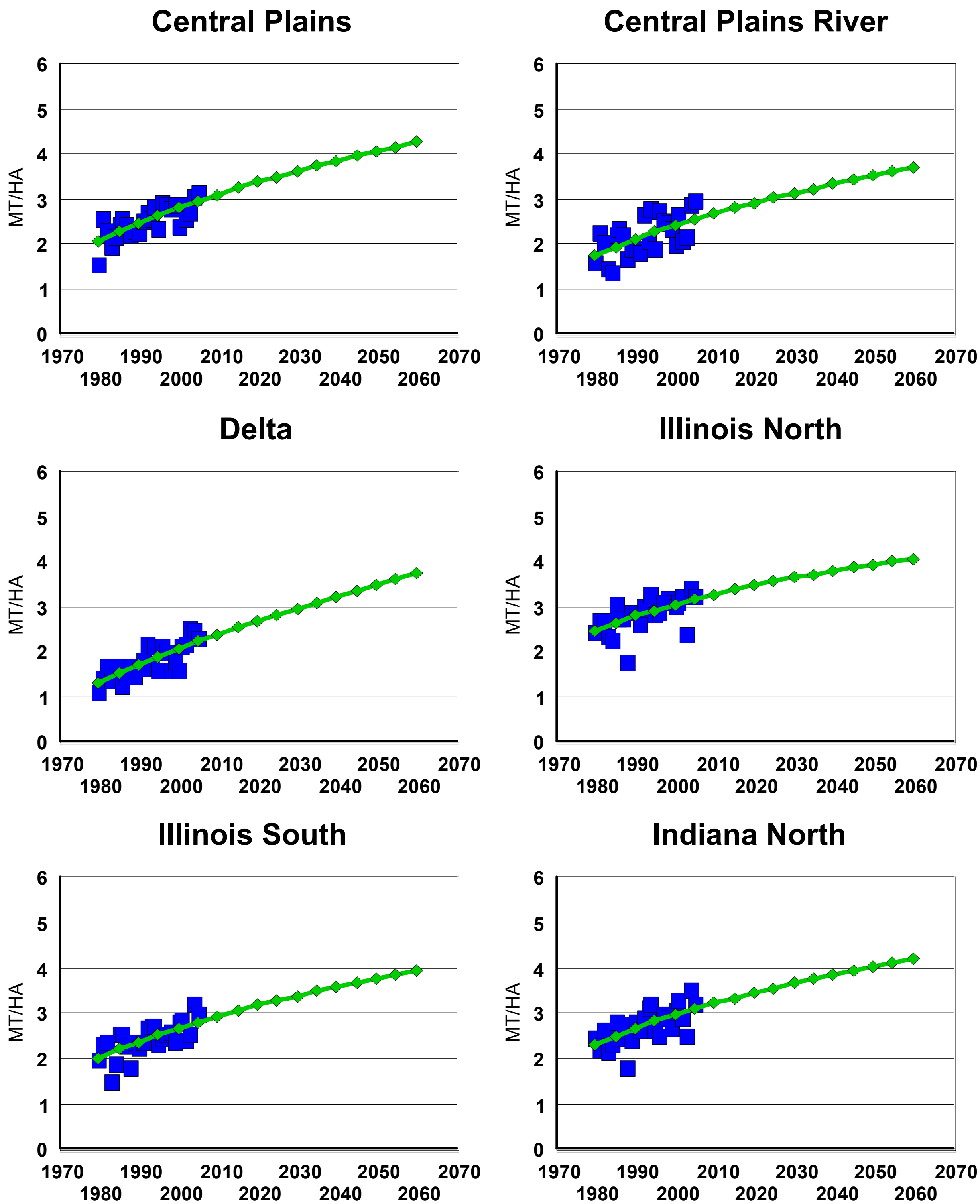

Figure 4.3. Soybeans: Actual and Forecast Yields by Production Region (mt/ha)

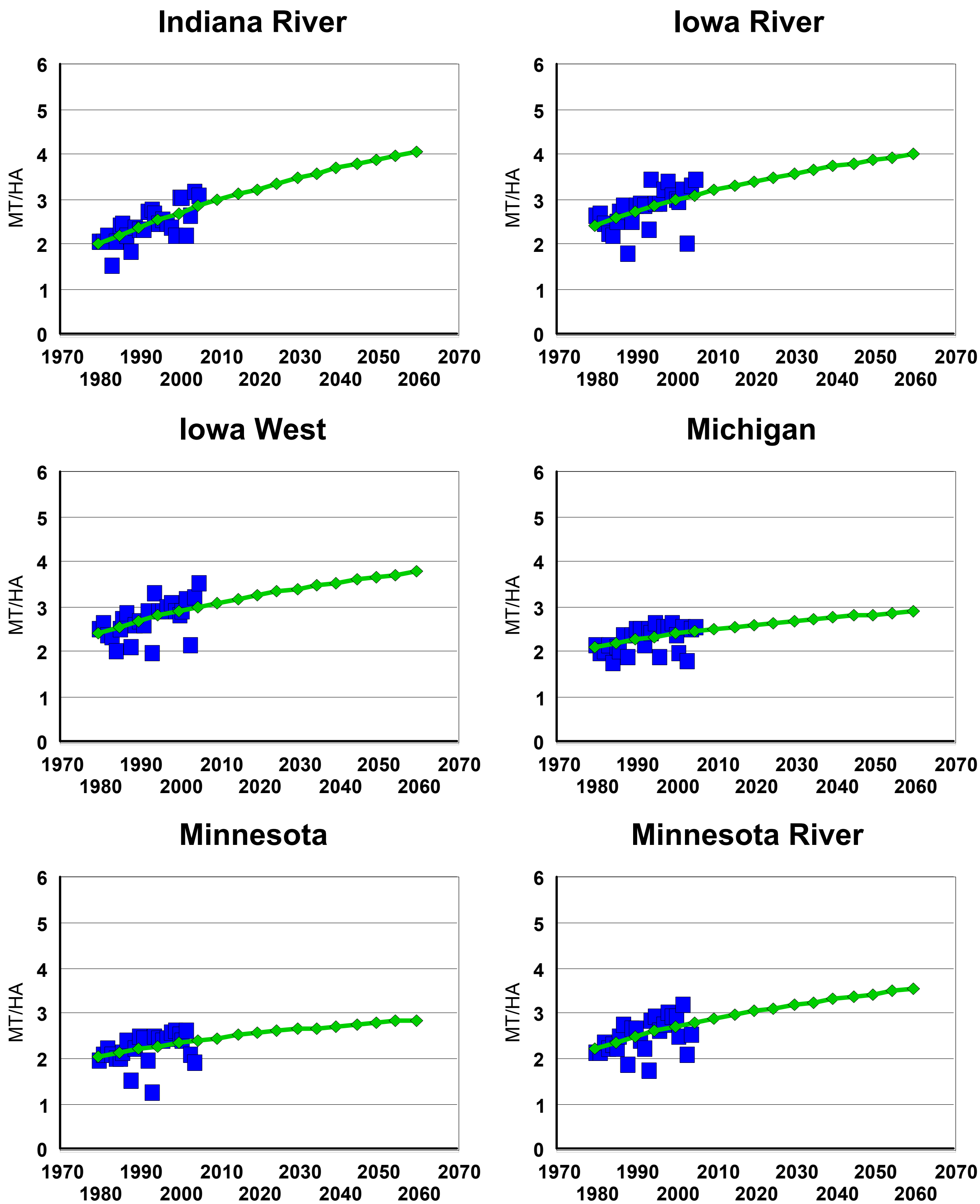

Figure 4.3. (cont.) Soybeans: Actual and Forecast Yields by Production Region (Mt/ha)

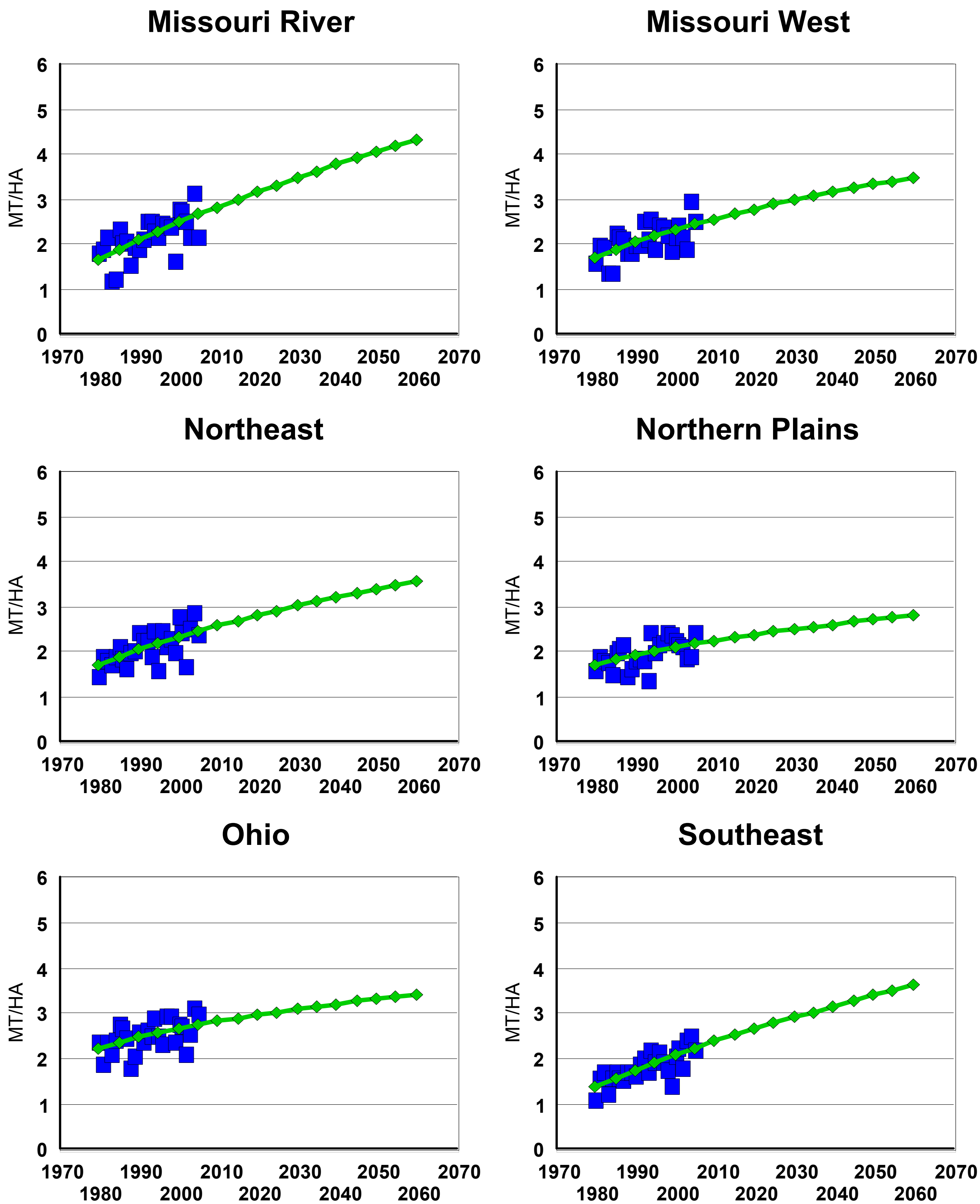

Figure 4.3.(cont.) Soybeans: Actual and Forecast Yields by Production Region (mt/ha)

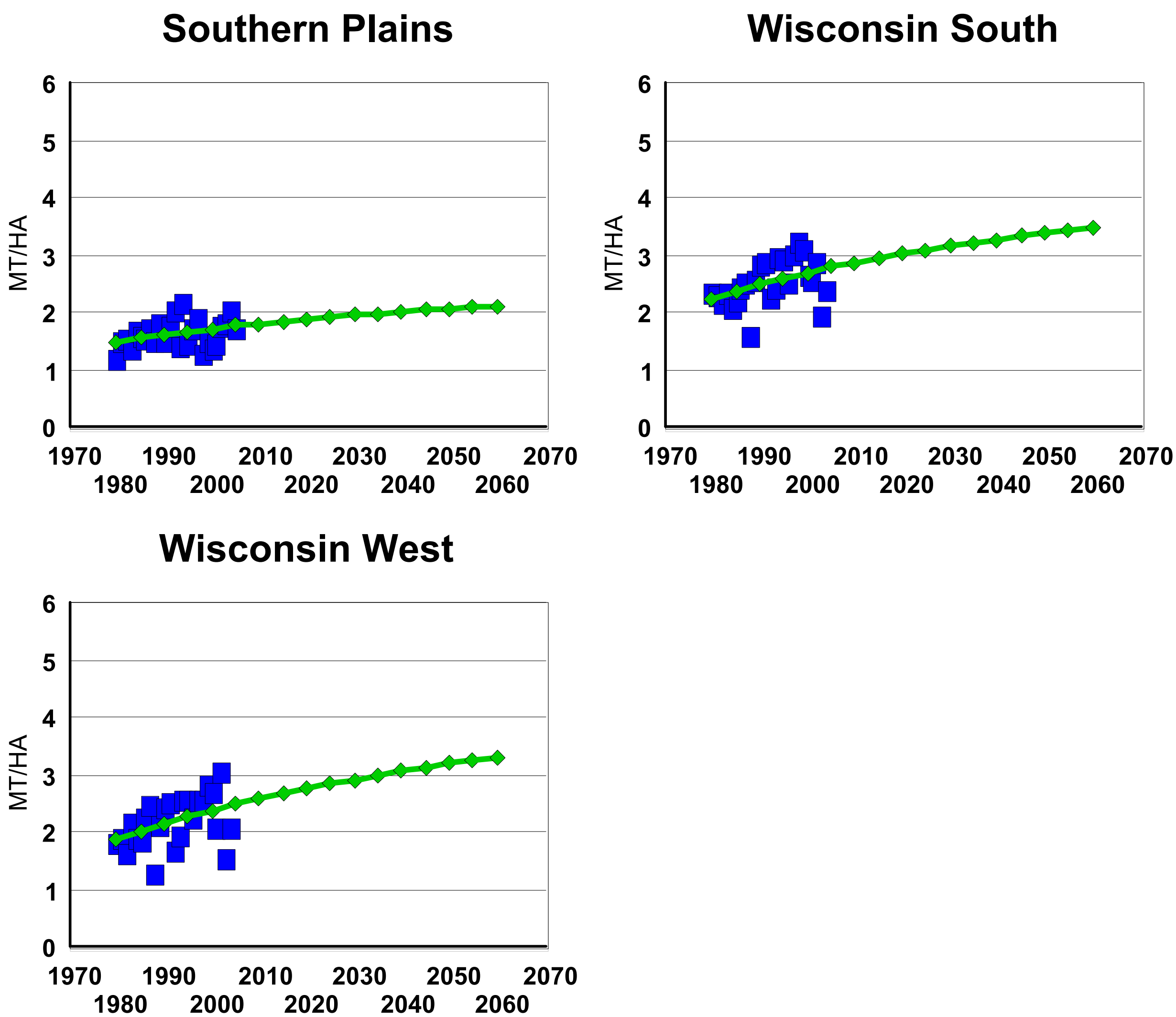

Figure 4.3. (cont.) Soybeans: Actual and Forecast Yields by Production Region (mt/ha)

To put these results into perspective, the forecast yields were used to derive the percent growth rate. These were derived as the percent change in longer-term growth on a per year basis. Longer term means this is the average of the growth that has occurred during the sample period. Specifically, average growth rates across the forecast period were estimated assuming average growth rate $R = \ln(p_n/p_1)/n$ where p_n and p_1 are the last and first observations in the period and n is the number of years between p_n and p_1 (World Bank). The result is strictly interpreted as the average percentage growth rate in yield. These should be interpreted as the longer term average, and representative of the growth that occurred during this period. Separate growth rates were estimated for each crop and region.

Results are shown in Table 4.14. These suggest that in the major growing regions for corn, average growth rate is in the area of +.5% per year. These are somewhat less than others suggest as summarized in the section on ethanol. It is also important that these rates vary substantially across regions, and, across grains. For example, in corn, the growth rates vary from as low as .1% in the Northeast, to as high as .83% in the Delta and Southeast. Growth rates on soybeans are typically lesser, and vary from as low as .14% to as high as .8. And wheat growth rates are much more variable, ranging from -.2% in Minnesota to 1.08%.

Table 4.14 Estimated Average Growth Rates in Yields (2004-2060) for U.S. Production Yields, by Crop.

U.S. Prod. Reg.	Wheat	Corn	Soybean
	--Average % Increase/Year--		
USCP	0.40%	0.38%	0.58%
USCPR	0.37%	0.40%	0.42%
USD	0.61%	0.83%	0.70%
USILN	0.42%	0.53%	0.29%
USILS	0.26%	0.46%	0.35%
USINN	0.68%	0.46%	0.29%
USINR	0.55%	0.43%	0.43%
USIAR	0.46%	0.49%	0.33%
USIAW	0.37%	0.43%	0.25%
USMI	0.64%	0.40%	0.23%
USMN	-0.21%	0.78%	0.66%
USMNR	-0.19%	0.59%	0.56%
USMOR	0.33%	0.51%	0.55%
USMOW	0.55%	0.73%	0.29%
USNE	0.80%	0.10%	0.36%
USNP	0.25%	0.81%	0.66%
USOH	0.82%	0.30%	0.14%
USPNW	0.17%	0.62%	NA
USSE	0.84%	0.83%	0.65%
USSP	0.06%	0.33%	0.03%
USW	-0.01%	0.60%	NA
USWIS	0.63%	0.50%	0.64%
USWIW	1.08%	0.66%	0.80%
USWNP	0.04%	0.51%	NA

4.5 Derivation of Production Potential Using the product of these estimated yields and area, we derived the production potential for each country and region. This should be interpreted carefully as it is production potential as opposed to production that is produced. The analytical model determines the amount of area in each region to draw into production.

Percentage changes are shown in Table 4.15 and the projections for major producing regions are shown in Figure 4.4.

Table 4.15. Estimated Percent Change (to 2025) in World Production

	Wheat	Corn	Soybean
		Percent Change	
United States	0.16	0.30	0.32
Canada	0.23	0.26	0.08
Europe	0.22	0.10	0.44
Australia	0.43	0.55	0.32
China	0.45	0.40	0.40
Japan	0.14	0.00	0.16
Argentina	0.33	0.53	0.22
Brazil	0.40	0.51	0.39
Mexico	0.12	0.53	0.03
South Korea	0.04	-0.15	0.10
Latin	0.43	0.27	0.45
N Africa	0.47	0.60	0.12
FSU_ME	0.18	-0.18	0.25
S Africa	0.02	0.18	0.37
S Asia	0.43	0.35	0.31
SEA	0.10	0.42	0.33
World	0.40	0.42	0.43

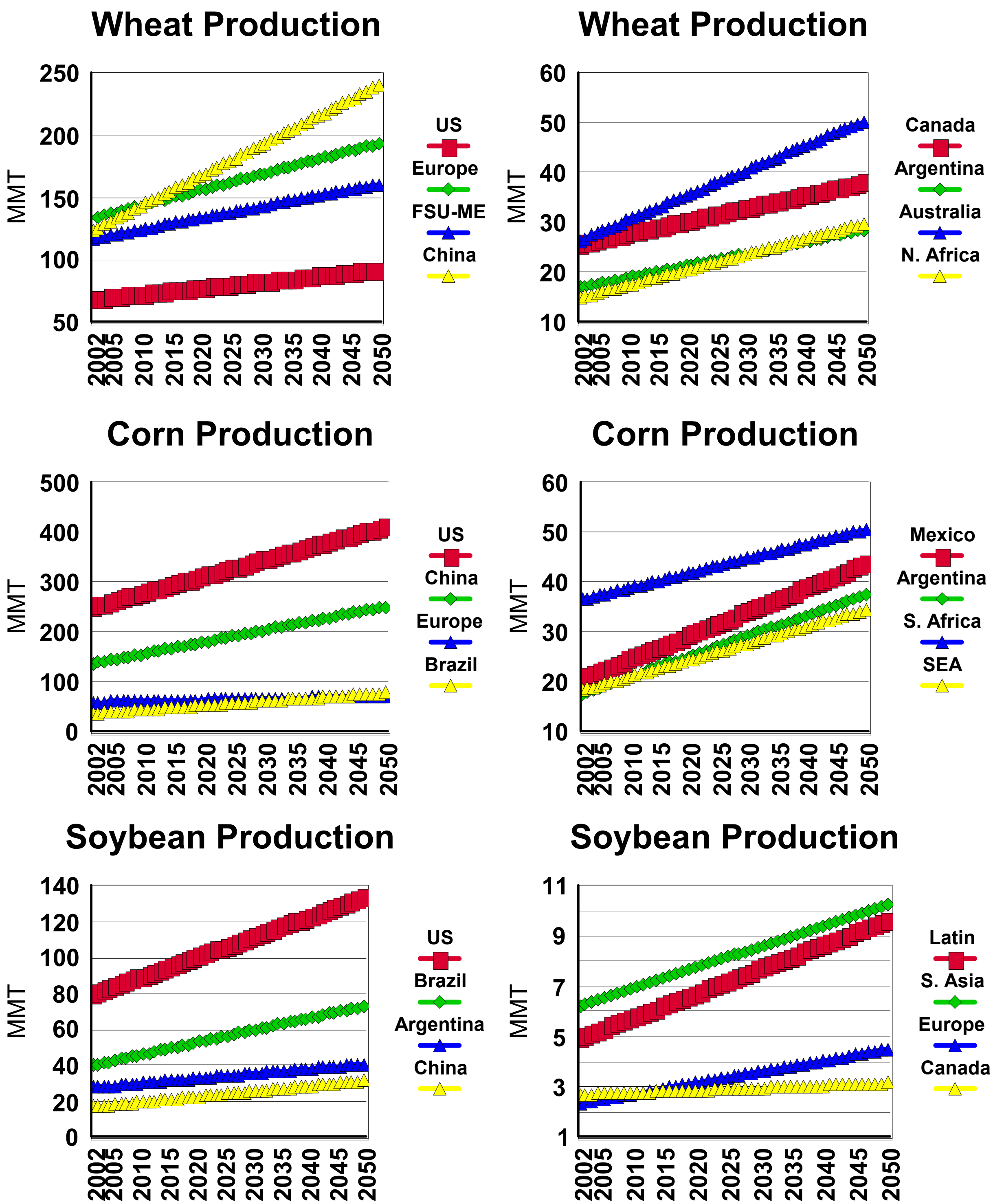

Figure 4.4 Forecast Production for Selected Producing Countries/Regions 2005-2050.

5. Production Costs in Major Producing and Exporting Regions

5.1 Data sources

Data on production costs for each country and crop were taken from Global Insights which uses a comparable methodology to derive production costs for each crop for each of the major projecting countries in the world. The value used in our analysis is defined as "Total Variable Costs" per hectare. These include costs for seed, chemical, herbicide, fuel, repairs, etc. These exclude fixed and economic costs such as land, interest on investment, depreciation, unpaid family labor, etc., which seems appropriate given the desire to use the direct production costs. Further, availability of variable costs was consistent across countries and regions, whereas, fixed and economic costs were not treated consistently for all countries and regions.

All values were published for years 1995 to 2025 and estimated assuming continuing trends to 2060. Costs of production were reported in $/hectare and utilized as such in the model (Tables 5.1.1 - 5.2.3). For comparison purposes, here they are converted to $/mt, using the yields estimated from the regression analysis for each country as described in Section 4. Results are shown in Figures 5.1-5.3 and Tables 5.3.1 - 5.4.3. Finally, different production regions were used for the United States as defined in Section 6.

5.2 Results

The results are summarized in Table 5.1.1-5.1.3 for current periods and in Tables 5.2.1-5.2.3 for future periods. For wheat, low-cost producers from the period 1995 to 2002 were Australia, Saskatchewan and several production regions within the U.S. (Central Plains, Northern Plains, Southern Plains). For corn, low-cost producers from 1995-2002 were U.S. producing regions, Argentina and Brazil. U.S. production regions have costs in the $35-$55/MT range, while China and the EU are $86 and 152$/MT, respectively. Low-cost producers for soybeans are the U.S. producing regions, EU and Argentina. Brazil's costs are higher.

The cost advantage for U.S. producing regions diminishes over time. There are several reasons for this. Most important is that while increases in production costs for U.S. regions rise at similar rates to that for major competing exporters, the rate of increase in yields is less than competing exporters. In competing countries, the rate of increase in yields is comparable to that of production costs. But in the United States, yield increases are less than competing exporters' as illustrated in the previous section; and, are less than production cost increases. The impact of these is very subtle, but, when extrapolated forward, results in a changing competitive position of the United States relative to competing countries.

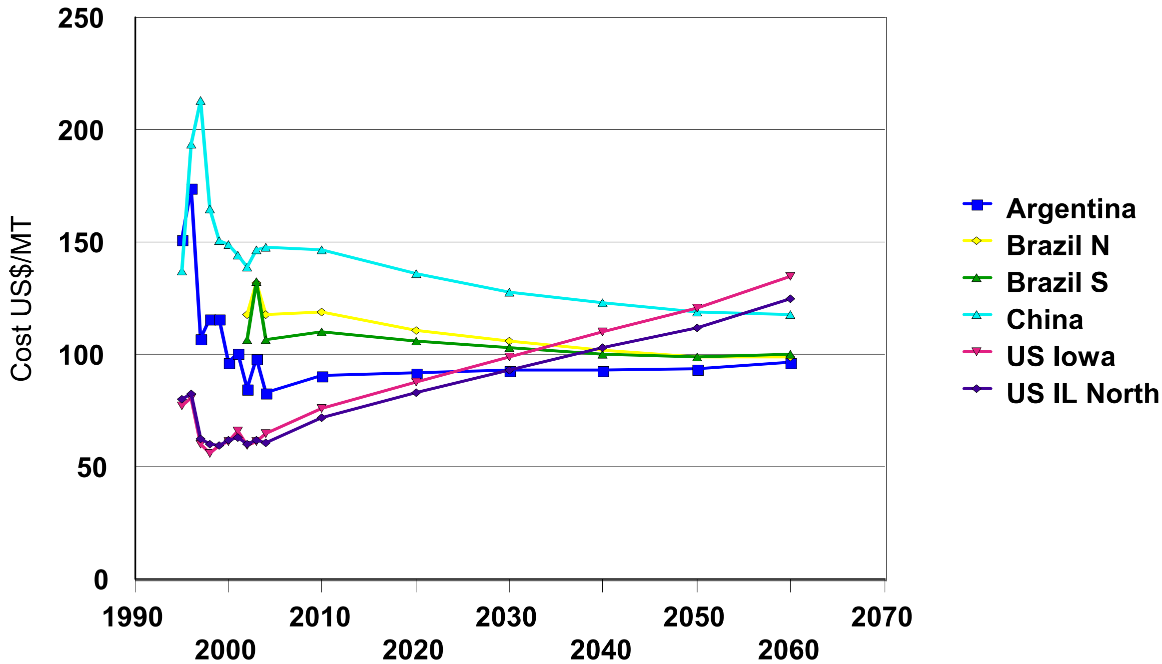

Figure 5.1 Soybean Cost of Production.

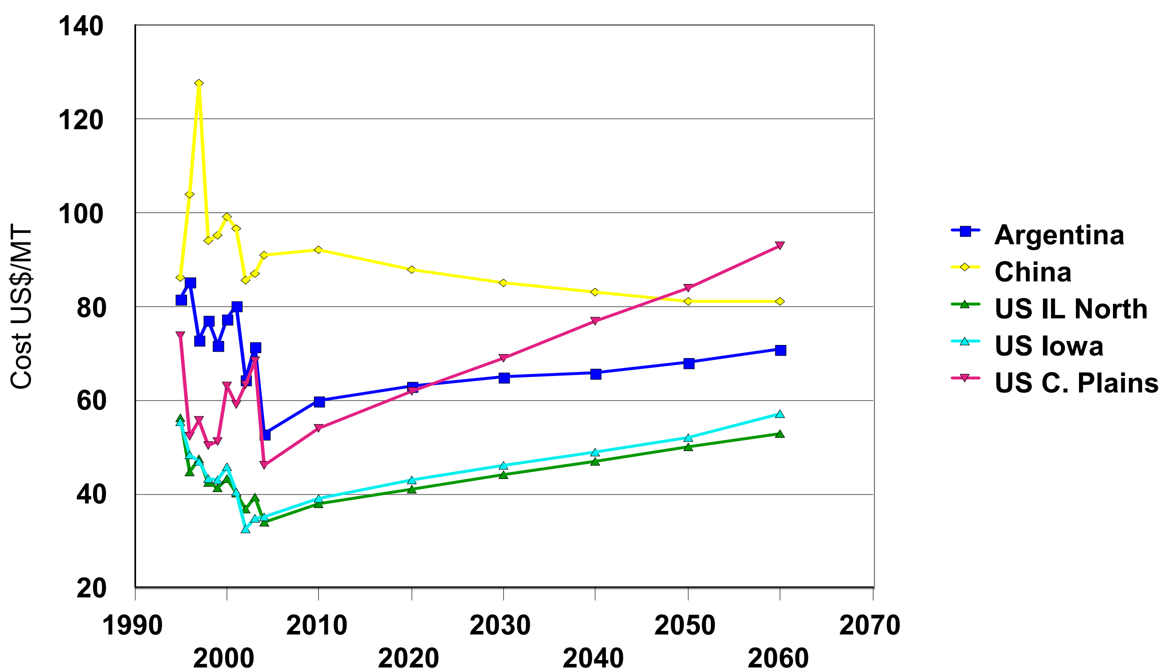

Figure 5.2 Corn Cost of Production.

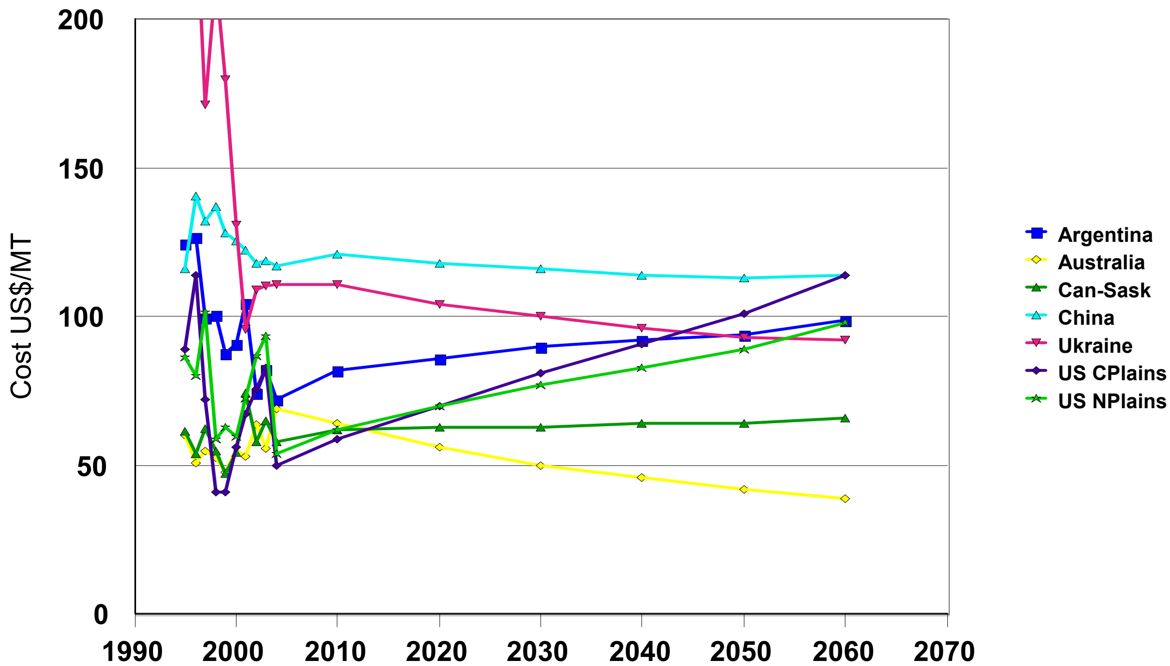

Figure 5.3 Wheat Cost of Production.

Table 5.1.1. Wheat Cost of Production ($/HA), 1995-2002

	1995	1996	1997	1998	1999	2000	2001	2002
Argentina	238	284	259	243	224	235	241	186
Australia	108	107	101	98	97	101	102	130
Brazil N	339	339	330	319	197	279	252	244
Brazil S	339	339	330	319	197	279	252	244
Can Alb.	169	171	164	153	157	167	166	162
Can BC	169	171	164	153	157	167	166	162
Can Man	169	171	164	153	157	167	166	162
Can Ont	339	331	303	276	279	258	261	249
Can Sas	121	123	118	110	113	120	119	116
China	411	525	542	505	506	470	457	486
Europe	636	642	576	566	543	503	520	540
FSU-ME	460	352	291	315	289	204	183	189
Japan	800	900	1000	1100	1200	1300	1400	1500
Latin America	321	314	306	298	291	283	275	268
Mexico	744	757	830	741	710	827	898	854
North Africa	357	335	341	344	357	356	322	300
South Africa	244	220	214	188	175	166	148	134
South Asia	294	276	233	216	209	220	222	224
Korea	284	266	225	208	202	212	214	215
S. E. Asia	284	266	225	208	202	212	214	215
USCplains	175	178	192	123	119	127	145	127
USCplainsR	175	178	192	123	119	127	145	127
USDelta	174	177	191	122	119	126	145	127
USIllinoisN	225	233	191	189	180	186	209	177
USIllinoisS	225	233	191	189	180	186	209	177
USIndianaN	225	233	191	189	180	186	209	177
USIndianaR	225	233	191	189	180	186	209	177
USIowa	225	233	191	189	180	186	209	177
USIowaR	225	233	191	189	180	186	209	177
USMichigan	233	241	198	196	187	192	217	183
USMinnesota	160	169	161	129	123	132	144	126
USMinnesotaR	225	233	191	189	180	186	209	177
USMissouriR	225	233	191	189	180	186	209	177
USMissouriW	225	233	191	189	180	186	209	177
USNorthEast	233	241	198	196	187	192	217	183
USNPlains	160	169	161	129	123	132	144	126
USOhio	233	241	198	196	187	192	217	183
USPNW	327	357	351	284	273	288	305	296
USSouthEast	228	245	247	256	247	255	270	241
USSPlains	175	178	192	123	119	127	145	127
USWest	327	357	351	284	273	288	305	296
USWisconsin	233	241	198	196	187	192	217	183
USWisconsinW	233	241	198	196	187	192	217	183
USWNPlains	160	169	161	129	123	132	144	126

Table 5.1.2. Corn Cost of Production ($/HA), 1995-2002

	1995	1996	1997	1998	1999	2000	2001	2002
Argentina	336	389	444	400	399	438	448	362
Australia	550	543	536	529	521	514	507	500
Brazil N	146	145	142	139	103	114	106	94
Brazil S	128	125	123	120	89	99	93	83
Can Alb.	684	643	620	571	556	564	561	519
Can BC	684	643	620	571	556	564	561	519
Can Man	684	643	620	571	556	564	561	519
Can Ont	476	447	431	397	387	393	390	361
Can Sas								
China	424	541	560	496	470	457	452	454
Europe	994	1020	875	861	824	746	783	812
FSU-ME	230	224	219	213	207	201	196	190
Japan	800	900	1000	1100	1200	1300	1400	1500
Latin America	418	483	551	497	495	543	556	449
Mexico	464	499	545	561	621	651	739	704
North Africa	520	503	486	469	451	434	417	400
South Africa	280	249	243	215	198	185	167	149
South Asia	254	231	215	221	189	200	184	201
Korea	240	234	227	221	214	208	201	195
S. E. Asia	240	234	227	221	214	208	201	195
USCplains	530	469	472	454	448	478	488	441
USCplainsR	530	469	472	454	448	478	488	441
USDelta	490	434	436	419	414	442	451	407
USIllinoisN	400	394	397	388	385	404	381	339
USIllinoisS	400	394	397	388	385	404	381	339
USIndianaN	400	394	397	388	385	404	381	339
USIndianaR	400	394	397	388	385	404	381	339
USIowa	400	394	397	388	385	404	381	339
USIowaR	400	394	397	388	385	404	381	339
USMichigan	358	365	372	361	364	386	401	375
USMinnesota	400	394	397	388	385	404	381	339
USMinnesotaR	400	394	397	388	385	404	381	339
USMissouriR	400	394	397	388	385	404	381	339
USMissouriW	400	394	397	388	385	404	381	339
USNorthEast	358	365	372	361	364	386	401	375
USNPlains	569	504	507	487	481	513	524	473
USOhio	358	365	372	361	364	386	401	375
USPNW	569	504	507	487	481	513	524	473
USSouthEast	440	410	411	381	383	414	407	377
USSPlains	530	469	472	454	448	478	488	441
USWest	569	504	507	487	481	513	524	473
USWisconsin	358	365	372	361	364	386	401	375
USWisconsinW	358	365	372	361	364	386	401	375
USWNPlains	569	504	507	487	481	513	524	473

Table 5.1.3. Soybeans Cost of Production ($/HA), 1995-2002

	1995	1996	1997	1998	1999	2000	2001	2002
Argentina	314	315	301	284	287	256	261	214
Australia	600	586	571	557	543	529	514	500
Brazil N	437	445	440	424	315	348	314	284
Brazil S	437	443	436	420	316	348	306	277
Can Alb.								
Can BC								
Can Man								
Can Ont	260	268	250	221	227	222	221	205
Can Sas								
China	228	343	376	294	269	250	245	259
Europe	232	234	198	191	189	174	173	182
FSU-ME	250	241	233	224	216	207	199	190
Japan	3425	2994	2650	2442	2640	2910	2685	2578
Latin America	437	446	440	424	315	348	315	284
Mexico	800	786	771	757	743	729	714	700
North Africa	375	364	354	343	332	321	311	300
South Africa	420	384	371	323	303	287	257	237
South Asia	214	218	194	168	174	170	165	174
Korea	239	244	216	187	194	190	184	194
S. E. Asia	239	244	216	187	194	190	184	194
USCplains	194	207	180	173	173	172	187	179
USCplainsR	194	207	180	173	173	172	187	179
USDelta	220	238	218	220	212	222	239	234
USIllinoisN	227	238	195	194	187	187	197	195
USIllinoisS	227	238	195	194	187	187	197	195
USIndianaN	227	238	195	194	187	187	197	195
USIndianaR	227	238	195	194	187	187	197	195
USIowa	227	238	195	194	187	187	197	195
USIowaR	227	238	195	194	187	187	197	195
USMichigan	194	207	180	173	173	172	187	179
USMinnesota	193	205	179	171	171	171	185	177
USMinnesotaR	227	238	195	194	187	187	197	195
USMissouriR	227	238	195	194	187	187	197	195
USMissouriW	227	238	195	194	187	187	197	195
USNorthEast	194	207	180	173	173	172	187	179
USNPlains	193	205	179	171	171	171	185	177
USOhio	194	207	180	173	173	172	187	179
USPNW								
USSouthEast	251	262	234	240	230	236	268	250
USSPlains	182	193	168	161	161	161	174	167
USWest								
USWisconsin	194	207	180	173	173	172	187	179
USWisconsinW	194	207	180	173	173	172	187	179
USWNPlains	193	205	179	171	171	171	185	177

Table 5.2.1. Wheat Cost of Production ($/HA), 2004-2060

	2004	2010	2020	2030	2040	2050	2060
Argentina	186	228	282	335	388	442	512
Australia	130	133	136	140	144	147	151
Brazil N	244	279	322	365	408	452	505
Brazil S	244	279	322	365	408	452	505
Can Alb.	162	189	223	257	291	325	367
Can BC	162	189	223	257	291	325	367
Can Man	162	189	223	257	291	325	367
Can Ont	249	291	343	395	446	498	564
Can Sas	116	136	160	184	209	233	263
China	486	547	623	700	776	852	945
Europe	540	614	707	800	893	986	1101
FSU-ME	189	207	228	250	272	294	319
Japan	1500	1500	1500	1500	1500	1500	1500
Latin America	268	329	406	483	560	637	738
Mexico	854	872	894	916	939	961	985
North Africa	300	300	300	300	300	300	300
South Africa	134	147	164	181	197	214	234
South Asia	224	246	274	302	330	358	391
Korea	215	266	328	391	454	517	600
S. E. Asia	215	266	328	391	454	517	600
USCplains	127	154	187	221	254	288	332
USCplainsR	127	154	187	221	254	288	332
USDelta	127	151	181	212	242	273	312
USIllinoisN	177	210	252	293	335	376	430
USIllinoisS	177	210	252	293	335	376	430
USIndianaN	177	210	252	293	335	376	430
USIndianaR	177	210	252	293	335	376	430
USIowa	177	210	252	293	335	376	430
USIowaR	177	210	252	293	335	376	430
USMichigan	183	216	258	300	341	383	436
USMinnesota	126	150	181	212	242	273	312
USMinnesotaR	177	210	252	293	335	376	430
USMissouriR	177	210	252	293	335	376	430
USMissouriW	177	210	252	293	335	376	430
USNorthEast	183	216	258	300	341	383	436
USNPlains	126	150	181	212	242	273	312
USOhio	183	216	258	300	341	383	436
USPNW	296	360	441	521	602	682	788
USSouthEast	241	290	351	412	473	534	613
USSPlains	127	154	187	221	254	288	332
USWest	296	360	441	521	602	682	788
USWisconsin	183	216	258	300	341	383	436
USWisconsinW	183	216	258	300	341	383	436
USWNPlains	126	150	181	212	242	273	312

Table 5.2.2. Corn Cost of Production ($/HA), 2004-2060

	2004	2010	2020	2030	2040	2050	2060
Argentina	362	453	567	680	794	908	1060
Australia	500	500	500	500	500	500	500
Brazil N	94	105	119	132	146	160	176
Brazil S	83	93	105	118	130	143	158
Can Alb.	519	597	694	791	888	986	1107
Can BC	519	597	694	791	888	986	1107
Can Man	519	597	694	791	888	986	1107
Can Ont	361	415	483	550	618	686	770
Can Sas							
China	454	512	584	657	730	802	891
Europe	812	910	1033	1156	1280	1403	1552
FSU-ME	190	202	216	231	245	260	276
Japan	1500	1500	1500	1500	1500	1500	1500
Latin America	449	562	703	845	986	1127	1315
Mexico	704	730	762	794	827	859	894
North Africa	400	400	400	400	400	400	400
South Africa	149	164	182	201	220	238	260
South Asia	201	221	247	272	297	322	352
Korea	195	240	297	354	411	468	543
S. E. Asia	195	240	297	354	411	468	543
USCplains	441	532	646	760	874	987	1135
USCplainsR	441	532	646	760	874	987	1135
USDelta	407	487	586	685	785	884	1012
USIllinoisN	339	403	482	562	642	721	824
USIllinoisS	339	403	482	562	642	721	824
USIndianaN	339	403	482	562	642	721	824
USIndianaR	339	403	482	562	642	721	824
USIowa	339	403	482	562	642	721	824
USIowaR	339	403	482	562	642	721	824
USMichigan	375	450	544	637	731	825	926
USMinnesota	339	403	482	562	642	721	824
USMinnesotaR	339	403	482	562	642	721	824
USMissouriR	339	403	482	562	642	721	824
USMissouriW	339	403	482	562	642	721	824
USNorthEast	375	450	544	637	731	825	926
USNPlains	473	546	638	729	820	911	1026
USOhio	375	450	544	637	731	825	926
USPNW	473	546	638	729	820	911	1026
USSouthEast	377	453	547	642	736	831	953
USSPlains	441	532	646	760	874	987	1135
USWest	473	546	638	729	820	911	1026
USWisconsin	375	450	544	637	731	825	926
USWisconsinW	375	450	544	637	731	825	926
USWNPlains	473	546	638	729	820	911	1026

Table 5.2.3. Soybeans Cost of Production ($/HA), 2004-2060

	2004	2010	2020	2030	2040	2050	2060
Argentina	214	262	323	383	444	504	584
Australia	500	500	500	500	500	500	500
Brazil N	284	318	361	403	446	489	541
Brazil S	277	319	371	423	474	526	591
Can Alb.							
Can BC							
Can Man							
Can Ont	205	249	305	360	416	471	544
Can Sas							
China	259	293	336	380	423	466	520
Europe	182	199	220	241	262	283	308
FSU-ME	190	202	216	231	245	260	276
Japan	2578	2803	3084	3366	3647	3929	4258
Latin America	284	348	428	508	588	669	774
Mexico	700	731	771	810	849	888	931
North Africa	300	300	300	300	300	300	300
South Africa	237	261	290	320	349	379	414
South Asia	174	191	213	235	257	279	304
Korea	194	232	280	327	375	422	483
S. E. Asia	194	232	280	327	375	422	483
USCplains	179	216	262	308	355	401	461
USCplainsR	179	216	262	308	355	401	461
USDelta	234	281	339	398	456	515	591
USIllinoisN	195	236	288	339	391	443	510
USIllinoisS	195	236	288	339	391	443	510
USIndianaN	195	236	288	339	391	443	510
USIndianaR	195	236	288	339	391	443	510
USIowa	195	236	288	339	391	443	510
USIowaR	195	236	288	339	391	443	510
USMichigan	179	216	262	308	355	401	461
USMinnesota	177	215	261	308	354	401	461
USMinnesotaR	195	236	288	339	391	443	510
USMissouriR	195	236	288	339	391	443	510
USMissouriW	195	236	288	339	391	443	510
USNorthEast	179	216	262	308	355	401	461
USNPlains	177	215	261	308	354	401	461
USOhio	179	216	262	308	354	400	460
USPNW							
USSouthEast	250	303	370	436	503	570	657
USSPlains	167	206	254	303	352	400	464
USWest							
USWisconsin	179	216	262	308	354	400	460
USWisconsinW	179	216	262	308	354	400	460
USWNPlains	177	215	261	308	354	401	461

Table 5.3.1. Wheat Cost of Production ($/MT), 1995-2002

	1995	1996	1997	1998	1999	2000	2001	2002
Argentina	125	127	100	95	88	91	104	74
Australia	60	51	55	48	48	55	53	64
Brazil N	253	214	231	183	115	271	147	148
Brazil S	225	190	205	163	102	240	131	131
Can Alb.	71	67	73	56	58	65	81	74
Can BC	66	62	67	52	53	60	75	68
Can Man	71	67	73	56	58	65	81	74
Can Ont	84	76	79	59	60	59	75	64
Can Sas	62	58	63	48	50	56	70	61
China	116	141	132	128	128	126	123	118
Europe	136	131	121	115	110	101	108	109
FSU-ME	313	238	171	196	179	131	96	109
Japan	272	299	276	319	348	346	380	412
Latin America	145	119	126	117	114	101	102	103
Mexico	200	197	183	155	149	171	191	197
North Africa	210	153	180	182	189	212	160	140
South Africa	76	76	74	62	57	55	50	43
South Asia	125	121	96	90	87	85	87	85
Korea	57	72	45	70	67	106	71	76
S. E. Asia	265	248	250	188	182	191	193	171
USCplains	119	120	119	70	68	73	88	76
USCplainsR	77	78	77	45	44	48	57	49
USDelta	77	77	77	45	44	48	57	49
USIllinoisN	64	65	49	45	43	45	53	44
USIllinoisS	87	89	67	62	59	62	72	60
USIndianaN	69	71	53	49	46	49	57	48
USIndianaR	89	91	69	63	60	63	73	61
USIowa	91	93	70	64	61	64	75	63
USIowaR	87	89	67	62	59	62	72	60
USMichigan	60	62	47	43	41	43	50	42
USMinnesota	89	93	81	60	57	63	71	62
USMinnesotaR	117	120	90	83	79	83	97	81
USMissouriR	88	90	68	62	59	62	73	61
USMissouriW	103	105	79	73	69	73	85	71
USNorthEast	70	72	54	50	47	50	58	49
USNPlains	126	131	115	85	81	89	101	87
USOhio	68	69	52	48	46	48	56	47
USPNW	104	112	101	76	73	78	86	82
USSouthEast	127	136	125	120	116	122	134	118
USSPlains	210	212	209	124	120	129	155	134
USWest	109	118	106	80	77	82	91	87
USWisconsin	71	72	55	50	48	50	59	49
USWisconsinW	90	92	70	64	61	64	75	62
USWNPlains	143	149	130	96	92	100	114	99

Table 5.3.2. Corn Cost of Production ($/MT), 1995-2002

	1995	1996	1997	1998	1999	2000	2001	2002
Argentina	82	85	73	72	72	78	80	65
Australia	99	91	112	88	87	109	99	84
Brazil N	63	57	55	56	41	36	37	34
Brazil S	52	46	44	45	34	29	30	26
Can Alb.	122	119	113	92	89	110	109	93
Can BC								
Can Man	147	144	136	111	108	133	131	113
Can Ont	65	63	60	49	47	58	58	48
Can Sas								
China	86	104	128	100	107	99	97	86
Europe	192	187	137	139	133	143	131	152
FSU-ME	80	83	63	82	80	73	75	68
Japan	400	900	1000	1100	304	1300	1400	509
Latin America	221	252	286	261	261	279	287	224
Mexico	204	217	232	212	235	276	307	266
North Africa	124	94	90	78	75	74	69	66
South Africa	170	167	173	138	127	133	115	97
South Asia	161	140	128	128	110	113	106	112
Korea	62	58	55	56	98	52	47	49
S. E. Asia	127	117	110	101	43	94	90	86
USCplains	92	73	74	67	66	69	70	63
USCplainsR	105	83	84	76	75	78	79	72
USDelta	81	64	65	59	58	61	61	56
USIllinoisN	53	46	47	43	43	44	41	37
USIllinoisS	70	61	62	57	57	58	54	49
USIndianaN	63	56	56	52	52	53	49	44
USIndianaR	84	74	75	69	69	70	66	59
USIowa	47	41	41	38	38	39	36	33
USIowaR	49	43	44	41	40	41	39	34
USMichigan	67	61	62	57	57	60	61	57
USMinnesota	55	49	49	45	45	46	43	39
USMinnesotaR	52	45	46	42	42	43	40	36
USMissouriR	86	75	76	71	70	72	67	60
USMissouriW	74	65	65	61	60	62	58	51
USNorthEast	154	140	143	132	133	138	142	133
USNPlains	148	117	118	108	106	111	112	102
USOhio	85	78	79	73	73	76	78	74
USPNW	172	137	138	125	124	129	130	118
USSouthEast	109	90	91	80	80	85	82	77
USSPlains	106	84	84	77	76	79	80	73
USWest	222	176	178	162	160	167	169	153
USWisconsin	65	59	61	56	56	58	60	56
USWisconsinW	63	58	59	54	55	57	58	55
USWNPlains	266	211	213	193	191	199	202	183

Table 5.3.3. Soybeans Cost of Production ($/MT), 1995-2002

	1995	1996	1997	1998	1999	2000	2001	2002
Argentina	151	174	108	115	121	97	101	85
Australia	263	272	319	253	247	252	245	227
Brazil N	208	202	185	177	116	131	121	122
Brazil S	193	186	170	162	107	121	109	102
Can Alb.								
Can BC								
Can Man								
Can Ont	93	107	97	80	82	88	140	81
Can Sas								
China	137	194	214	164	156	150	144	139
Europe	85	82	63	67	75	77	62	62
FSU-ME	298	306	259	231	222	180	203	179
Japan	1980	1664	1514	1412	1985	1524	1428	1456
Latin America	206	201	186	179	127	141	133	117
Mexico	559	672	521	485	302	536	489	490
North Africa	160	146	138	137	133	132	249	122
South Africa	369	346	323	223	209	201	186	184
South Asia	231	266	202	182	189	189	172	178
Korea	158	150	139	141	162	145	141	130
S. E. Asia	203	197	177	156	109	152	153	148
USCplains	96	96	80	82	130	79	82	77
USCplainsR	109	109	92	93	148	89	93	87
USDelta	121	122	109	116	177	113	117	112
USIllinoisN	80	79	63	66	101	62	62	60
USIllinoisS	107	105	83	88	133	82	82	80
USIndianaN	91	89	70	74	113	69	70	68
USIndianaR	120	118	94	100	151	92	93	90
USIowa	80	78	62	66	100	61	62	60
USIowaR	82	80	64	67	102	63	63	61
USMichigan	86	86	73	74	117	71	74	69
USMinnesota	84	84	70	72	113	69	72	67
USMinnesotaR	82	80	64	67	102	63	63	61
USMissouriR	104	102	81	86	130	79	80	78
USMissouriW	119	117	93	98	149	91	92	89
USNorthEast	135	135	113	116	184	111	116	108
USNPlains	107	107	90	92	145	88	91	86
USOhio	104	104	88	89	142	86	89	84
USPNW								
USSouthEast	164	162	139	152	230	143	157	143
USSPlains	126	126	106	108	171	104	108	101
USWest								
USWisconsin	78	78	65	67	105	64	66	62
USWisconsinW	73	73	61	62	99	60	62	58
USWNPlains								

Table 5.4.1. Wheat Cost of Production ($/MT), 2004-2060

	2004	2010	2020	2030	2040	2050	2060
Argentina	72	82	86	90	92	94	99
Australia	69	64	56	50	46	42	39
Brazil N	116	123	123	123	123	123	126
Brazil S	111	113	108	105	102	100	101
Can Alb.	68	72	73	74	74	74	77
Can BC	62	67	67	68	68	69	71
Can Man	68	72	73	74	74	74	77
Can Ont	61	65	66	66	67	67	69
Can Sas	58	62	63	63	64	64	66
China	117	121	118	116	114	113	114
Europe	107	110	108	106	105	103	105
FSU-ME	111	111	104	100	96	93	92
Japan	372	345	301	267	240	218	200
Latin America	83	93	98	101	103	105	110
Mexico	187	175	154	138	125	115	107
North Africa	144	132	113	99	88	79	72
South Africa	42	42	40	38	37	35	35
South Asia	78	79	75	72	70	68	68
Korea	55	63	68	72	76	78	83
S. E. Asia	160	184	201	214	225	234	250
USCplains	50	59	70	81	91	101	114
USCplainsR	46	54	61	68	74	80	89
USDelta	38	43	47	51	55	58	63
USIllinoisN	41	47	53	58	63	67	74
USIllinoisS	49	57	65	73	81	89	99
USIndianaN	40	45	50	54	58	62	67
USIndianaR	47	53	59	64	70	75	82
USIowa	59	67	74	81	87	92	101
USIowaR	51	58	64	70	75	80	87
USMichigan	43	49	53	57	61	65	71
USMinnesota	45	52	61	69	77	85	95
USMinnesotaR	64	75	88	100	112	124	139
USMissouriR	52	60	68	76	83	90	100
USMissouriW	52	60	66	72	78	83	91
USNorthEast	47	53	58	62	67	71	77
USNPlains	54	62	70	77	83	89	98
USOhio	41	46	51	54	58	61	66
USPNW	68	81	96	110	124	138	156
USSouthEast	69	79	86	93	100	105	114
USSPlains	61	73	87	100	114	127	145
USWest	60	72	86	101	115	129	148
USWisconsin	46	52	58	64	69	74	81
USWisconsinW	57	63	66	70	73	76	81
USWNPlains	63	73	85	97	108	119	133

Table 5.4.2. Corn Cost of Production ($/MT), 2004-2060

	2004	2010	2020	2030	2040	2050	2060
Argentina	53	60	63	65	66	68	71
Australia	100	90	76	65	57	51	46
Brazil N	30	30	28	27	26	25	25
Brazil S	25	25	23	22	22	21	21
Can Alb.	88	92	90	89	88	88	89
Can BC							
Can Man	106	111	109	108	106	106	107
Can Ont	43	45	45	44	44	43	44
Can Sas							
China	91	92	88	85	83	81	81
Europe	132	133	127	122	119	116	116
FSU-ME	61	59	54	51	48	45	44
Japan	1500	1360	1147	991	873	780	705
Latin America	230	261	275	285	292	298	314
Mexico	246	229	200	179	163	150	141
North Africa	62	57	48	42	37	33	30
South Africa	85	85	79	75	72	70	69
South Asia	111	108	98	92	87	83	81
Korea	46	51	52	53	54	55	57
S. E. Asia	83	91	93	94	95	96	99
USCplains	46	54	62	69	77	84	93
USCplainsR	51	59	65	71	77	82	90
USDelta	51	57	61	64	67	70	74
USIllinoisN	34	38	41	44	47	50	53
USIllinoisS	37	41	45	48	51	54	58
USIndianaN	36	41	45	49	52	55	60
USIndianaR	39	44	48	52	55	59	64
USIowa	35	39	43	46	49	52	57
USIowaR	35	40	43	46	49	52	56
USMichigan	49	56	63	70	76	82	90
USMinnesota	38	43	46	48	51	53	57
USMinnesotaR	36	40	44	47	50	53	57
USMissouriR	42	47	50	52	55	57	60
USMissouriW	40	44	46	48	50	51	54
USNorthEast	53	61	70	78	85	92	102
USNPlains	69	73	75	77	78	80	83
USOhio	44	50	57	62	68	73	81
USPNW	40	45	48	52	55	58	62
USSouthEast	50	56	59	62	65	67	71
USSPlains	55	64	73	81	89	96	107
USWest	42	47	51	55	58	62	67
USWisconsin	44	51	57	63	69	74	81
USWisconsinW	47	54	60	65	71	76	83
USWNPlains	58	64	70	75	80	85	92

Table 5.4.3. Soybeans Cost of Production ($/MT), 2004-2060

	2004	2010	2020	2030	2040	2050	2060
Argentina	83	91	92	93	93	94	97
Australia	243	220	185	160	141	126	113
Brazil N	118	119	111	106	102	99	99
Brazil S	107	110	106	103	100	99	100
Can Alb.							
Can BC							
Can Man							
Can Ont	81	89	92	94	95	97	101
Can Sas							
China	148	147	136	128	123	119	118
Europe	73	72	66	62	59	57	55
FSU-ME	175	165	146	132	122	114	109
Japan	1820	1799	1673	1581	1511	1456	1427
Latin America	117	129	132	134	135	137	142
Mexico	424	396	344	308	281	260	244
North Africa	133	122	104	91	81	73	66
South Africa	164	160	147	137	130	124	122
South Asia	175	173	159	149	142	137	134
Korea	133	142	141	140	140	139	143
S. E. Asia	148	158	155	153	152	151	155
USCplains	60	69	77	85	92	98	108
USCplainsR	70	81	90	98	106	114	124
USDelta	105	118	126	134	141	147	158
USIllinoisN	61	72	83	93	103	112	125
USIllinoisS	69	80	90	100	109	118	130
USIndianaN	63	73	83	92	101	110	122
USIndianaR	68	79	89	98	106	114	125
USIowa	65	76	88	99	110	121	135
USIowaR	62	73	84	95	105	114	127
USMichigan	73	86	100	114	128	141	159
USMinnesota	74	87	102	116	130	143	161
USMinnesotaR	69	81	94	106	118	129	144
USMissouriR	73	83	91	97	103	109	118
USMissouriW	79	92	103	114	124	133	146
USNorthEast	72	83	93	102	110	118	129
USNPlains	81	95	109	123	135	148	164
USOhio	65	76	88	99	110	121	135
USPNW							
USSouthEast	111	127	139	149	159	168	181
USSPlains	94	113	134	155	174	193	219
USWest							
USWisconsin	64	75	86	97	108	118	132
USWisconsinW	72	83	95	105	115	125	138
USWNPlains							

6. U.S. Domestic Production, Consumption and Ethanol

6.1 Regional definitions for production and consumption The United States was divided into 10 consumption regions and 24 production regions. Production regions mirrored consumption regions, except several were further divided to groups of states, states, or crop reporting districts adjacent to the Mississippi and Ohio rivers. Regions are shown in Figure 6.1 and 6.2 for production and consumption respectively.

6.2 Data sources Data on domestic consumption by state were obtained from ProExporter(2006a, 2006b, 2006c) for crop years 2003/04 to 2005/06. To our knowledge, there is no other public set of data reporting use of individual grains at the state level. While a longer period of data was available for major producing states, data for non-producing states were only available over this period. State consumption numbers for corn, wheat and soybeans were aggregated to consumption regions and then the percent of total U.S. consumption by region was estimated.[7] Consumption for corn was further disaggregated to that used for ethanol production and for all other uses.

6.3 US domestic consumption The results are shown in Table 6.1. To estimate the quantity of consumption for each region, the annual consumption for the entire United States estimated in Section 3 above was applied to these values. These were used as the estimated level of consumption by region.

[7]The raw data is state level and is protected by copyright and therefore cannot be released.

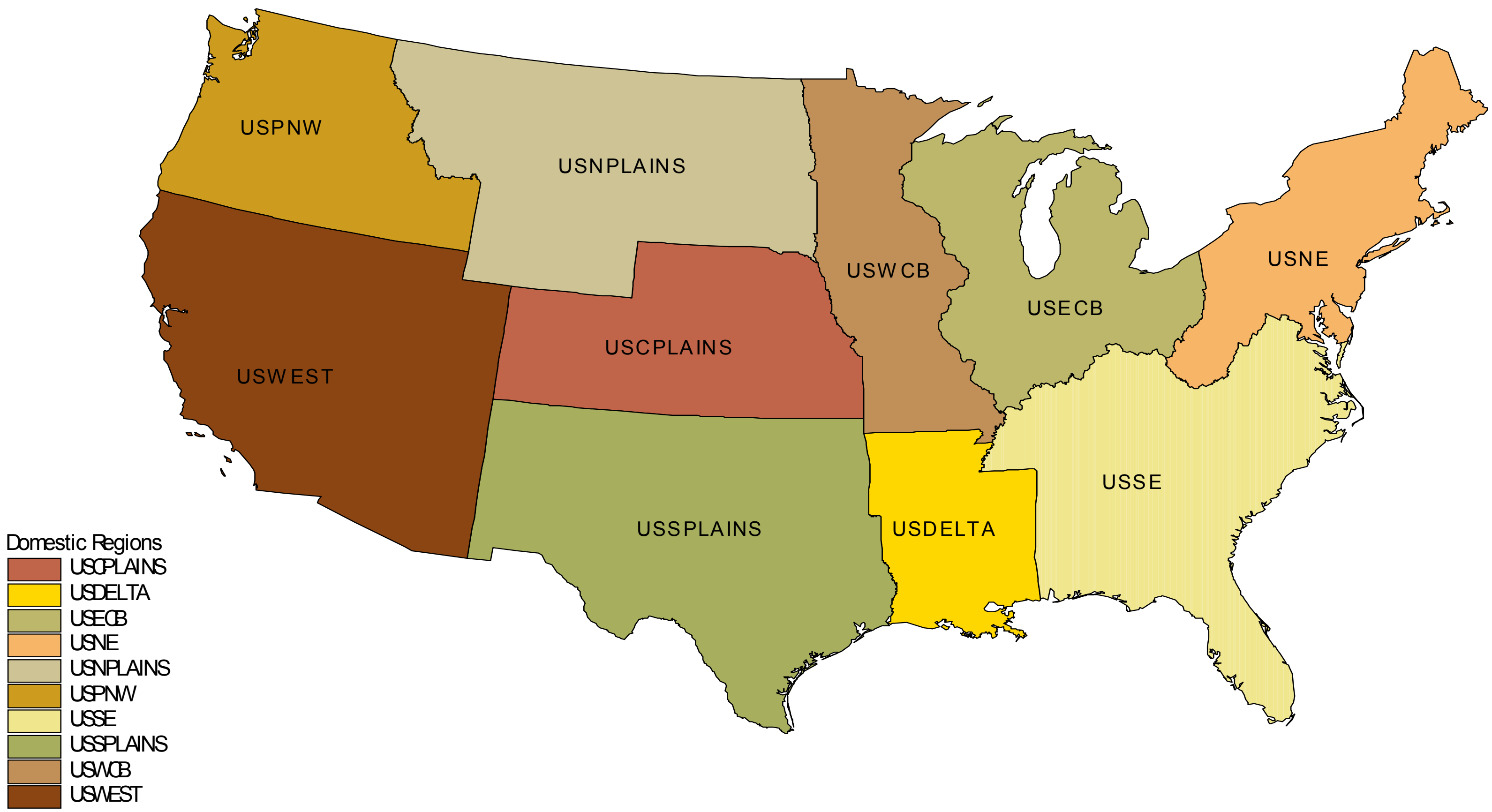

Figure 6.1. U.S. Consumption Regions.

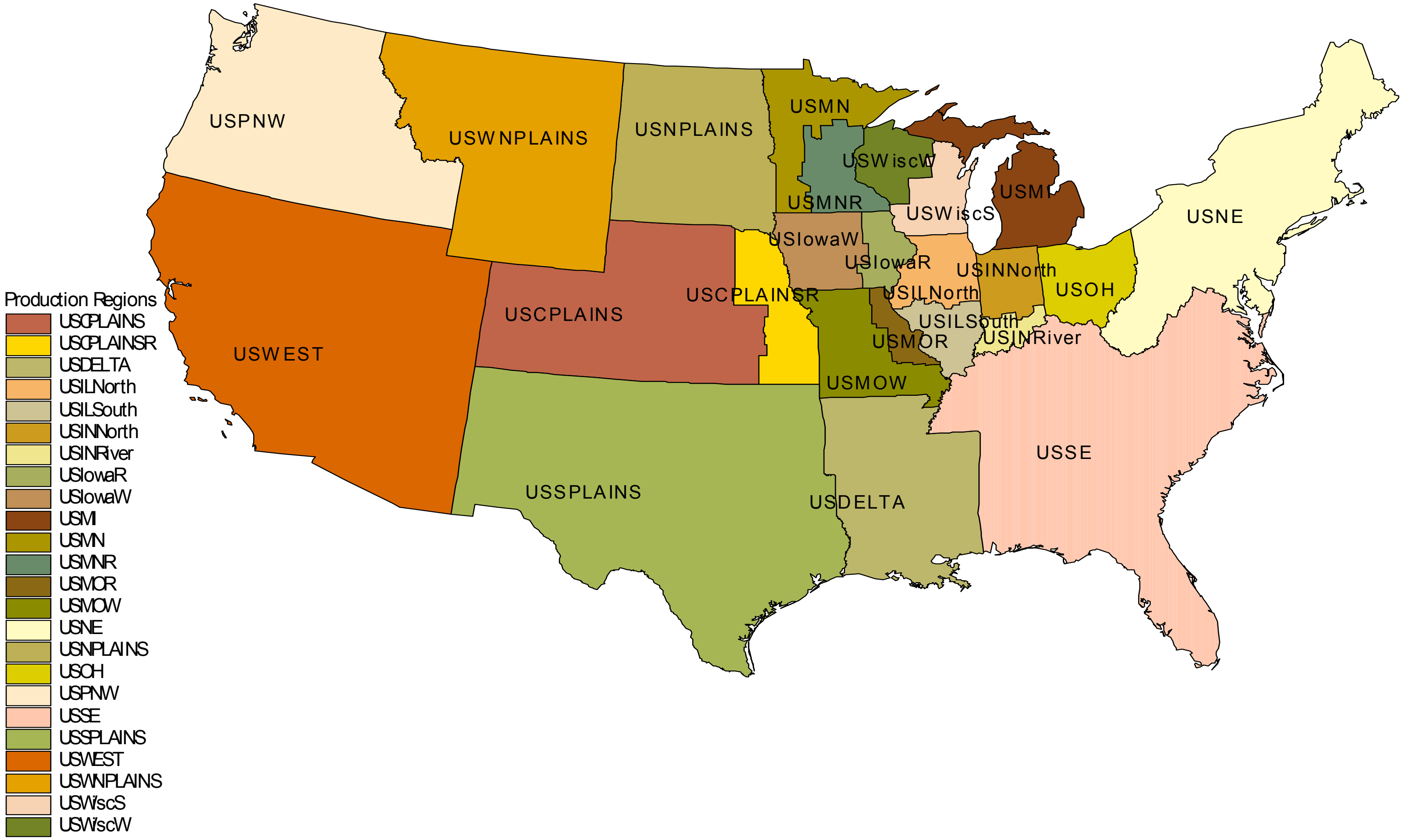

Figure 6.2. U.S. Production Regions.

6.4 Ethanol Given the importance of ethanol to the rapidly changing US corn economy, it was treated separately within the model to accommodate the details of that industry.

Model treatment of ethanol and assumptions: Corn demand was split into that for ethanol and that for all other domestic consumption using data from ProExporter(2006a) (2005). Then, the assumptions/transformations below were used to derive ethanol demand by region:

» Estimates of total U.S. consumption were calculated over the period 2002-2004 (Table 6.1) for ethanol and all other uses of U.S. domestic corn by region;

» Ethanol production from corn estimates were taken from the EIA using their 2005 and 2006 estimates. These values were converted to corn assuming 2.8 gallons of ethanol per bushel of corn. This added demand for corn for ethanol was added to consumption for years 2010-2050 based on the proportions for plant expansion in each region estimated above;

» Corn demand for other domestic uses was estimated as described above;

» Distillers dry grains (DDGs) are assumed fed in the region in which the ethanol was produced. The model did not explicitly include a function for shipping DDGs (due to the numerous uncertainties on this issue). Conceptually, our approach had the impact of 1) increasing demand for corn in regions for ethanol production, and corn shipments to those regions; and 2) increasing feed supplies in region where ethanol is produced. Shipments from that region could expand but the amount of DDGs would be less than the corn that would have been available for shipping;

» Feed demand displaced by DDGs from expanded ethanol production was derived assuming 17 lbs of DDG are produced for every bushel of corn converted to ethanol. This was used to adjust the displacement of corn demand as feed by DDG;[8]

» An implicit assumption is that DDGs were used in regions in which they were produced (i.e. the model did not allow DDG shipments);

» Two projections were made using different EIA assumptions about ethanol as reported in ProExporter(2006d). The base case assumes the ethanol demand for corn from the 2005 projections. This most consistently coincides with the base case parameters and generally has ethanol from corn production at just less than 4 billion gallons. Then a

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[8] The maximum conversion rate varies by animal type and composition of herds. The value used is similar to that used by ProExporter(2006d) (2006) averaged over the period 2000-2004 The rate of adoption of DDG for corn is less than the rate of substitution in corn rations (i.e., a lot more corn could be displaced with wider adoption of DDG for livestock ratios). The substitition rate of DDG for corn in livestock is 40 lbs. of corn is displaced by 400 lbs. of DDG and for swine and poultry, 177 lbs. of corn is displaced by 200 lbs. of DDG (Urbanchuk). The effect of ethanol in Iowa indicated DDGs are largely fed to cattle and that swine and poultry are largely untapped markets (Otto and Gallagher, 2003).

scenario is analyzed in which we used the EIA 2006 estimate which reflects current notions of ethanol production as reflected in the EIA projections and reflective of the President's policy goals. In this case, corn used in ethanol production increases from 4 billion gallons to nearly 10 billion gallons in 2015, and then converges to about 11 billion gallons in 2020 forward. In the period after 2015 a minor portion of this will be met by ethanol from cellulose (EIA 2005).

Table 6.1 Percent of U.S. Consumption by Crop and Region, 2003-2005.

	Crop			Corn Disaggregated	
Region	Corn	Wheat	Soybeans	Ethanol	All Other
US Central Plains	14%	14%	9%	17%	13%
US Delta	4%	1%	9%	0%	5%
US Eastern Corn Belt	21%	13%	35%	26%	21%
US North East	5%	11%	2%	0%	6%
US Northern Plains	4%	6%	2%	12%	2%
US Pacific North West	2%	4%	0%	0%	2%
US South East	15%	13%	16%	2%	17%
US Southern Plains	8%	14%	0%	0%	9%
US Western Corn Belt	24%	14%	28%	42%	20%
US West	4%	11%	0%	0%	5%

Features of Ethanol Important to the Analysis There are numerous features of ethanol that are important to the analysis and results. A few of these are noted below.

The rapid pace of ethanol plant adoption is illustrated graphically in Figures 6.4.3 and 6.4.4. These plants and planned projects were taken from Renewable Fuels Association (April 2006). These are located throughout the corn belt, with a heavy concentration in the western corn belt, and many are geographically aligned to river locations. These existing/operating plants comprise 4,490 million gallons of capacity and when combined with the planned plants, total capacity would be 6,715 million gallons. Current expansion plans suggest that south central Minnesota and Central Nebraska will soon be corn deficit areas (ProExporter 2006a).

There are numerous views on the prospects of there being enough corn to meet demands for both the growing world market and the US ethanol market. As examples:

» At the BIO 2006 conference, Schlicher indicated "Improvements in corn yields and the ethanol process will allow the number of gallons of ethanol produced per acre to increase from 385 gal in 2004 to 618 gal by 2015....the historical average annual corn yield increase was 1.87 b/a; and is now averaged at 3.14 b/ac over the past 10 years..."which shows the impact of ag biotech." ...With such improvements, she said, 10% of the country's gasoline can come from corn ethanol within a decade without sacrificing corn use elsewhere.

Meyer indicated that corn yields in past 10 years have increased from 126 b/a in 1996 to a projected 153 b/a in 2006. 2005 had a yield lower yield than 2004 at 160 b/a due to drought in the Midwest. Gains substantially over trend line are possible due to genetic modification as these are adopted by growers. Stacking of traits in the next 3-5 years could result in corn crops in 14-15 bill bu per year on the same acres as 1996.

» Dr. Robert Thompson, in a presentation to the Chicago Farmers meeting indicated skepticism of the ethanol industry predicated upon import tariffs, excise tax exclusion and mandated oxygenate requirements. US ethanol policy may work for next decade or two but continued rapid growth in corn used for ethanol will set stage for collision of "food vs. fuel when US ag productivity growth is no longer able to meet needs of fuel, export and domestic food sectors.

» Feltes, in summarizing ProExporter's (2006d) ethanol workshop suggested that estimated ethanol production of 5.9 bil gallons (2.15 bill bu corn) is understated. This underscored the importance of steady gains in US corn yield and timing and impacts of China's transition from a corn exporter to importer. He suggested US agriculture can produce the volume of corn and soybeans necessary to meet biofuel, feed, food and export needs over the next decade. However, he noted that moving these crops and byproduct is a colossal challenge to the transportation sector. Specifically, they projected railroad tonmile demand will increase by 20% and the need to double the ethanol rail car fleet.

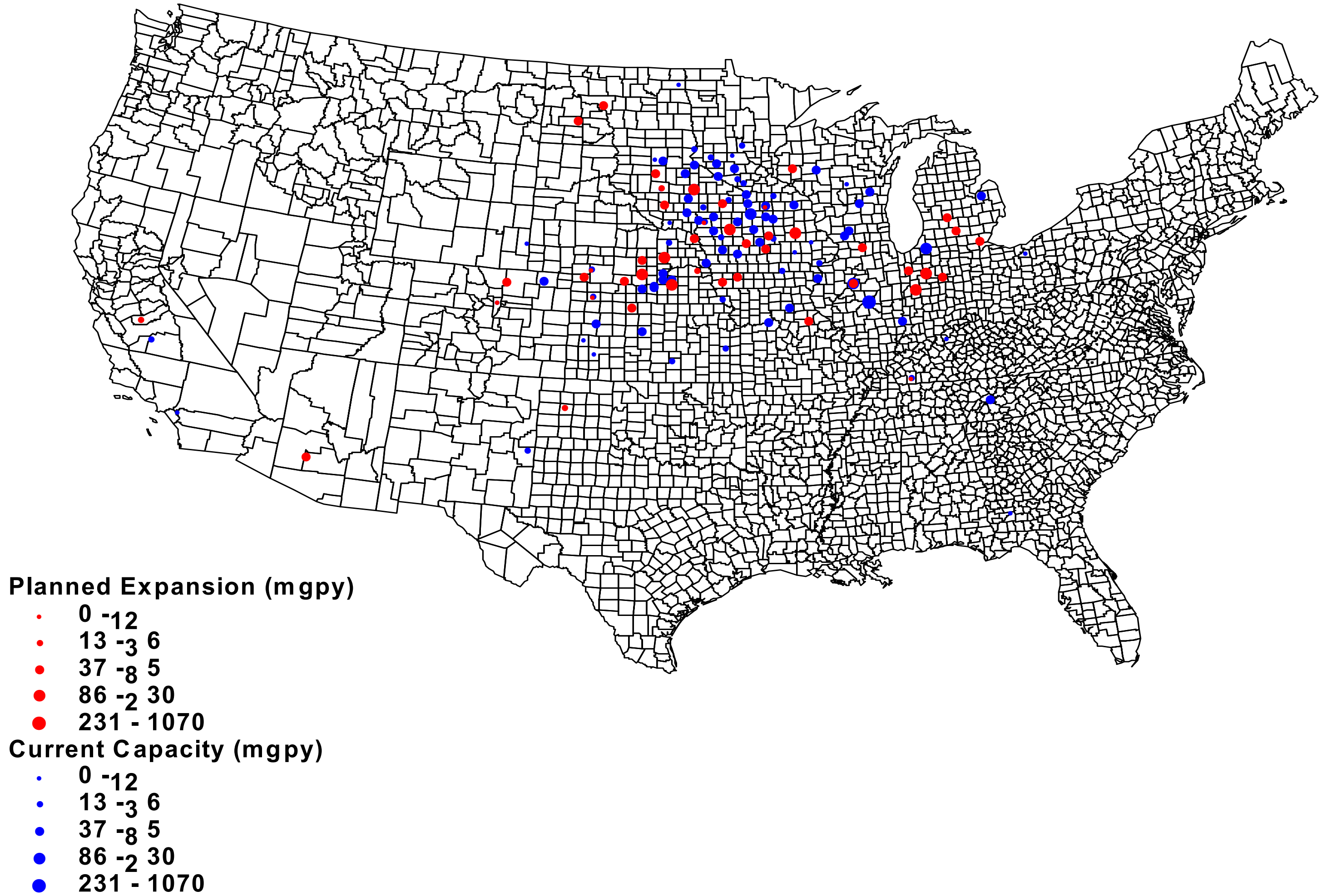

Figure 6.4.3. Location of Current and Planned Ethanol Capacity, 2006.

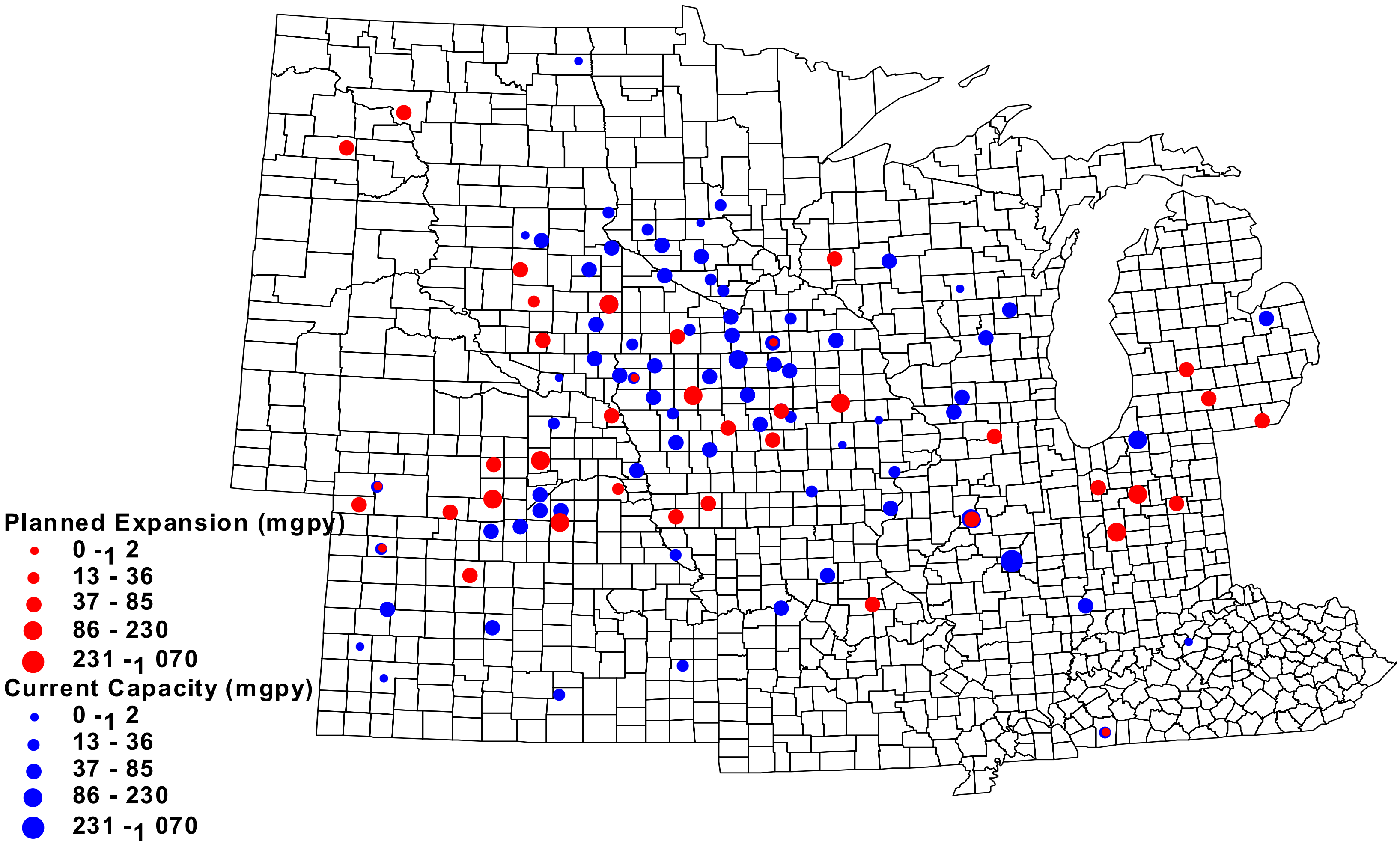

Figure 6.4.4 Expanded View of Ethanol Plant Locations (May 2006).

» The DOE forecasts steep growth in ethanol production from now through 2013, followed by steady but slower rate of expansion. The ethanol share of US gasoline use will go up from 2% today to 4 % by 2016.

» Ethanol production is not capable of keeping the pace of the growth in ethanol demand (USA Today, March 30, 2006) and suggested that there would be an ethanol shortage. This is caused in part by the rapid elimination of MTBE. Allegedly This was due to that Congress chose not to provide liability protection for refiners and producers of MTBE;

» China is the 3rd largest ethanol producer. A domestic fuel ethanol program was lauched in 2001 amid rising petroleum consumption, increase pollution and the fast pace of urban development. Ethanol blends of 10% were trialed in five provinces in central and northeastern China, before being extended to a further four in 2005. (Sosland, Milling and Baking News, April 25, 2006).

» Ethanol has had an impact on grain flows and barge demand in particular. Informa Economics indicated that "... ethanol expansion is changing the grain flow landscape. In Illinois, the representatives share of it s corn production that would have gone to ethanol production in 2004 totaled 13%. For the 2005/06 crop year, it is anticipated that ethanol's share of the Illininois' cron harvest will be 18% increasing to more than 25% of this coming fall harvest. In South Dakota, ethanol's share is teetering on nearly half of the state's corn harvest expected for 2006, up from 30% two years ago. This is a similar situation for many corn belt states, especially those in the western Corn Belt where there is a surplus supply of corn. As more ethanol plants pop up throughout the corn belt, this will have implications on the availability of surplus gain for various markets whether for export moves to the PNW or feed markets into the Southeast and Southwest.

» Looking into the longer term, ethanol production from corn is not expected to increase beyond these levels to 2050 (see U.S. Department of Energy Scenarios, (Steiner)). If ethanol production increases beyond these levels, Steiner suggests that source of feedstock for production would shift from starch to cellulosic with increases above current levels from cellulosic rather than starch (corn, sorghum, wheat, etc.). Steiner examined effects of cellulosic production of ethanol to 2050. This study has two scenarios which both indicate growth in ethanol production from 2010 to 2050 growing to 49.3 to 50.4 billion gallons, of which, most of the growth past 2010 is in ethanol produced from cellulosic feedstocks rather than starch based (corn, sorghum). These are tied back to US Department of Energy scenarios forecast to 2050. This suggests that corn demand for ethanol beyond 2010 would be somewhat stable to 2050 with increases in ethanol production coming from other feedstocks.

7. Modal Rates/Cost Analysis

7.1 Regions and Logic Demand regions were defined to allow for estimation of domestic consumption by region as made up of groups of states from which we could use rail shipment data and production to calculate percent of demand by region. Smaller aggregations for demand regions would complicate allocations of total demand substantially. Consumption regions are shown in Figure 7.1.1 and are the same as in section 6.

Production regions were defined to accommodate potential diverse flows within The United States. See Figure 7.1.2. Specifically, The Northern Plains region was split into a Western Northern Plains (Montana and Wyoming) and a Northern Plains region (North and South Dakota). Another existing region (Central Plains) has crop reporting districts (CRD's) close to the Missouri River separated to form a new Central Plains River region. In the eastern and western corn belt regions, production regions were defined first at the state level and further refined to specify CRD's adjacent to the river system as separate production regions. These types of adjustments were made in several states within the old Eastern and Western Corn Belt Regions.

The rationale for changes was to more accurately reflect tradeoffs between truck/rail shipping costs to barge movements and to reflect limits on production available via trucks from nearby production areas for feeding barge loading facilities.

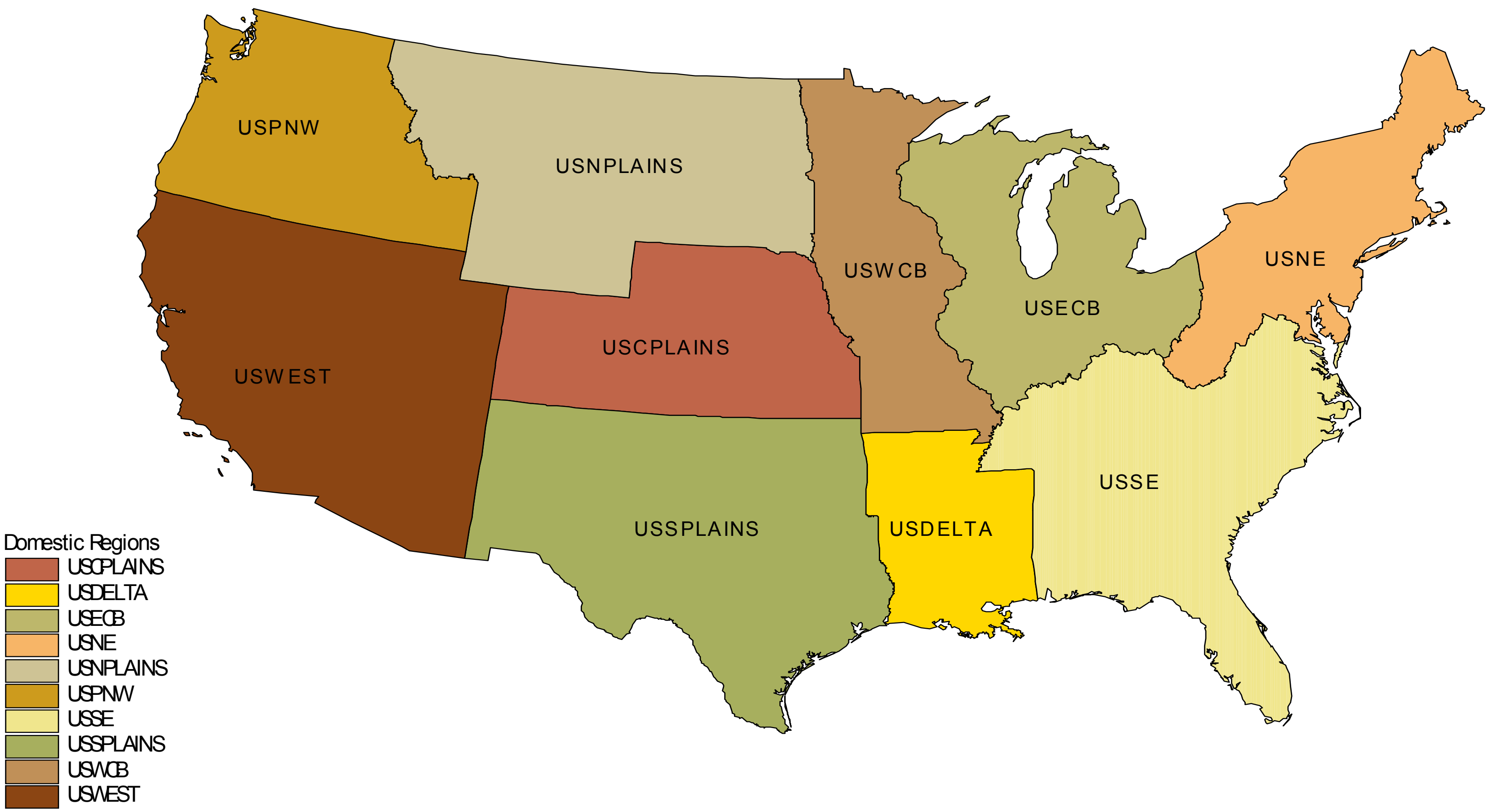

Figure 7.1.1. U.S. Consumption Regions.

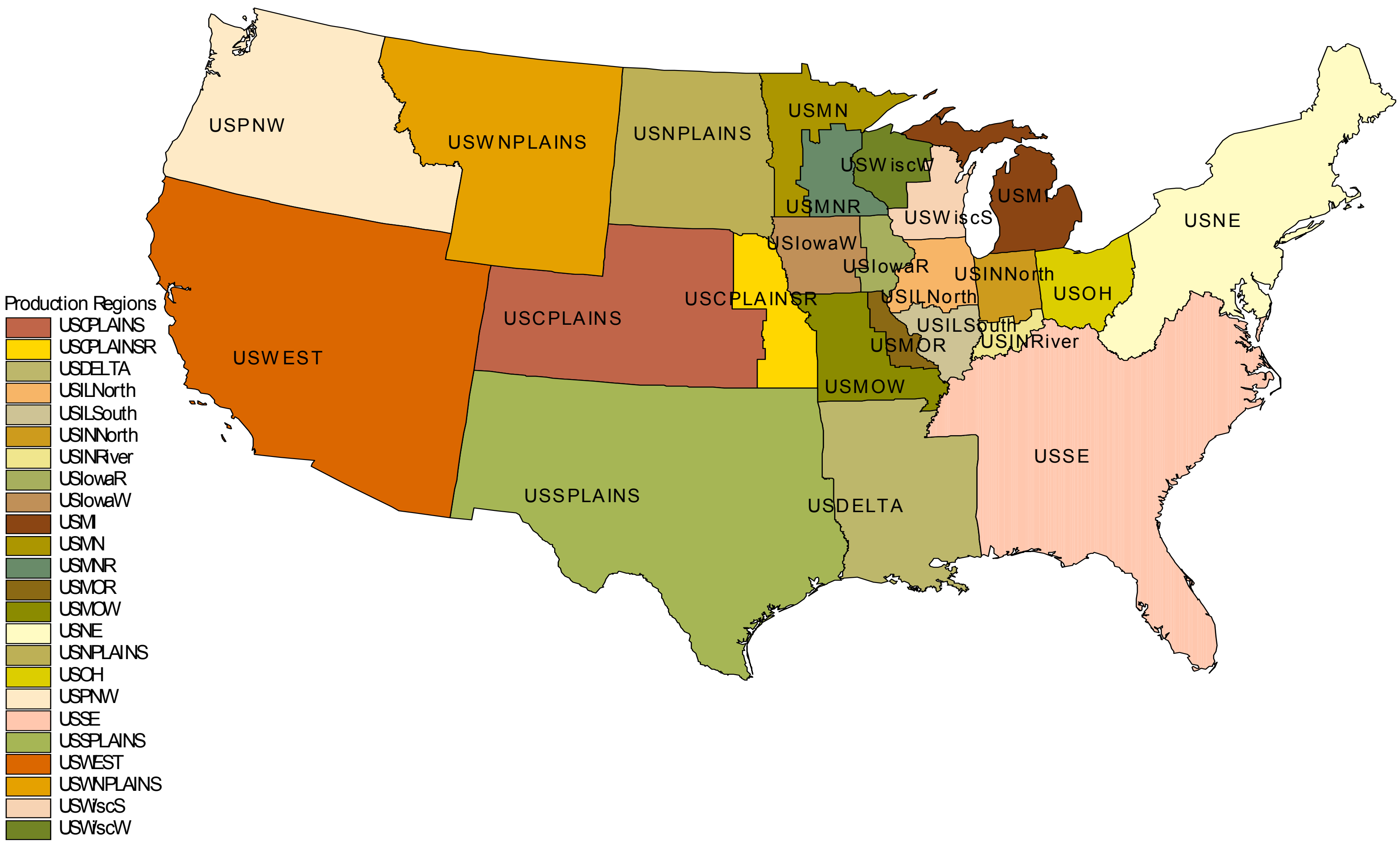

Figure 7.1.2. U.S. Production Regions.

7.2 US Rail Rail rate matrixes were derived with data from the Surface Transportation Board (STB) (2004 and previous years) Confidential Waybill data set. This data was for the years 1995-2004 and was assembled by Tennessee Valley Authority (TVA). The values used were the "line-haul" rate and converted to $/MT using conventional values.[9]

Two matrixes were derived for each crop, one for domestic and one for export shipments. Data were first differentiated by which county shipments terminated. If shipments terminated at counties containing export terminals, river terminals or export border transit points, then they were placed in an export/barge movement data set. Further perspective on eliminating counties which contained both river terminals and domestic processors where river terminals operated either to support domestic processors or focused on intra-river trade and Mexican border transit points were elicited from TVA and revisions applied (Figure 7.2.1-7.2.2). In Reach 6, all river terminals supported domestic processors. In that reach, rail deliveries to river terminals were for domestic use only. Export shipments originated from reach 6 from truck receivals only. For Reach 5, rail receivals for barge loadings of export corn only were located only at Evansville, IN and Mt. Vernon, IN.

All other barge loadings (corn, wheat, and soybeans) for export originated from truck receivals. This resulted in a data set that contained movements from production regions to export and barge loading locations. These included export destinations of Duluth/Superior, Pacific Northwest, Northern Louisiana, Texas Gulf, East Coast of US, Toledo, and for direct rail shipment to Mexico.

Six barge loading regions (reaches) were included: Reach 1 - Cairo - LaGrange (St. Louis); Reach 2 - LaGrange to McGregor (Davenport); Reach 3- McGregor to Mpls (Mpls); Reach 4-Illinois River (Peoria); Reach 5 Cairo to Louisville (Louisville); and Reach 6 Cincinnati (Cincinnati). The second rail rate matrix was from production regions to domestic consumption regions (See figure 7.2.1).

The data sets were constructed which included year, commodity, origin region (production region), destination (export port area or barge loading area for export and domestic region for domestic), total revenue and total tons by shipment. Then weighted average rates (individual observations for $/MT were weighted by the tons shipped) were derived for each year, crop and movement. These weighted average rates were averaged for the years 2000-2004

[9] We used the reported rates which are the "line-haul rate." However, treatment of private car costs are unclear and treated inconsistently across carriers; and different carriers report fuel charges differently. In addition, treatment of rebates on shuttle programs are not explicitly included in this rates.

by crop and movement (Tables 7.2.1-7.2.6).[10] These were utilized in the model.

There were two adjustments to these observed rates ultimately used in the base case model. One of these relates to shuttle rate discounts or rebates on rail shipment to the PNW. It is not clear how the STB data set deals with rail rate rebates under shuttle-like programs. While the overall base rate is fully reflected in the STB rate, rebates to shippers due to being able to attain origination and termination efficiencies are not. In our case, the PNW rail movement is the dominant movement in which shuttle shipments prevail. To adjust these, we observed data as reported by USDA AMS in which rates on shuttle and non-shuttle shipments are reported. From these, it appears the mean difference is about $2/mt. Thus, based on this, we deducted $2/mt from shipments going to the PNW.

The second adjustment was for rail shipments to Mexico. Shipments to that country were treated as a domestic shipment in our specification. Rail rates were adjusted to more accurately reflect shipments to that country. In particular, the total volume of corn and soybeans was limited for direct rail shipments by rail to 5 mmt. This was the high end of recent observed shipments. The logic to this likely has to do with the location of interior demands relative to US ports, relationships with and among US and Mexican carriers, as well as the US concerns on too much equipment in Mexico which may slow their cycle times. The balance of Mexican imports is by ocean shipments.

The implicit assumptions about these rates are 1) rail rate relations maintain their same spatial relationship in the projection period as during the base period (2000-2004 average); and 2) rail rates that are missing in the waybill during the base period, are treated as missing during the calibration and projection period. The latter are important in that in the waybill if a rate is not shown, it would typically be due to that movement resulting in a nil movement, which would imply it was noncompetitive relative to alternatives. This assumption implies that if it were not competitive during the base period that would be retained in the projection period.

[10]Disclosure rules limit the information that can be revealed. As a result, in this report, we only show selected averages, but, discuss the general results. Rates are not included in these tables for STB disclosure restrictions.

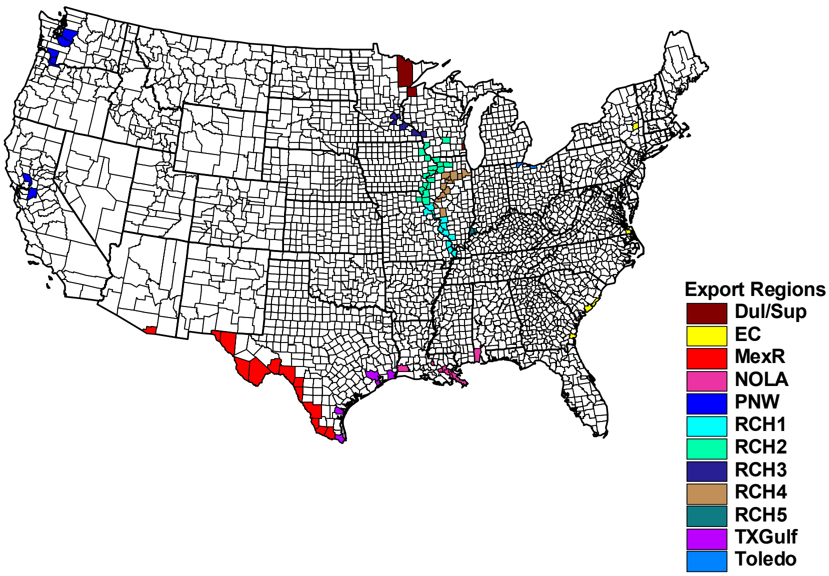

Figure 7.2.1. Terminating Counties for Definition of Export Regions.

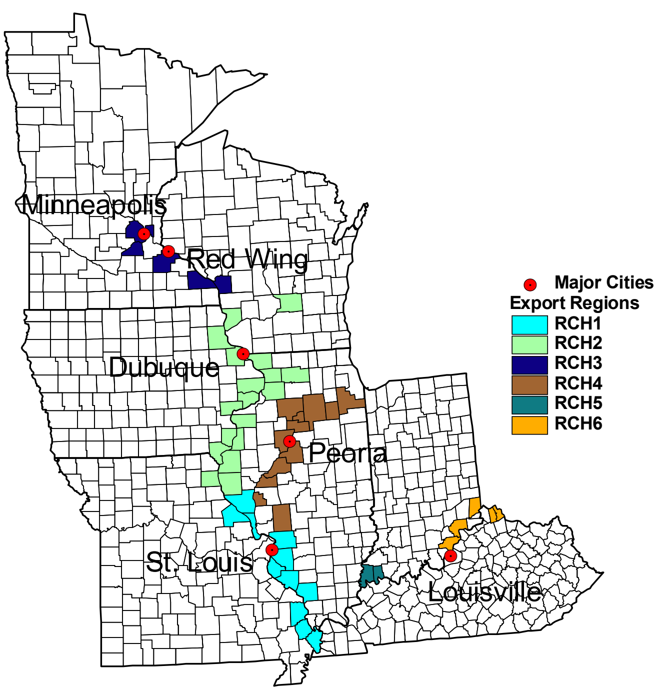

Figure 7.2.2. Expanded View Barge Reach Definitions.

Table 7.2.1 Corn to Export and Barge Loading Regions: Rail Rates from U.S. Production Regions, 2000-2004 ($/MT).

ProdReg	DulSup	EastCo	Mexico	NOLA	PNW	TexasGulf	Toledo	Reach1	Reach2	Reach3	Reach4	Reach5
USCPLAINS												
USCPLAINSR												
USDELTA												
USILNorth												
USILSouth												
USINNorth												
USINR												
USIOWAR												
USIOWAW												
USMI												
USMN												
USMNR												
USMOR												
USMOW												
USNE												
USNPLAINS												
USOH												
USPNW												
USSE												
USSPLAINS												
USWEST												
USWISCS												
USWISCW												
USWNPLAINS												

Note: No Rate implies no reported movement.

Reach 1 - St. Louis, Reach 2 - Davenport, Reach 3-Mpls, Reach 4-Peoria, and Reach 5-Louisville.

Table 7.2.2. Wheat to Export and Barge Loading Regions: Rail Rates from U.S. Production Regions, 2000-2004 ($/MT).

ProdReg	DulSup	EastCo	Mexico	NOLA	PNW	TexasG	Toledo	Reach1	Reach2	Reach3	Reach4
USCPLAINS											
USCPLAINSR											
USDELTA											
USILNorth											
USILSouth											
USINNorth											
USINRiver											
USIOWAR											
USIOWAW											
USMI											
USMN											
USMNR											
USMOR											
USMOW											
USNE											
USNPLAINS											
USOH											
USPNW											
USSE											
USSPLAINS											
USWEST											
USWiscS											
USWiscW											
USWNPLAINS											

Note: No Rate implies no reported movement.

Reach 1 - St. Louis, Reach 2 - Davenport, Reach 3-Mpls, Reach 4-Peoria, and Reach 5-Louisville.

Table 7.2.3. Soybean to Export and Barge Loading Regions: Rail Rates from U.S. Production Regions, 2000-2004 ($/MT).

ProdReg	DulSup	EastCo	Mexico	NOLA	PNW	TexasG	Toledo	Reach1	Reach2	Reach3	Reach4
USCPLAINS											
USCPLAINSR											
USDELTA											
USILNorth											
USILSouth											
USINNorth											
USINRiver											
USIOWAR											
USIOWAW											
USMI											
USMN											
USMNR											
USMOR											
USMOW											
USNE											
USNPLAINS											
USOH											
USPNW											
USSE											
USSPLAINS											
USWEST											
USWISCS											
USWISCW											
USWNPLAINS											

Note: No Rate implies no reported movement.

Reach 1 - St. Louis, Reach 2 - Davenport, Reach 3-Mpls, Reach 4-Peoria, and Reach 5-Louisville.

Table 7.2.4. Corn to Domestic Regions: Rail Rates from U.S. Production Regions, 2000-2004 ($/MT).

ProdReg	CPlains	Delta	ECornB	NEast	NPlains	PNW	SEast	SPlains	WCornB	West
USCPLAINS										
USCPLAINSR										
USDELTA										
USILNorth										
USILSouth										
USINNorth										
USINRiver										
USIowaR										
USIowaW										
USMI										
USMN										
USMNR										
USMOR										
USMOW										
USNE										
USNPLAINS										
USOH										
USPNW										
USSE										
USSPLAINS										
USWEST										
USWiscS										
USWiscW										
USWNPlains										

Note: No Rate implies no reported movement.

Table 7.2.5. Wheat to Domestic Regions: Rail Rates from U.S. Production Regions, 2000-2004 ($/MT)

ProdReg	CPlains	Delta	ECornB	NEast	NPlains	PNW	SEast	SPlains	WCornB	West
USCPLAINS										
USCPLAINSR										
USDELTA										
USILNorth										
USILSouth										
USINNorth										
USINRiver										
USIOWAR										
USIOWAW										
USMI										
USMN										
USMNR										
USMOR										
USMOW										
USNE										
USNPLAINS										
USOH										
USPNW										
USSE										
USSPLAINS										
USWEST										
USWiscS										
USWiscW										
USWNPLAINS										

Note: No Rate implies no reported movement.

Table 7.2.6. Soybeans to Domestic Regions: Rail Rates from U.S. Production Regions, 2000-2004 ($/MT)

ProdReg	CPlains	Delta	ECornB	NEast	NPlains	PNW	SEast	SPlains	WCornB	West
USCPLAINS										
USCPLAINSR										
USDELTA										
USILNorth										
USILSouth										
USINNorth										
USINRiver										
USIowaR										
USIowaW										
USMI										
USMN										
USMNR										
USMOR										
USMOW										
USNE										
USNPLAINS										
USOH										
USPNW										
USSE										
USSPLAINS										
USWEST										
USWISCS										
USWISCW										
USWNPLAINS										

Note: No Rate implies no reported movement.

7.3 US truck rates Two sets of truck rates were used. One was for shipments from farm origins to the export ports including the River system, the other was for shipments to domestic demands.

For shipments to the river by truck we used rates from Dager (2007 forthcoming). These were stated to be in the area of \$3.70/mt per 20 miles for the base period for shipments to each reach. The exception was for Illinois in which the rates were \$4.60/mt per 20 mile increment. These were slightly higher due to a greater portion of shipments in or around urban areas.[11]

For truck shipments to domestic markets, rate functions were estimated as a function of distance. Distance matrixes were created from centroids of production regions to export and barge loading regions and to centroids of domestic consumption regions (Tables 7.3.1-7.3.2). These distance matrixes will be used to estimate truck shipping costs.

Rate functions were derived from USDA-AMS data on trucking costs from 4th quarter 2003 to 3rd quarter 2004. Data were for specific milage distances (25, 100 and 200 miles). Logrithmic relations were estimated between rates/mile and distance. Results indicated:

$$Truck\cos t / Mile = 4.12 \cdot -.472 \cdot LN(Miles)$$

R-square for relationship was .90. Relationships between distance and rate per loaded mile and per MT are shown in figures 7.3.1 and 7.3.2.

This relationship was used along with distance matrixes to derive an estimate of the truck rate from each origin to each destination. In the model, a limit was placed at 350 miles at which point truck rates were set to arbitrarily high values to preclude their choice as shipment option.

[11]Further, these results indicated that the only rail to barge shipment was at Savage and St. Louis. All other locations were 100% truck to barge. Farm trucks were being used for a maximum of 50-60 miles. Commercial trucks went to a maximum of 120 miles with outbound shipments from the river terminal being the headhaul and grain being a backhaul. The reason for the difference in costs across regions of commercial shipments is due to a combination of the share of shipments being classified as rural vs urban, and that trucks in the Upper regions used dump trailers, and those going to Illinois used end dump trailers. Finally, since our base period, the truck rates have nearly doubled to 15 to 20c/b/20 mile and those from Illinois origins increased to 20-25c/b/20 mile increment (Dager 2007).

Table 7.3.1. Estimated Miles between Centroids of Production and Consumption Regions.

ProdReg	USCPLAINS	USDELTA	USECB	USNE	USNPLAINS	USPNW	USSE	USSPLAINS	USWCB	USWEST
USCPLAINS	59	815	956	1463	407	858	1201	582	567	700
USCPLAINSR	297	568	611	1119	610	1173	877	635	265	1051
USDELTA	770	0	719	1111	1164	1672	467	579	691	1391
USILNorth	664	589	237	745	875	1480	671	926	205	1422
USILSouth	674	413	330	802	961	1547	529	815	336	1418
USINNorth	833	605	114	591	1048	1654	558	1034	375	1589
USINRiver	834	493	233	650	1095	1692	445	963	435	1581
USIowaR	564	635	337	842	754	1360	778	892	85	1321
USIowaW	420	664	488	991	613	1214	885	812	93	1173
USMI	937	843	131	484	1058	1671	761	1233	427	1690
USMN	543	975	632	1069	482	1087	1158	1062	301	1202
USMNR	575	870	482	932	610	1222	1016	1035	180	1288
USMOR	593	439	365	858	877	1462	609	775	268	1340
USMOW	527	388	460	951	847	1415	636	681	303	1264
USNE	1405	1111	508	0	1541	2153	808	1612	904	2162
USNPLAINS	411	1019	819	1280	263	874	1278	980	432	993
USOH	1009	707	150	427	1212	1822	529	1186	541	1766
USPNW	907	1672	1684	2153	613	0	2048	1317	1281	596
USSE	1146	467	636	808	1481	2048	0	1045	860	1834
USSPLAINS	578	579	1139	1612	987	1317	1045	0	892	893
USWEST	758	1391	1656	2162	777	596	1834	893	1263	0
USWiscS	722	805	273	722	820	1433	859	1091	214	1465
USWiscW	674	871	388	820	723	1334	963	1097	206	1398
USWNPLAINS	516	1282	1242	1715	174	442	1626	1031	839	653

Table 7.3.2. Estimated Miles between Centroids of Production Regions and Export and Barge Loading Locations.

ProdReg	Ecoast	Dul/Sup	TxGulf	NOLA	Toledo	PNW	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach6
USCPLAINS	1446	717	827	1003	1010	1068	679	650	599	698	857	975
USCPLAINSR	1106	522	709	777	680	1376	342	325	385	363	521	634
USDELTA	892	977	313	201	753	1879	416	616	857	567	423	587
USILNorth	769	415	851	766	309	1681	175	65	329	24	264	296
USILSouth	725	586	697	590	376	1755	43	218	486	153	137	267
USINNorth	591	531	900	747	162	1859	247	242	477	179	190	126
USINRiver	567	633	798	628	258	1897	204	298	561	222	72	109
USIowaR	885	337	872	829	407	1565	239	53	228	128	371	414
USIowaW	1031	348	854	869	558	1419	324	201	212	266	488	557
USMI	656	421	1135	993	153	1861	458	338	435	328	436	320
USMN	1213	225	1157	1181	696	1284	613	429	164	505	751	767
USMNR	1064	120	1081	1071	549	1418	487	292	21	366	612	620
USMOR	809	537	694	629	424	1666	49	173	425	135	225	342
USMOW	884	589	615	589	521	1619	120	247	465	227	290	428
USNE	401	905	1432	1192	451	2362	845	809	938	769	720	551
USNPLAINS	1384	397	1140	1222	877	1082	709	562	344	636	871	920
USOH	420	657	1016	813	113	2036	416	423	631	365	292	112
USPNW	2219	1239	1632	1845	1725	231	1484	1386	1198	1454	1661	1745
USSE	480	1125	764	448	659	2301	612	779	1049	703	456	492
USSPLAINS	1463	1171	368	680	1205	1507	797	917	1034	915	912	1080
USWEST	2207	1439	1314	1599	1787	694	1439	1426	1344	1473	1612	1743
USWiscS	851	226	1064	988	333	1636	397	204	210	247	465	428
USWiscW	965	115	1108	1062	446	1535	467	263	118	325	561	540
USWNPLAINS	1835	873	1322	1502	1343	614	1105	1003	821	1071	1281	1362

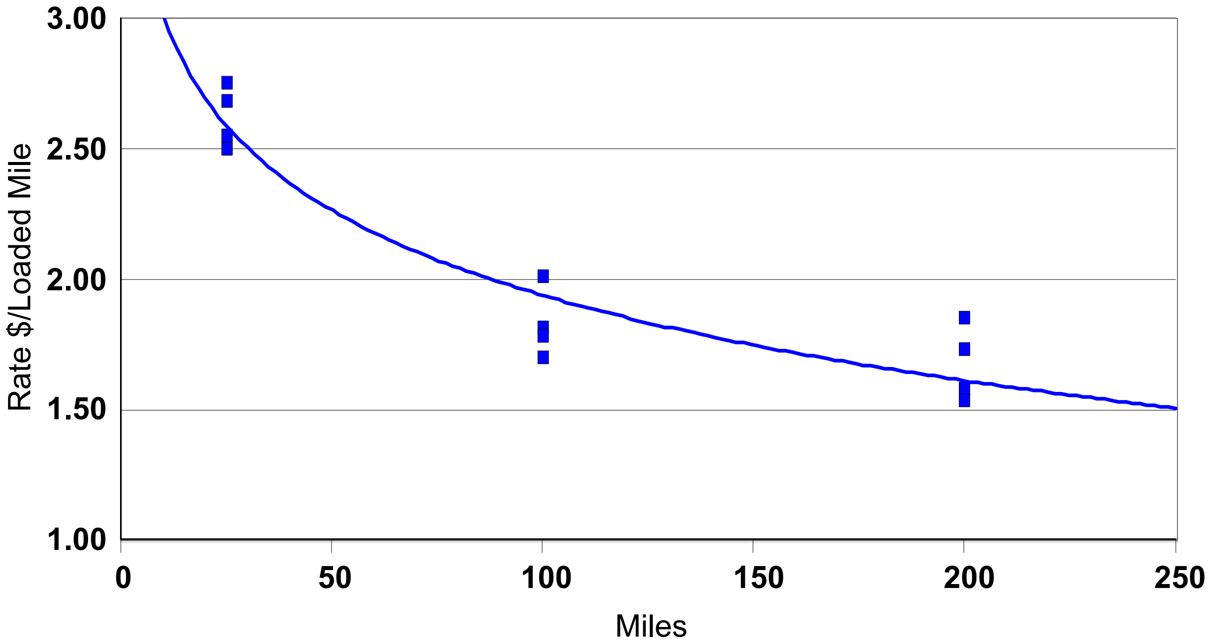

Figure 7.3.1. Estimated Relationship Between Distance of Shipment and Rate per Loaded Mile (Q4-2003 to Q3-2004).

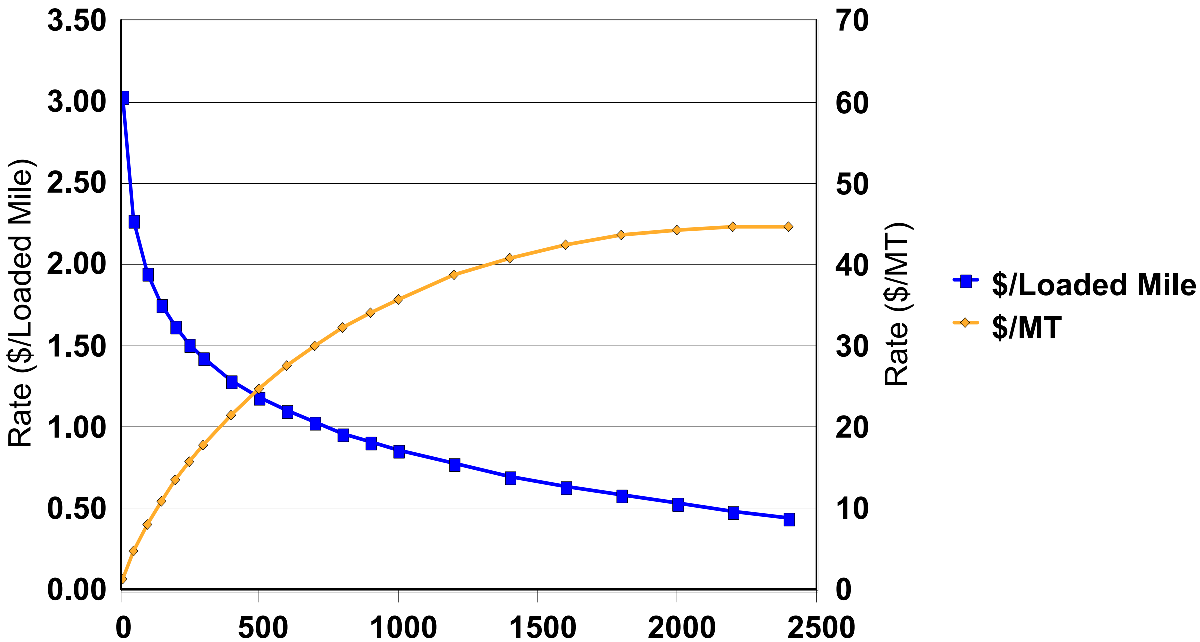

Figure 7.3.2. Estimated Relationship Between Distance, Rate Per Loaded Mile and Cost/MT.

7.4 US Barge Rates Barge rates from each origin were derived from data (percent of tariff) as reported by AMS. The values were annual means and standard deviations for the 6 reaches and converted these to $/MT rates assuming draft adjustments.

Draft adjustments were made for the following locations where the draft adjustment was applied to % of the tariff before converting to a $/MT measure. (i.e., for St. Louis in 2002 the % tariff was 128.38 and the draft adjustment was 15%. The rate is (128.38 - 15)/100 * Tariff rate in $/MT). Draft Adjustments were 0% of Illinois River and Cincinnati, 5% lower for Mpls, McGregor and Louisville and 15% for St. Louis.

Results are shown in Tables 7.4.1-7.4.2 and in Figures 7.4.1-7.4.2.

Table 7.4.1. Simple Average Percent of Tariff and Standard Deviation by Barge Loading Area, 1990-2005.

Year	St. Louis	McGregor	Mpls.	Peoria	Louisville	Cincinnati
			Average Annual % of Tariff			
1990	121.15	141.83	161.17	138.25	120.25	122.90
1991	130.19	150.16	175.68	146.32	135.57	141.28
1992	123.62	149.57	161.18	138.78	130.06	131.33
1993	118.91	153.37	167.62	143.52	122.72	126.47
1994	134.01	163.45	176.33	151.86	141.89	142.78
1995	205.34	251.54	293.65	243.08	211.12	210.17
1996	131.86	160.27	183.27	167.78	138.87	138.96
1997	115.97	150.71	181.06	140.70	127.73	129.13
1998	144.25	193.70	222.24	166.02	147.63	145.17
1999	147.06	194.90	232.37	184.05	149.39	146.28
2000	153.85	184.52	210.28	182.06	161.47	161.74
2001	153.53	191.12	215.83	184.10	162.17	160.06
2002	128.21	173.60	191.90	155.58	127.08	125.36
2003	158.30	192.64	215.16	188.22	161.58	161.37
2004	183.42	214.17	241.63	217.36	192.99	191.60
2005	337.16	374.84	383.86	336.24	335.95	333.08
			Standard Deviation			
1990	20.26	19.72	25.73	25.57	16.70	16.39
1991	43.23	41.52	50.39	42.00	43.89	46.64
1992	42.54	37.83	32.74	36.00	48.42	45.58
1993	34.69	36.57	26.47	41.17	37.75	38.11
1994	62.51	65.64	57.12	64.20	65.67	64.96
1995	48.58	55.20	66.45	45.73	55.82	55.17
1996	40.09	40.03	38.55	58.51	39.90	40.26
1997	33.76	41.29	44.73	41.25	39.77	41.21
1998	73.94	69.28	69.70	65.50	67.13	65.76
1999	49.60	51.56	52.40	46.16	51.99	49.62
2000	46.91	46.59	36.37	43.70	49.11	49.05
2001	29.37	17.38	11.52	26.33	34.03	33.63
2002	32.39	47.35	43.29	33.82	25.94	25.75
2003	57.97	46.54	37.39	48.43	51.40	51.12
2004	62.25	66.78	64.51	62.67	71.57	69.29
2005	178.04	159.54	133.57	152.16	173.44	169.83

Table 7.4.2. Simple Average Estimated Barge Rates ($/MT) and Standard Deviations Adjusted for Draft Differences, 1990-2004.

Year	St Louis	McGregor	Mpls	Peoria	Louisville	Cincinnati
			Average Barge Rates ($/MT)			
1990	4.67	8.02	10.66	7.33	5.13	6.35
1991	5.07	8.51	11.65	7.76	5.81	7.30
1992	4.78	8.48	10.66	7.36	5.57	6.79
1993	4.57	8.70	11.10	7.61	5.24	6.54
1994	5.23	9.29	11.69	8.05	6.10	7.38
1995	8.37	14.46	19.70	12.89	9.18	10.87
1996	5.14	9.11	12.16	8.90	5.96	7.18
1997	4.44	8.54	12.01	7.46	5.47	6.68
1998	5.68	11.07	14.82	8.80	6.35	7.51
1999	5.81	11.14	15.51	9.76	6.43	7.56
2000	6.11	10.53	14.01	9.65	6.97	8.36
2001	6.09	10.91	14.39	9.76	7.00	8.27
2002	4.98	9.89	12.75	8.25	5.44	6.48
2003	6.30	11.00	14.34	9.98	6.97	8.34
2004	7.41	12.27	16.15	11.52	8.37	9.91
2005	14.17	21.69	25.85	19.42	14.74	17.22
			Standard Deviation of Barge Rates ($/MT)			
1990	0.89	1.16	1.76	1.36	0.74	0.85
1991	1.90	2.43	3.44	2.23	1.95	2.41
1992	1.87	2.22	2.23	1.91	2.16	2.36
1993	1.53	2.14	1.81	2.18	1.68	1.97
1994	2.75	3.85	3.90	3.40	2.92	3.36
1995	2.14	3.24	4.53	2.42	2.49	2.85
1996	1.76	2.35	2.63	3.10	1.78	2.08
1997	1.48	2.42	3.05	2.19	1.77	2.13
1998	3.25	4.06	4.76	3.47	2.99	3.40
1999	2.18	3.02	3.58	2.45	2.32	2.57
2000	2.06	2.73	2.48	2.32	2.19	2.54
2001	1.29	1.02	0.79	1.40	1.52	1.74
2002	1.42	2.78	2.95	1.79	1.15	1.33
2003	2.55	2.73	2.55	2.57	2.29	2.64
2004	2.74	3.92	4.40	3.32	3.19	3.58
2005	7.83	9.36	9.11	8.07	7.72	8.78

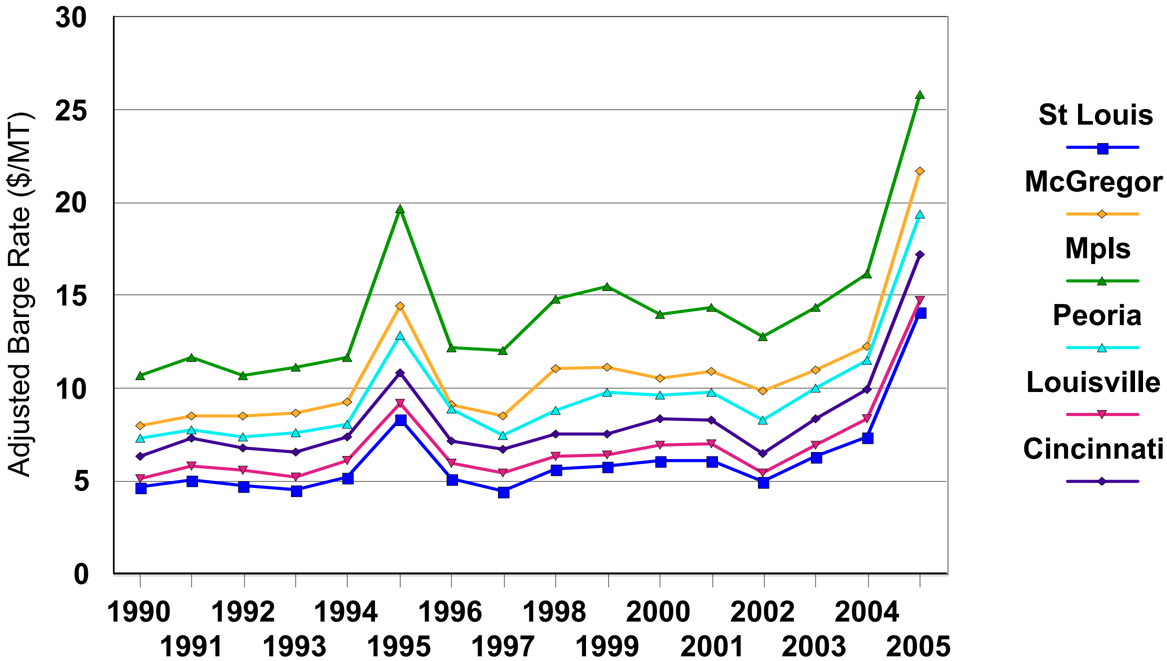

Figure 7.4.1. Draft Adjusted Average Barge Rates for the Six Reaches, 1990-2005 ($/MT).

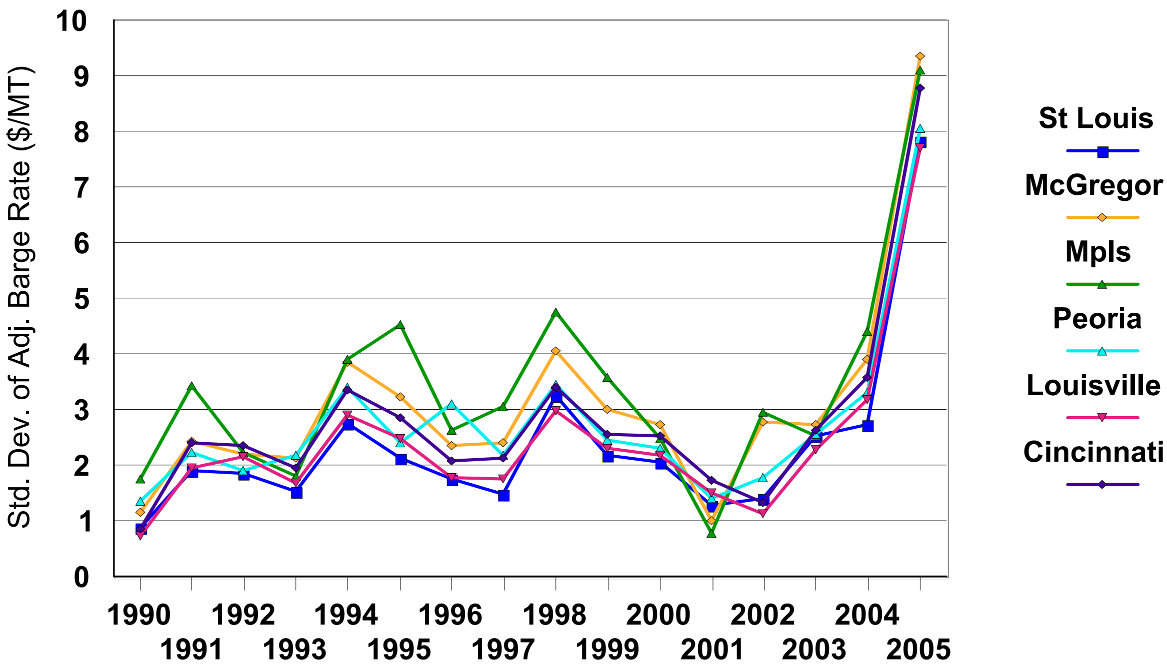

Figure 7.4.2. Standard Deviation of Draft Adjusted Barge Rates for Six Reaches, 1990-2005 ($/MT).

7.5 Barge Rate Functions

A barge rate/volume relationship was estimated for each of the reaches (1-6). Average draft adjusted barge rates from 2000-2004 were utilized by month along with average monthly barge movement volumes. Prices and volumes were sorted from lowest to highest and a cumulative volume shipped as barge rates increased was calculated. Cumulative volumes were graphed (Figure 7.5.1) and linear relationships of the average annual supply relationships were estimated for inclusion as barge rates (Figure 7.5.2).

Parameters for estimated function varied by reach with intercepts reflecting minimum barge rates by reach. Slope parameters varied across reaches reflecting differences in the supply relationships (Table 7.5.1). Reaches 5-6 had the highest slope indicating a higher rate sensitivity to volume shipped. Reach 4 had the lowest slope, followed by Reach 2, 1 and 3.

Table 7.5.1. Parameters for Estimated Average Supply Relationships for Barge Rates by Reach, 2000-2004.

	Intercept	Slope	R-square
Reach 1	3.84 (15.29)	0.00061 (10.75)	.91
Reach 2	7.55 (20.47)	0.00059 (9.95)	.90
Reach 3	11.45 (56.20)	0.00071 (13.83)	.95
Reach 4	6.95 (42.05)	0.00038 (19.48)	.97
Reach 5	4.64 (19.43)	0.00126 (11.48)	.92
Reach 6	5.55 (18.81)	0.00240 (10.86)	.91

Values in ( ) are t-statistics.

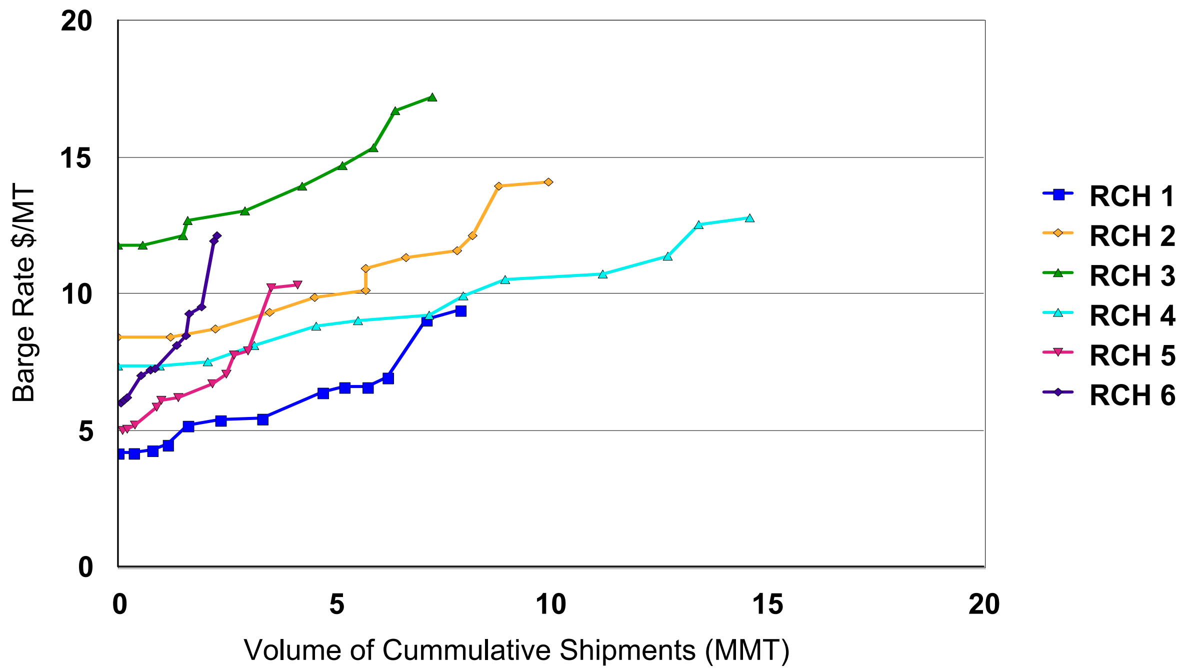

Figure 7.5.1. Relationship Between Cumulative Barge Shipments and Barge Rate, by Reach, Average of 2000-2004.

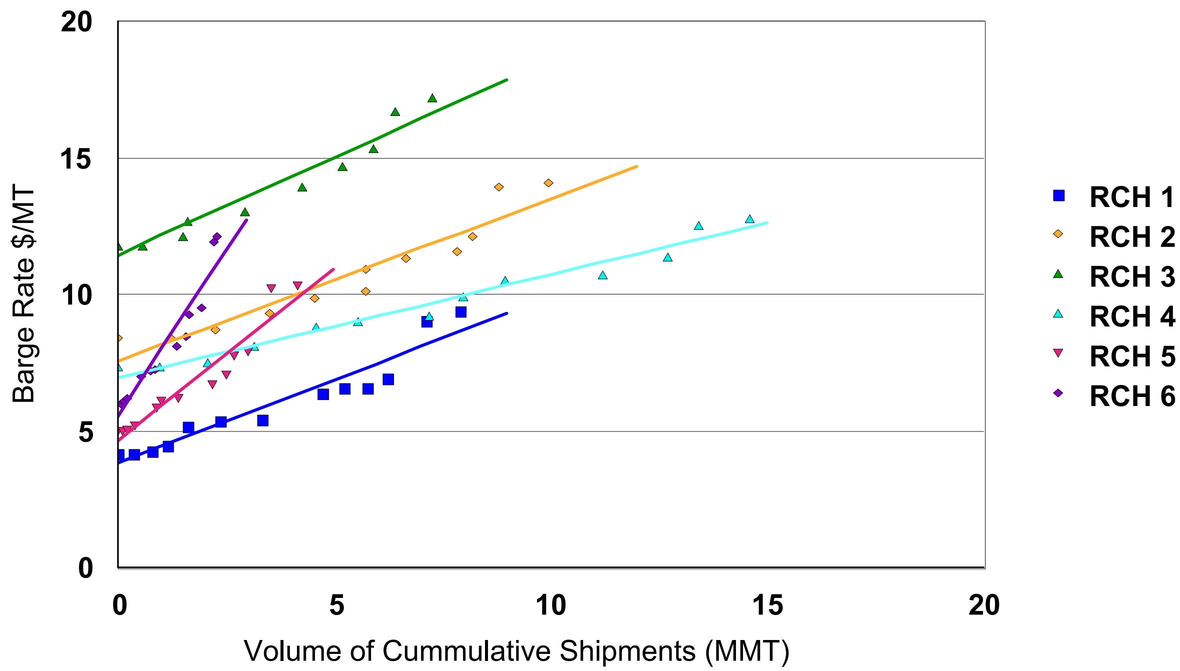

Figure 7.5.2. Relationship Between Cumulative Barge Shipments and Barge Rate, by Reach, Average of 2000-2004 and Linear Estimation.

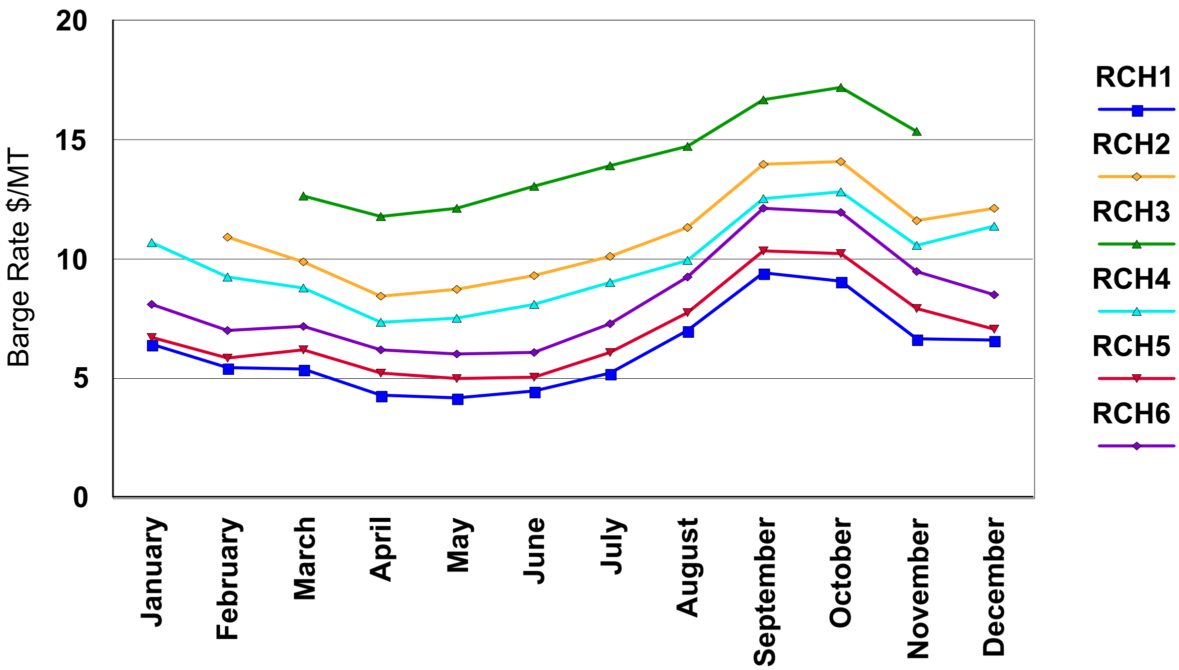

Figure 7.5.3. Average Draft Adjusted Barge Rate by Reach (2000-2004).

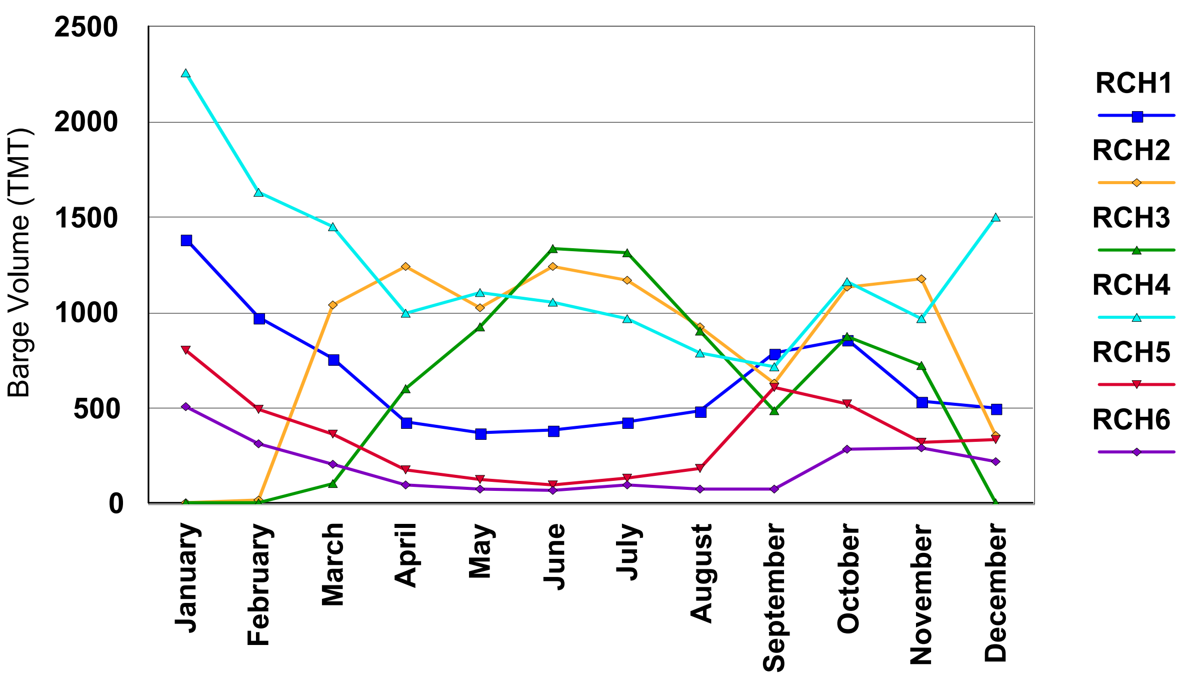

Figure 7.5.4. Average Barge Export Volume by Reach and Month, 2000-2004.

7.6 Handling rates For each of the major grain producing countries, handling fees were included. These are shown in Table 7.6.1.

Table 7.6.1. Barge transfer costs

Function	***c/b***	***$/t***	***Conversion***	***$/mt***
Transfer	3	1.05	35.00	1.10
Direct	4	1.43	35.75	1.47
Rough	5	1.45	29.00	1.84

In addition to these, the handling costs for soybeans were adjusted based on recent field surveys (Dager 2007 forthcoming). In the field surveys, it was found that handling margins and costs were greater for soybeans due to greater breakage and due to wear and tear on the equipment. For these reasons, handling costs on soybeans were increased by $1.20/mt per handle for handles on both ends of a barge shipment.

Finally, a special set of handling fees was derived for shipments through the Great Lakes (Table 7.6.2). An added cost of handling rail at the U.S. Gulf elevators was also added. This is due to the added costs of testing and inspection, handling and demurrage of rail versus barge. The value was $2.50/mt and was provided from industry input.

Table 7.6.2. Handling Fees on the Great Lakes

Element/function	***Units***	***US via*** Duluth	***US via*** Toledo	***Canada via*** T. Bay
	c/b	$/t	$/t	C$/mt
Port Elevation 1	2000 lb	2.75	2.25	8.17
Laker rates to St. Law	2000 lb	8.75	5	15
Locakage (incl other)	2000 lb	3	3	3
Transfer elevator	2000 lb	2.75	2.75	2.59
Total: Fob Ship St. Lawrence		17.25	13	28.76
		$/mt	*$/mt*	*$/mt*
Country elevation				
Port Elevation 1		3.03	2.48	5.20
Laker rates to St. Law		9.65	5.51	9.55
Locakage (incl other)		3.31	3.31	3.31
Transfer Elevator		3.03	3.03	1.65
Total: Fob Ship St. Lawrence		19.01	14.33	19.71

7.7. Competitiveness of Rail Rates and Barges Rates

These data were reviewed and compared among each other and relative to barge rates. From this, two sets of comparisons are made.

Iowa River and Rail Shipment: One relates to the overall rail rate from Iowa River for corn to the Western corn belt and to the Southeast. Compared to other grains and/or other origins these rates are extremely low. These are so low in fact, that this origin would be the lowest cost origin for demand in either of these two regions. And, if applied unconstrained in the model, flows from this origin to these destinations dominate and as a result there are nil shipments available to ship to the river. Upon further inspection of the STB data on volume it is apparent that shipments from this origin to the Southeast are near nil. However, shipments from Iowa River to the Western corn belt are not nil. In particular, rail shipments for this flow have increased from near nil in 2000 to 443,296 mt in 2004. And, the volume from Iowa West to the Western Corn Belt from 2000 to 2004 has been decreasing over time (1.6 mmt to 0.7 mmt).

Thus, the common perception that all corn in Iowa River goes to the river by truck is incorrect as there are several other competing regions and demands for this grain.

Rail versus barge on Selected Shipments: These data were also combined to make comparisons of some of the critical rail and barge rate relationships for illustration. Table 7.7.1[12] shows the elements of rates for shipments from Illinois North (as defined in our production regions) to the U.S. Gulf via rail shipments to Reach 1 and barge to the U.S. Gulf; rail shipments to Reach 4 and then barge to U.S. Gulf; their total costs; and then direct shipments by rail to New Orleans (NOLA); and to the Texas Gulf. In each case the least cost movement is identified.

Shipments by direct rail are nearly always lower cost than a combination of shipments through the river system. These differences are minor in most cases. Some of the important impacts of these relationships are noted below, particularly as they would impact spatial competition amongst modes (Table 7.7.1):

- For corn shipments direct rail to NOLA is always lowest cost. Next are rail shipments to Reach 1 and then barge beyond;
- For wheat, direct rail shipments to NOLA are lower cost versus shipments via Reach 1; and, Reach 4 was never reported to be utilized by rail;
- For soybeans, shipments via Reach 4 and direct rail to NOLA are very close in cost to each other.

Similar comparisons are made in Table 7.7.2 to 7.7.4 using the average of these costs (i.e., averaged across years) for each grain from three origins that are naturally tributary to the river.

[12]Rates are not included in this table for STB disclosure restrictions.

Results indicate:

- Corn: from Northern Illinois favors direct rail to the U.S. Gulf, followed by shipments via Reach 1 (as above). From Minnesota the least cost is by barge through Reach 2 and from Minnesota River regions the least cost is by barge from Reach 3;

- Wheat: the least cost wheat movement from Northern Illinois is direct rail (by nearly $7/mt); direct rail to Texas Gulf from Minnesota (by over $2/mt); and for shipments from the Minnesota River to Reach 3 and then barge to U.S. Gulf;

- Soybean: Shipments via Reach 4 from Northern Illinois are least cost. Barge shipments via Reach 1 from Minnesota and from Reach 2 from Minnesota River are least cost. The advantage of Reach 1 versus Reach 3 is about $6/mt; and of Reach 2 versus Reach 3 is about $3.50/mt.

These relationships are critical, though do not include all costs in the system. A number of differences are important. First the model also allows for truck shipments to the reaches. Second, the analytical model adds handling costs and the differentials are important. Third, the model uses barge rate functions to determine volumes and rates. Finally, the base model includes a rail capacity constraint. If bounded, results in what would otherwise be lower cost shipments by rail to be shifted to the next least cost routing.

<u>Elements of Costs on Selected Shipments:</u> Table 7.7.4 illustrates the elements of individual costs on the total modal shipments for two typical movements. These are shown for corn shipments from Minnesota River and Illinois North to the U.S. Gulf, for each of rail direct, rail to barge and truck to barge. In part the barge rates depend on total barge volume and these impacts are illustrated in Figures 7.7.1-7.7.2.

Table 7.7.1. Comparison of Rail-Barge vs Direct Rail to US Gulf by Year and Crop from Northern Illinois ($/MT).

	Rail		Barge		Total Rail + Barge		Direct Rail		Least Coset Flow
	RCH1	RCH 4	RCH1	RCH 4	RCH1	RCH 4	NOLA	TxGulf	
Corn									
2000									NOLA
2001									NOLA
2002									NOLA
2003									NOLA
2004									NOLA
Wheat									
2000									NOLA
2001									NOLA
2002									NOLA
2003									NOLA
2004									NOLA
Soybeans									
2000									RCH4
2001									NOLA
2002									RCH4
2003									NOLA
2004									NOLA

Table 7.7.2. Corn: Comparison of Rail-Barge vs. Direct Rail to Gulf, Average of 2000-2004 ($/MT)

	Rail	Barge	Total	Least Cost
Northern Illinois				
RCH1	6.55	5.81	12.36	
RCH4	3.95	9.97	13.92	
NOLA	10.69		10.69	**
Minnesota				
RCH3	8.36	14.03	22.39	
RCH2	10.16	10.71	20.87	**
RCH1		6.51		
NOLA	24.23		24.23	
TXGulf	24.12		24.12	
Minnesota River				
RCH3	5.53	14.03	19.56	**
RCH2	9.23	10.71	19.94	
RCH1	13.99	6.51	20.50	
NOLA	25.21		25.21	
TXGulf				

Table 7.7.3. Wheat: Comparison of Rail-Barge vs. Direct Rail to Gulf, Average of 2000-2004 ($/MT)

	Rail	Barge	Total	Least Cost
Northern Illinois				
RCH1	12.16	6.51	18.67	
RCH4		9.97		
NOLA	11.75		11.75	**
Minnesota				
RCH3	16.48	14.03	30.51	
RCH2	23.61	10.71	34.32	
RCH1	23.21	6.51	29.72	
NOLA	36.85		36.85	
TXGulf	28.16		28.16	**
Minnesota River				
RCH3	7.52	14.03	21.55	**
RCH2		10.71		
RCH1	18.46	6.51	24.97	
NOLA				
TXGulf	50.60		50.60	

Table 7.7.4. Soybeans: Comparison of Rail-Barge vs. Direct Rail to Gulf, Average of 2000-2004 ($/MT)

	Rail	Barge	Total	Least Cost
Northern Illinois				
RCH1	10.01	6.86	16.87	
RCH4	2.54	9.60	12.14	**
NOLA	13.19		13.19	
Minnesota				
RCH3	13.22	14.03	27.25	
RCH2	15.22	10.71	25.93	
RCH1	14.77	6.51	21.28	**
NOLA	24.56		24.56	
TXGulf	27.79		27.79	
Minnesota River				
RCH3	7.89	14.03	21.92	
RCH2	7.87	10.71	18.58	**
RCH1		6.51		
NOLA	23.62		23.62	
TXGulf	35.07		35.07	

Table 7.7.4 Summation of Costs for Shipment by Mode From Minnesota River and Illinois North to Gulf Ports.

Minnesota River to Gulf

	Rail Direct	Rail Barge	Truck Barge
Production Costs	338.79	338.79	338.79
Yield	9.47	9.47	9.47
Cost / MT	35.78	35.78	35.78
Rail	25.21	5.53	
Truck			3.86
Barge (Minimum)		11.38	11.38
Handling	2.50	1.47	1.47
Total	63.49	54.16	52.49

Illinois North to Gulf

	Rail Direct	Rail Barge	Truck Barge
Production Costs	338.79	338.79	338.79
Yield	9.99	9.99	9.99
Cost / MT	33.91	33.91	33.91
Rail	10.69	3.95	
Truck			4.41
Barge (Minimum)		6.58	6.58
Handling	2.50	1.47	1.47
Total	47.10	45.92	46.38

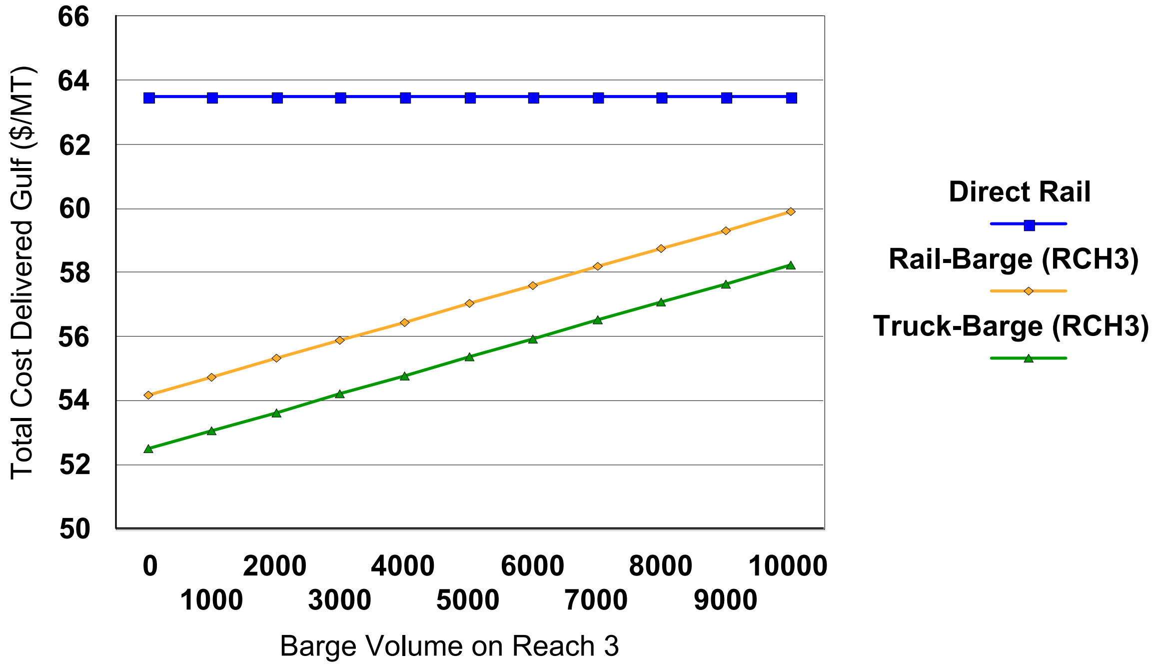

Figure 7.7.1. Summation of Total Costs From Minnesota North To Gulf Ports, by Mode.

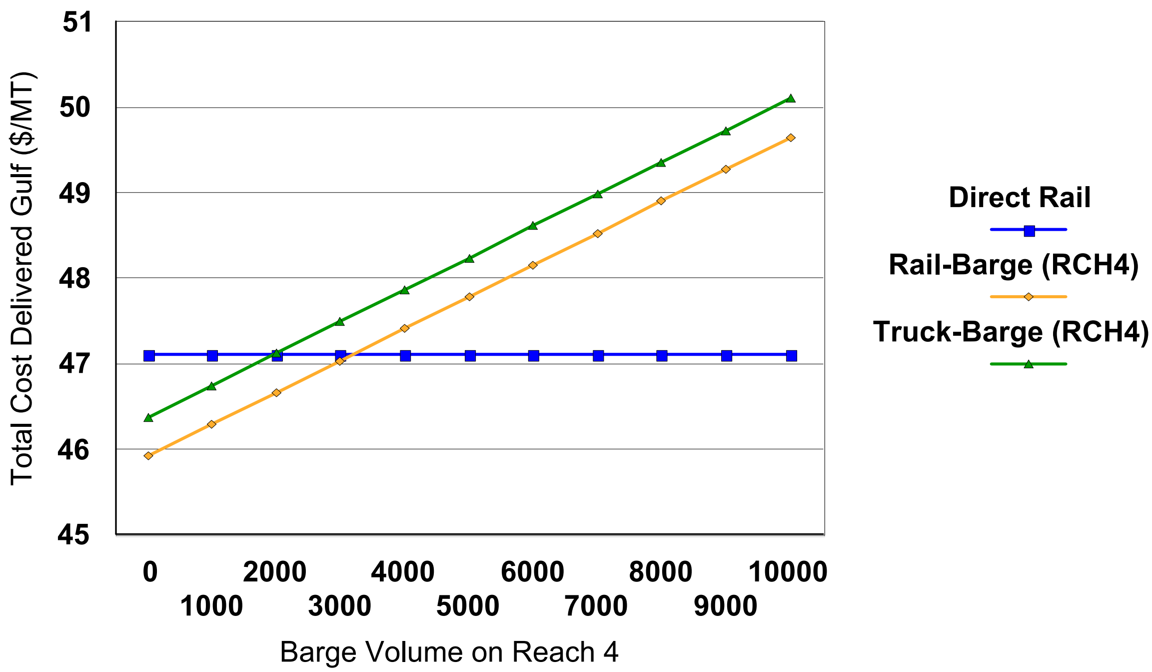

Figure 7.7.2. Summation of Total Costs From Illinois North To Gulf Ports, by Mode.

7.8 Shipping and Handling Costs in Other Countries. Finally, for each of the major competing exporting countries, a set of shipping and handling costs were included. These were obtained from industry sources in each of Argentina, Australia, India and the EU.

Those for Canada and Brazil were modeled explicitly as described below. Shipping costs for Canada were taken from the CN rail tariffs to export locations and to US destinations. For Brazil, we used shipping and handling costs from USDA Grain Transportation Bulletin (various issues). These values show shipping costs from each of the producing regions in Brazil South and Brazil North, to the respective port areas.

7.9 Ocean rates Ocean freight rate data were obtained from Maritime Research Institute. World wide shipping rates from 1994 to 2004. The data consisted of origin, destination, rate, size of vessel, date, and commodity. Miles between ports were obtained from U.S. Defense Mapping Agency. Current and projected oil prices were obtained from WEFA Macroeconomics.

A double log equation was used because of the non-linearity of the ocean rate schedule. Ocean tariffs are a function of size of vessel, miles between ports, oil prices, trend, and a series of dummy variables representing origins and destinations.

$Rate_{odt} = f(Size_{odt}, Mile_{odt}, Oil_t, D_{ec}, D_{eu}, D_{su}, D_{gf}, D_{wc}, D_{br}, D_{ca}, D_{sa}, D_{ch}, D_{sea}, Trend)$

where o=origins, d= destinations, and t= year. The subscripts on the dummy variables are origins: ec= east coast United States; eu= Europe; su= Former Soviet Union; gf=gulf port United States; wc=west coast United States; br= Brazil north or Brazil south; and for destinations: ca=Central America; sa=South America; ch=China and sea= South East Asia.

The regression results are shown in Table 7.9.1. Rates were projected from this relationships and using Global Insights projections for oils prices. Current and projected rates are shown in Tables 7.9.2 and 7.9.3.

Table 7.9.1. Estimated coefficients and t-values for the ocean tariff equation

	Coefficient(s)	t-value
Constant	4.02	10.41
Size	-0.55	-57.01
Mile	0.45	41.57
Oil	0.24	10.33
Dec	0.04	1.23
Deu	0.04	1.00
Dsu	-0.16	-3.35
Dgf	0.13	3.84
Dwc	0.03	0.72
Dbr	0.03	0.99
Dca	0.11	5.05
Dsa	0.23	8.62
Dch	0.03	2.60
Dsea	0.10	4.20
Trend	-0.01	-1.23
R Squared	0.42	

Table 7.9.2. Estimated Shipping Costs ($/MT)

	Brazil N	Brazil S	Korea	Mexico	Japan	N Africa
Arg	16	12	23	31	22	22
Aus	31	28	16	30	15	29
Canada E	20	24	24	25	23	18
Canada W	28	32	19	23	18	28
US East	19	24	23	17	21	25
US Gulf	22	28	24	14	23	23
US PNW	27	31	19	23	18	27
Europe	22	24	23	27	22	12
ME_FSU	21	22	17	28	16	11
Brazil N			26	20	25	21
Brazil S			24	28	24	22

	S Africa	Latin	China	S Asia	SE Asia	Europe
Arg	19	32	24	22	23	26
Aus	24	34	16	15	14	26
Canada E	27	27	26	25	27	11
Canada W	32	33	20	30	25	30
US E	27	27	24	27	30	11
US G	30	25	26	32	32	16
US P	32	26	20	26	25	30
Europe	24	43	23	26	28	10
ME_FSU	22	33	18	21	21	13
Brazil N	20	25	29	23	27	21
Brazil S	22	30	26	23	26	23

Table 7.9.3. Projected Ocean Tariffs for Selected Routes ($/MT)

Origins	Destinations	2004	2010	2030	2060
Brazil N	China	26	26	30	30
Brazil S	China	29	30	27	27
US Gulf	China	26	25	27	26
US PNW	China	20	27	20	20
Brazil N	Japan	25	15	26	26
Brazil S	Japan	24	26	25	25
US Gulf	Japan	23	22	23	23
US PNW	Japan	18	24	18	18
Brazil N	SE Asia	27	14	28	27
Brazil S	SE Asia	26	28	27	27
US Gulf	SE Asia	32	32	34	33
US PNW	SE Asia	25	34	26	26

8. Logistical Constraints and Delay Costs

A series of logistical constraints and delay costs were developed and incorporated into the model. This section describes details behind these restrictions.

For reference, we define 6 reaches as follows where cities are the geographical range of cities contained in the reach and the city in ( ) is the city used for deriving our shipping rates (Figure 8.1):

Reach 1	Cairo to LaGrange (St Louis)
Reach 2	LaGrange to McGregor (Davenport)
Reach 3	McGregor to Minneapolis (Minneapolis)
Reach 4	Illinois waterway (Peoria)
Reach 5	Ohio River Cairo to Louisville (Louisville)
Reach 6	Ohio River Cincinnati (Cincinnati)

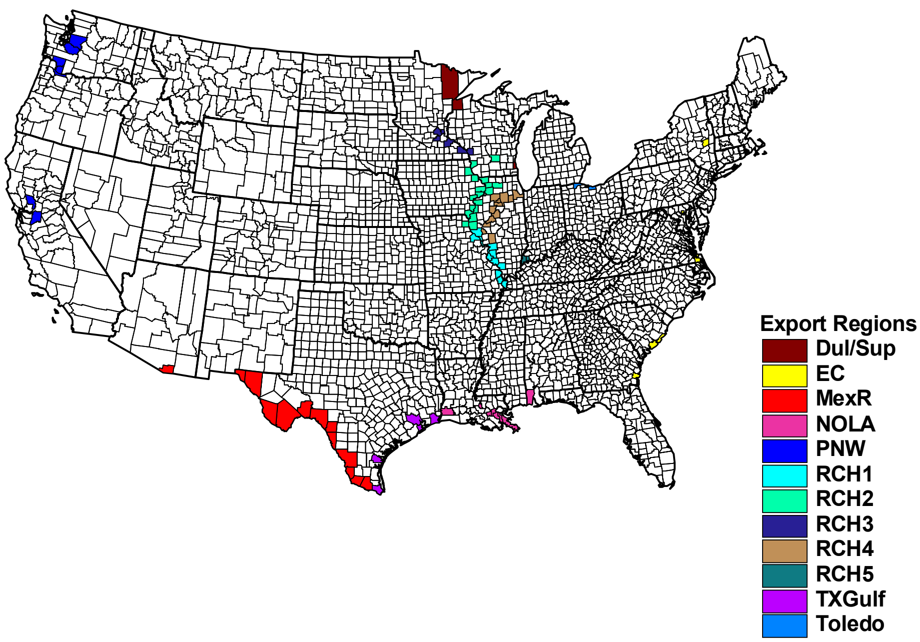

Figure 8.1. Terminating Counties for Definition of Export Regions.

8.1 Barge Delay Costs: The barge shipping cost was defined as $B=B_r + D_r$ where B_r is the barge rate defined earlier in Section 7.5 which is a function of volume shipped from reach r, and D is a "delay cost" for reach r. A delay cost was defined for each of the reaches as discussed below.

The barge delay functions were derived by the US Army Corps of Engineers (ACE) following the procedures defined in Oak Ridge National Laboratory (2004). For Reaches 1-4, the delay costs were derived using simulation procedures. For Reaches 5 and 6, it was assumed after discussions with the ACE that the delay costs would be so inconsequential they were not derived. This is based on the contribution of the Ohio River to lower Mississippi River grain exports and the significantly greater lock capacities on the Ohio compared to the Mississippi.

To derive the delay costs, a barge capacity-volume relationship was estimated for each lock within the reach. Then, a model was developed where

Average wait time = f(volume); and,

Cost = f(wait time)

and results in hyperbolic function. Factors impacting the cost include value of grain, equipment and labor costs. These were defined relative to "normal traffic" assumed for other commodities, both upbound and downstream traffic, and reflect the incremental impact on cost for an assumed change in grain traffic. The delay costs for each reach represent the sum of the delay curves at individual locks within the reach. The values were annualized using procedures in Oak Ridge National Laboratory (2004) Section 1.1.3.2.2.

Delay costs for each reach reflects the cumulative impact of grains originating on that reach. Shipments originating upstream and going through a Reach is added to this total. There is an additional critical relationship between grain coming in from the Illinois River (Reach 4) and Reach 1 of the Mississippi River. The capacities of the 600 foot locks at Lock 21-25 are restrictive. For traffic coming onto the Mississippi River below St Louis (Lock 27) there is no lock and therefore no lock delays. Reach 4 traffic enters below the point of congestion.

The delay costs were measured with assumptions regarding improvements. The first assumes existing capacity and operating infrastructure during the base period, 2000-2004. Improvements have been proposed but not authorized by Congress. Thus they should be viewed as potential improvements.[13]

These transit curves reflect the relationship between total tonnage moving over the reach and expected delay costs. Grain originated on Reach 3 contributes to the traffic and delay in Reach 2 and in Reach 1. Shipments on Reach 1 would not contribute to traffic in Reach 2 or 3. Traffic levels for grain and non-grain during the base period (2000-2004) were used to calibrate

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[13]Funding to initiate detailed design for several of the new locks as been provided for FY0-5 only.

the curves. The base assumption is for nil growth in non-grain traffic and a sensitivity is used to illustrate the impacts of this assumption. Finally, the delay costs were derived for both the existing capacity, as well as for an expanded lock system. It is anticipated that any expansion would take 13-14 years, so, the impact of an expansion is expected in 2020.

These results are shown in Figures 8.2 and 8.3 for each Reach for grain volumes only. Interpretation of these values differs across reaches. 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 chance constrained 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.

The impact of non-grain volumes in addition to grain on delay costs (grain + non-grain) are shown in Figure 8.3.[14] Delay costs are near nil for most volumes. At higher volumes, delay costs escalate and ultimately become nearly vertical. The latter is an indicator of capacity, i.e., the level of volume at which the delay costs become perfectly inelastic. For most Reaches, current volume is less than the level at which delay costs would begin to escalate sharply. In addition, in some cases there is a very slight negative delay cost.[15]

For Reach 2, the increased costs associated with delay for traffic less than about 28 mmt of grain traffic is near nil. Costs increase very sharply for traffic greater than about 30 mmt. In addition, there are slight negative delay costs for volumes less than about 18 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 38 mmt. At grain traffic of about 38 mmt, the increase in delay costs is very sharp. Finally, at Reach 4, delay costs are near nil up to about 28 mmt and then increase sharply. 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.

The delay curves would change if there were an expansion, as proposed. 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. In addition, the value of the negative delay costs for lower volumes are slightly greater than in the previous case.

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[14] In the empirical model the delay cost curves were represented by estimated regressions using a double log-transformation of the data. We also represented these using an inherently nonlinear functional form but including this type of functional form in GAMS made it difficult to find a minimum, and we were not able to be certain the solution was a global minimum. Using double-log delay costs allowed GAMS to converge quickly, and resulted in a global minimum.

[15] To clarify, the solution for existing barge system occurs at lower values than the 5 year average. Thus, negative values should be interpreted relative to a reference point, and the change derived. The reference is the base period, 2000-2004, which imputes a certain level of delay cost. In the results, these are compared to alternative solutions and differences derived.

The total cost of shipping by barge comprises the rate generated from the barge rate function and the delay costs. These are shown in Figure 8.4. As volumes increase, there is an increase in barge rates corresponding to the barge rate function. Thereafter, at some level, the delay costs begin to have an impact and further increases occur due to the delay costs**.**

This approach differs from Fuller et al. In that study, they estimated a capacity delay function like transit curve for the entire river system, 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.

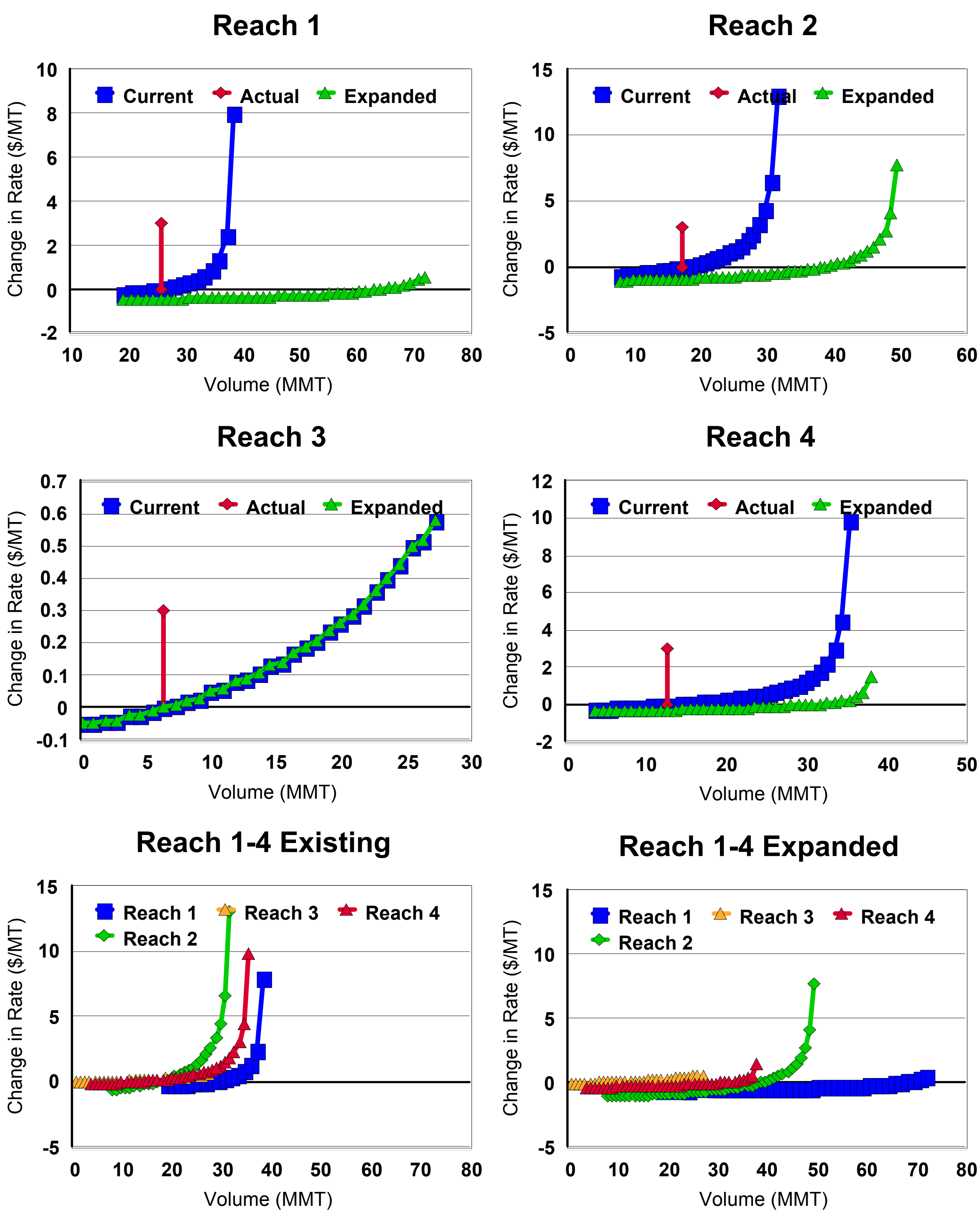

Figure 8.2 Delay Costs and Actual Volumes, Existing and Expanded Capacity: Grain Volumes Only.

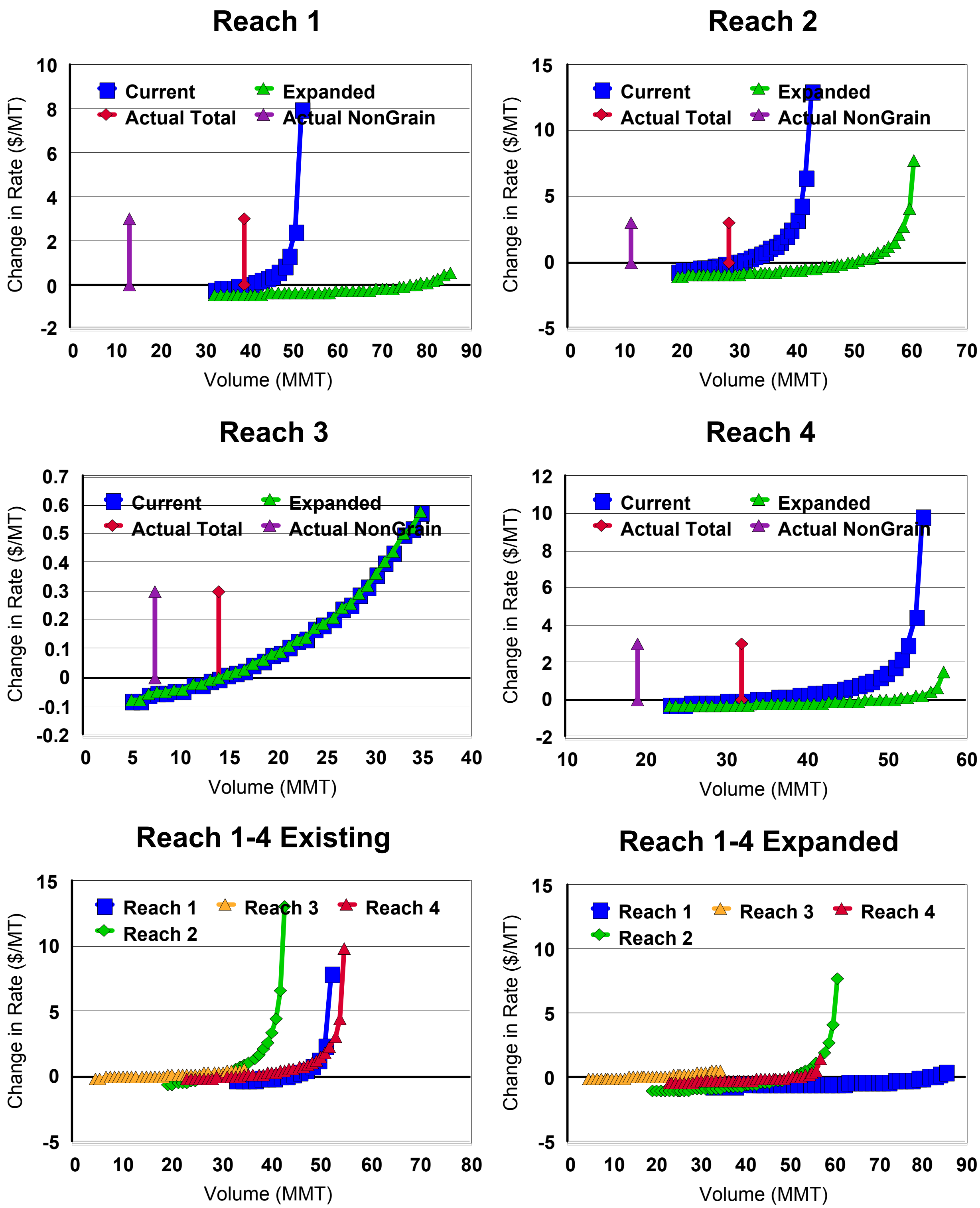

Figure 8.3 Delay Costs and Actual Non-Grain and Total Volumes, Existing and Expanded Capacity.

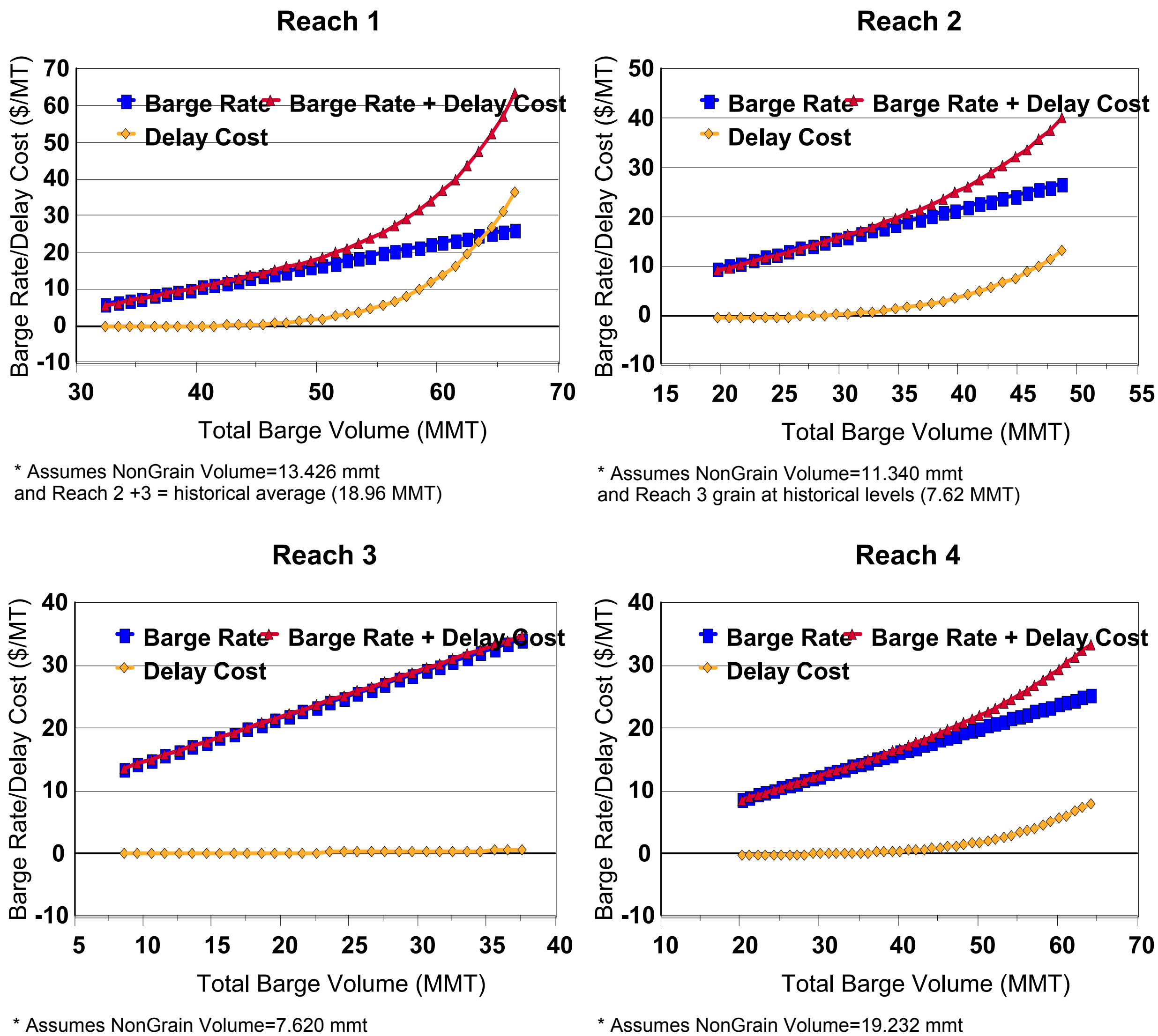

Figure 8.4. Barge Rates, Delay Costs and Total Barge Cost for Cumulative Barge Volume (Total Flows through Reach including Non-Grain Traffic), by Reach, Current Capacity.

8.2 Rail Capacity Constraints The model included a rail capacity restriction. In a sensitivity, we allowed different values of this restriction for illustration purposes on how it impacts barge flows.

This was derived from data reported in USDA Grain Transportation Bulletins (various issues). These values are reported for the different railroads. Adjustments were made for grains not included in the model, and for originations by non-Class I railroads. Specifically, the USDA data which is from the American Association of Railroads is labeled as car loadings for Grain by Class I railroads. However, a portion of grains is originated by short-line railroads which is not shown in the data. The best and most recent estimate of this were derived at 25% (Bitzan et al.) for the year 2000. Since then, this value has likely increased. These derived values are estimates of actual loadings.

This derivation resulted in a maximum rail capacity during the base period of the equivalent of 141 mmt. Strictly, we applied this to the total volume of rail that can be originated without restrictions to geography or grain-type. This value was used as the base case for the restriction in the model. Admittedly, defining rail capacity in terms of ton-miles of demand would be more appropriate, but data to do so is very limited.

9. International Trade Policies

A matrix of agricultural policies and trade mechanisms were included in the model. These were from varying sources including The USDA-ERS WTO Trade Policy Commitments Database and Agricultural Market Access Database (www.amad.org). While there are a multitude of sources for these data, those used were summarized in terms of domestic subsidies, export subsidies and import tariffs.

Domestic subsidies are shown in Table 9.1. Export subsidies are in Table 9.2. Argentina has an export tax which is comparable to a negative export subsidy. That value shown for Australia is for the research tax levy applied on all exports.

Import tariffs are shown in Table 9.3. In addition to these, several regional specific tariffs were included. For MERCUSOR countries, trade is assumed at nil tariffs. The projection period. Finally, a variable import levy was applied to imports into the EU.

Table 9.1 Domestic Subsidies

	Wheat	Corn	Soybean
		Percent	
Canada	5	5	5
EU	30	30	30
Japan	5	50	50
S. Korea	50	50	50
United States	6	7	8

Source: USDA-ERS

Table 9.2 Export Subsidies

	Wheat	Corn	Soybean
		Percent	
Argentina	-30	-30	-30
Australia	-1	-1	-1
EU	27	20	0

Source: USDA-ERS and personal communications.

Table 9.3 Import Tariffs

	Wheat	Corn	Soybean
		Percent	
Brazil	69	0	30
China	0	81	19
EU	0	88	12
FSU	51	6	44
Japan	62	19	20
S Korea	66	11	23
Latin America	52	0	48
Mexico	53	33	14
N. Africa	21	4	76
S Africa	27	0	73
S Asia	94	6	0
SE Asia	40	17	43

Source: USDA-ERS.

China Trade Policies: Chinese policies are changing rapidly, both during our base period and expected during the projection period. Most important are that China intervenes routinely in policies that impact its imports and exports of these grains. This has been done in the past using import/export quotas, and/or tariffs or subsidies in the case of corn.

In 2001 China joined the WTO and initiated trade policies to facilitate this change. In particular, it adopted a trade regime of tariff rate quotas. For imports within the quota an import tariff and value-added tax (VAT) were applied. In 2006, these are at 1% and 13% VAT for corn for imports less than the quota of 7.2 mmt; the same values applied to wheat; and for soybeans, the import tariff was 3% and 13% for the duty and VAT respectively. For imports above the TRQ value, the tariff was far greater at about 60%.

In addition, it retained a policy of subsidizing exports of corn. This was notably from northern China to Korea. Export subsidies were determined annually approximately reflecting the C&F differential to US corn at Korea. As recently as mid-2006 it was anticipated these would be eliminated. Finally, China has retained a large stockholding strategy for each of these grains. While this is a state of transition, the stock levels have been reduced. In fact, use of stocks relieves pressures on supplies when and if supplies are reduced. In particular, during 2004, China drew down its stocks of corn by 8 mmt.

To capture these impacts in the model we proceeded as follows. During the base period, we retained import tariffs in Table 9.3. In addition, we restricted the model for corn to nil imports, and for 8 mmt of exports. This reflects the impact of the export subsidy that is difficult to observe. During the projection period, these were retained but exports from China were restricted to nil. These were then relaxed to illustrate the impacts.

10. Stochastic Modeling

10.1 Introduction/overview

The model objective function is specified as the sum of expected production costs, transportation costs, and expected delay costs. Model constraints include satisfaction of demands, acreage limits, exports limited to production, and capacity constraints of the various river reaches/segments.

Many of the model constraints involve stochastic variables. In particular, the right-hand sides of the constraints are random variables. Total shipments to a region/country are constrained to be greater than or equal to import demand which is a random variable. To account for right-hand side uncertainty, Charnes and Cooper (1959) proposed chanced-constrained programming. Assuming that a decision maker is willing to allow constraint violations with some specified probability, α, the model constraints are written as, for example,

Prob(total shipments $\geq$ import demand) $\geq \alpha$.

Assuming that the distribution of import demand is triangular, it is possible to write the chance constraint using a linear equation.

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. Multiple chance constraints are usually solved by analytical computation of the joint cumulative density function (cdf). The difficulty here is that the distributions for most of the model's random variables are derived from error terms of econometric estimations. Error terms are generally distributed as normal and no closed-form expression exists for the normal cdf. These distributions were approximated using triangular distributions. The triangular distribution has a closed-form integral, reasonably approximates the normal distribution and can be uniquely determined by a mean and variance (assuming symmetry).

10.2 Model Specification

The model determines the least-cost method for satisfying demands. The objective function includes the sum of production costs, transportation costs–truck, rail, barge and ocean–and delay costs associated with barge transport . Mathematically,

$$
\begin{aligned}
TC = & \sum_g \sum_p \; prod\ cost_{gp} \cdot A_{gp} \\
& + \sum_g \sum_p \sum_c \; Q_{gpc} \cdot trucking_{gpc} \\
& + \sum_g \sum_p \sum_r \; Q_{gpr} \cdot domrail\ \ rate_{gpr} \\
& + \sum_g \sum_p \sum_e \; Q_{gpe} \cdot exprail\ \ rate_{gpe} \\
& + \sum_g \sum_r \sum_e \; Q_{gre} \cdot barge\ \ rate_{gre} \\
& + \sum_g \sum_e \sum_m \; Q_{gem} \cdot ocean\ \ rate_{gem} \\
& + \sum_g \sum_p \sum_e \; Q_{gpe} \cdot \ trucking_{gpe} \\
& + \sum_g \sum_p \sum_c \; Q_{gpc} \cdot \ trucking_{gpc} \\
& + \sum_r \hat{Q}_r \cdot delay\ \ rate_r \ .
\end{aligned}
$$

Subscripts are defined as: g = grain, p = producing region, c = consuming region, r = reach, e = export location, and m = import location. Production costs are $prod\ cost_{gp}$, and vary by grain, production region and year. Area harvested in hectares, A_{gp}, is a choice variable of the model. Quantities of grain shipped are given by Q with subscripts to indicate grain, origination and destination. Trucking costs are reported in Section 6 of this appendix. All other transportation and delay rates are estimated and reported in Section 8. The functional forms for these rate functions are given below and parameter estimates are reported in Tables 10.1-10.4.

Barge rates functions and delay functions: Barge rates a function of volume. Specifically, $B_r = f(V_r) + e_{rb}$ where B_r is the barge rate, V_r is the volume shipped on reach r, and e_{rb} are the error terms. These indicate that higher volumes shipped by barge result in higher barge rates. Values for these parameters were shown in Table 7.5.1.

Delay costs were discussed in section 8 and were included as a component of barge shipping costs. Specifically, these are defined as:

delay $cost_r = a_{gem}\ \hat{Q}_r^{\,b_r}$ where

$$
\hat{Q}_r = \begin{cases} \sum_g \sum_e \; Q_{ger} - threshold_r \ if \ Q_{ger} > threshold_r \\ 0 \qquad\qquad\qquad\qquad otherwise \end{cases}
$$

For each reach, a volume threshold determines the maximum volume possible before significant delays are realized. Based on simulation results, provide by the IWR, we estimated the delay costs and the threshold for each reach.

Rail Rate Functions : Rail rate functions for domestic and export shipments are shown below.

Rail rate functions for both include affects of distance, distance squared, distance to barge and trends. Export rail shipments also included dummy variables for export destinations (ports and barge loading locations) as follows:

$$\text{Domrail rate}_{gpc} = \text{Intercept}_{gpc} + a_{gpc}\,\text{total distance}_{pc} + b_{gpc}\,(\text{total distance}_{gpc})^2 + c_{gpc}\,\text{distance to barge}_{pc} + d_{gpc}\,\log(\text{trend})$$

$$\text{Exprail rate}_{gpe} = \text{Intercept}_{gpe} + a_{gpe}\,\text{total distance}_{pe} + b_{gpe}\,(\text{total distance}_{gpe})^2 + c_{gpe}\,\text{distance to barge}_{pe} + d_{gpe}\,\log(\text{trend}) + e_{gpe}\,E2 + f_{gpe}\,E3 + g_{gpe}\,E5 + h_{gpe}\,E6 + i_{gpe}\,E7 + j_{gpe}\,EB1 + k_{gpe}\,EB2 + l_{gpe}\,EB3 + m_{gpe}\,EB4 + n_{gpe}\,EB5$$

where distances are measured in miles (total is total shipping distance; distance to barge is the distance to the nearest barge shipping point); and trend is measured from 1995=1. Dummy variables were introduced for export ports (E1=Duluth/Superior; E2=East Coast; E3=Laredo/Mexico transit points; E4=New Orleans; E5=PNW; E6=Toledo and E7=Texas Gulf) and barge reach destinations (EB1=Reach 1....EB6=Reach 6).

Ocean rates: Ocean rate functions were also estimated. The equation used was specified as:

$$\text{Ocean rate}_{gem} = \text{Intercept}_{gem} + a_{gem}\,\text{ship size}_{em} + b_{gem}\,\text{oil price} + c_{gem}\,\text{origin dummy}_{ge} + d_{gem}\,\text{destination dummy}_{g\,m} + e_{gem}\,\log(\text{trend}) + f_{gem}\,\log(\text{distance}_{em})$$

Additionally, several constraints are imposed. Balance constraints are imposed on all origins and destinations to insure that total inflows to a location equal total outflows from that location.

Chance constraints are imposed to insure that demands are satisfied with probability α_{gc} where $0.5 \leq \alpha_{gc} \leq 1$. Forecast variances are determined for each point in time, 2000, 2010, 2020, 2030, 2040, and 2060. Forecast variance is computed as (Greene, 1997, pg. 369):

$$Var[\epsilon^0] = \sigma^2 + x^{0\prime}[\sigma^2 (X'X)^{-1}]x^0$$

We assume that the errors from the grain demand equation estimations are distributed with mean zero and are contemporaneously uncorrelated. Residuals are assumed to be normally distributed, however we use triangular distributions to approximate these distributions as the triangular density function is integrable.

Let D_{ij} denote average demand by region *i* for grain *j* and ϵ_{ij} denote random error around the mean demand. Let Q_{gc} denote quantity of grain *g* transported (and consumed) to region *c*. Then, using chance constrained programming, we assure that, with probability α_{gc}, the quantity transported is great than or equal to the quantity demanded, or $\text{Prob}(\epsilon_{gc} \leq Q_{gc} - D_{gc}) \geq \alpha_{gc}$.

Assuming symmetrically distributed error terms with zero mean and using the triangular approximations, the probability density functions of the errors terms can be express as:

$$10.1)\quad f(\varepsilon_{gc}) = \begin{cases} \dfrac{(\varepsilon_{gc} + b_{gc})}{b_{ij}^2} if \quad -b_{gc} \le \varepsilon_{gc} \le 0; \\ \dfrac{(b_{gc} - \varepsilon_{gc})}{b_{gc}^2} if \quad 0 < \varepsilon_{gc} \le b_{gc}; \\ 0 \quad otherwise \end{cases}$$

where ($-b_{gc}$, b_{gc}) is the domain of the positive support (see Figure 9.1 below). The term b_{gc} can be solved for as a function of the variance of the error term. Since we are concerned with the left tail of the distribution (as we want to the probability of positive errors to be small), we focus on the half of the density function to the left of the origin.

Integrating the density function from $-b_{gc}$ to Q_{gc}-D_{gc} yields the probability that the error term is less than or equal to Q_{gc}-D_{gc}. Or, Prob($\epsilon_{gc} \le Q_{gc}$-D_{gc}) =

$$10.2) \int_{-b_{gc}}^{Q_{gc}-D_{gc}} f(\varepsilon_{gc}) d\varepsilon_{gc} = \frac{(Q_{gc} - D_{gc} + b_{gc})^2}{2b_{gc}^2}.$$

We then constrained the right-hand-side of (9.2) to be greater than or equal to alpha, our confidence level:

$$10.3)\quad \frac{(Q_{gc} - D_{gc} + b_{gc})^2}{2b_{gc}^2} \ge \alpha_{gc}.$$

Using the quadratic formula, we solve(9.3) for the level of consumption, Q_{gc}^* that satisfies the chance constraint:

$$10.4)\quad Q_{gc}^* \ge D_{gc} - b_{gc} + \sqrt{2b_{gc}^2 \alpha_{gc}}$$

Equation (9.1), when imposed as a constraint, assures that Prob($\epsilon_{gc} \le Q_{gc}$-D_{gc}) $\ge \alpha_{gc}$. As the required level of confidence increases, the quantity consumed also increases. This implies that our cost estimates are conservative compared to a deterministic model.

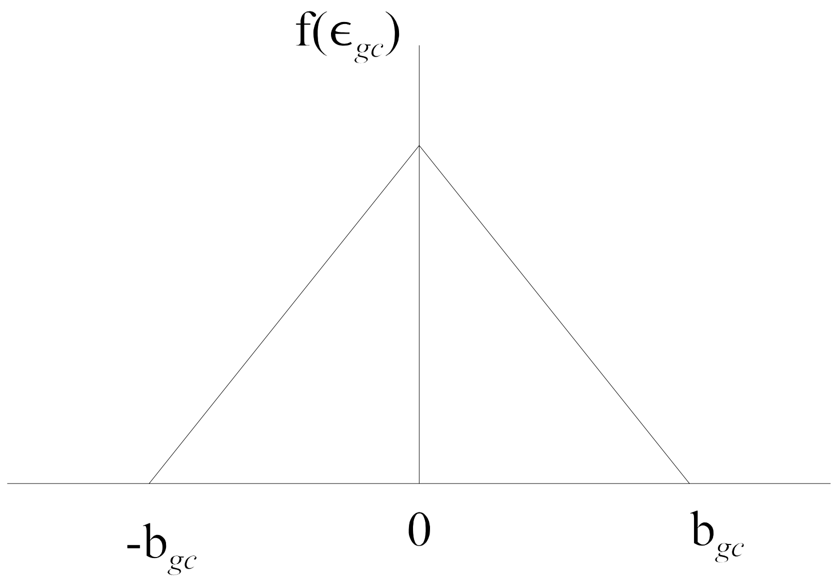

Figure 9.1 Triangular Density Function

Constraints are imposed to require that production of each grain in a region is equal to or greater than its total shipments of each grain to consuming regions, reaches, and export port by truck, barge, and rail. Total hectares planted, summed across grains, is constrained to be less than or equal to the total land area available for production.

Each producing region is required to plant at least 90% of its historical production area. This constraint is imposed to prevent the model from choosing to eliminate plantings in a region. Since the model has a least-cost objective function, the model might choose zero hectares planted in a region that traditionally plants a grain. This is highly unlikely. If a region is at a cost disadvantage for its predominant grain(s), prices of fixed factors, such as land, will adjust to assure that land is planted.

Constraints are imposed to require that certain consuming regions purchase sufficient quantities of high quality US and Canada wheat. Europe, Japan, China, S. Korea, S. Asia and SE Asia are required to purchase a minimum amount North American wheat, as percent of total wheat consumed, based on historical averages. These percentages are 2.6% for Europe, 42.6% for Japan, 17.7% for S. Korea, 13% for China, 36% for SE Asia and 1% for S. Asia. Finally, a constraint limits US exports through the St. Lawrence Sea Way to reflect season limitations on Great Lakes-St. Lawrence shipping. No more than 4 million MT is allowed to be shipped through US east coast ports.

The model determines the least-cost method for satisfying demands. The objective function considers the sum of production costs, transportation costs–truck, rail, barge and ocean–and delay costs associated with barge transport. Various levels of α were imposed and the minimum expected cost determined for the projection period. It is anticipated that in nearby time periods the model will be feasible for a wider range of α than for more distant time periods. This is due to increasing prediction error. As the time periods are more distant, the ability to accurate forecast stochastic variables declines, i.e., the variances increase, making it less likely that a feasible solution can be found with a high degree of certainty (α).

10.4 Modal Rate Functions

An important feature of this analysis is the modal rate functions. We evaluated several regression models with our data to determine that which most closely captures intermodal relationships.

We initially sought to define supply and demand funcitons for each model. We were not able to estimate supply and demand functions for rail and barge. In the experimentation, we extended the data, estimated them independently and jointly, used 3sls, and seemingly unrelated regressions, amongst others. We frequently got insignificant or incorrect signs on the price variable. Upon reviewing other studies, their findings are similar. In retrospect, we likely had too short of time series and some of these models were simultaneous. However, there were two outstanding issues. For rail, given it is an oligopoly (if not a duopoly), a supply function as conventionally thought of in perfectly competitive industries does not exist. Rather, railroads choose their rates to maximize profits and may choose to undersupply some movements (e.g. to St. Louis, or US Gulf) in order to benefit others (e.g., Portland). Second, our optimization model determines the demand for modes which are assumed perfectly substitutable.

However, the data for each mode came from varying sources that resulted in non-synchronous periods, durations, were unbalanced, and were not in anyway reported simultaneously. Hence, it was not possible to estimate these as a simultaneous set of equations which would be ideal. To do so would have resulted in data aggregations what would result in unacceptably small number of observations.

Ultimately, the regressions that were used should be interpreted as the reduced form equations and estimated separately for each mode from varying sources of pooled data. The logic of the resulting specifications is that: 1) rail vs. barge or combinations of truck and barge are perfect substitutes; 2) barge rates are related to barge volume on each reach; 3) rail rates adjust geographically and behaviorally (depending on distance, distance from barges, barge rates etc) and importantly experience longer term increases in productivity resulting in lower costs and these are reflected in lower rates by destination; 4) ocean rates depend on distance, fuel costs, and a series of origin/destination dummy variables.

The resulting equations are shown in Table 10.1-10.4.

Table 10.1 Ocean Rate Equation

Variable	*Parameter Estimate*
Intercept	4.01692
Ship Size (MT)	-0.5544 (-57.01)
Ocean Miles	0.4547557 (41.57)
Crude Oil Prices ($/barrel)	0.2409747 (10.33)
Binary for Origin = East Coast	0.0442165 (1.23)
Binary for Origin = Europe	0.037153 (1.00)
Binary for Origin = FSU-ME	-0.163897 (-3.35)
Binary for Origin = US Gulf	0.1265861 (3.84)
Binary for Origin = US PNW	0.0257501 (0.72)
Binary for Origin = Brazil	0.0339989 (0.99)
Binary for Destination = Central America	0.1058925 (5.05)
Binary for Destination = South America	0.2276558 (8.62)
Binary for Destination = China	0.0349367 (2.60)
Binary for Destination = S.E. Asia	0.1009639 (4.20)
Trend	-0.00242 (-1.22)
R^2	0.42

* t values in ( ).

Table 10.2. Average Ship Size (MT) for Ocean Movements

	Arg.	Aust.	Brazil N	Brazil S	Can East	Can West	China	Europe	Japan	South Korea	Latin Am	FSU-ME	Mexico	North Africa	Other Africa	South Asia	SE Asia	US E.C.	US Gulf	US PNW
Arg.	20858	32812	20858	20858	25000	25839	44863	34249	44863	44863	25839	27467	21081	20858	33969	44863	44863	25000	21081	25839
Aust.	32812	36750	32812	32812	48350	35851	52000	25000	52000	52000	35851	45357	40188	32812	33535	52000	52000	48350	40188	35851
Brazil N	20858	32812	20858	20858	25000	25839	44863	34249	44863	44863	25839	27467	21081	20858	33969	44863	44863	25000	21081	25839
Brazil S	20858	32812	20858	20858	25000	25839	44863	34249	44863	44863	25839	27467	21081	20858	33969	44863	44863	25000	21081	25839
Can East	22402	48350	22402	22402		20039	51125	40706	51125	51125	20039	24796	19203	22402	46381	51125	51125		19203	20039
Can West	27944	35851	27944	27944	20039	26552	53012	50188	53012	53012	26552	31912	20813	27944	37534	53012	53012	20039	20813	26552
China	44863	30000	44863	44863	51125	53012	35000	46256	35000	35000	53012	47771	52240	44863	26722	35000	35000	51125	52240	53012
Europe	22700	32490	22700	22700	40706	27250	46256	19310	46256	46256	27250	23808	23786	22700	35410	46256	46256	40706	23786	27250
Japan	44863	30000	44863	44863	51125	53012	35000	46256	35000	35000	53012	47771	52240	44863	26722	35000	35000	51125	52240	53012
S. Korea	44863	30000	44863	44863	51125	53012	35000	46256	35000	35000	53012	47771	52240	44863	26722	35000	35000	51125	52240	53012
Latin Am	27944	35851	27944	27944	20039	26552	53012	50188	53012	53012	26552	31912	20813	27944	37534	53012	53012	20039	20813	26552
FSU-ME	27467	35000	27467	27467	24796	31912	47771	28847	47771	47771	31912	19408	38507	27467	32166	47771	47771	24796	38507	31912
Mexico	17904	40188	17904	17904	19203	22982	52240	43980	52240	52240	22982	38507	18406	17904	33912	52240	52240	19203	18406	22982
N. Africa	20858	32812	20858	20858	25000	25839	44863	34249	44863	44863	25839	27467	21081	20858	33969	44863	44863	25000	21081	25839
Oth Africa	33969	23500	33969	33969	46381	35000	26722	35410	26722	26722	35000	14333	24000	33969	23503	26722	26722	46381	24000	35000
S. Asia	44863	30000	44863	44863	51125	53012	35000	46256	35000	35000	53012	47771	52240	44863	26722	35000	35000	51125	52240	53012
SE Asia	44863	30000	44863	44863	51125	53012	35000	46256	35000	35000	53012	47771	52240	44863	26722	35000	35000	51125	52240	53012
US E.C.	22402	48350	22402	22402		20039	51125	40706	51125	51125	20039	24796	19203	22402	46381	51125	51125		19203	20039
US Gulf	17904	40188	17904	17904	19203	22982	52240	43980	52240	52240	22982	38507	18406	17904	33912	52240	52240	19203	18406	22982
US PNW	27944	35851	27944	27944	20039	26552	53012	50188	53012	53012	26552	31912	20813	27944	37534	53012	53012	20039	20813	26552

Table 10.3. Domestic Rail Rate Equations by Grain

	Corn	*Soybean*	*Wheat*
Intercept	6.23357 (13.39)	0.19501 (0.09)	7.68050 (7.95)
Total Distance	0.02089 (26.34)	0.02873 (6.75)	0.02458 (13.83)
Total Distance^2	-0.00000238 (-6.16)	-0.00000507 (-2.19)	-0.00000233 (-2.70)
Distance to Nearest Barge	0.00313 (6.36)	0.00369 (1.10)	-0.00199 (-2.68)
ln(trend)	-1.32114 (-6.82)	1.02755 (1.03)	-1.14171 (-2.96)
RMSE	4.07153	15.36725	8.28355
R^2	0.82	0.23	0.61

* t values in ( ).

Table 10.4. Export Rail Rate Equations by Grain			
	Corn	***Soybean***	***Wheat***
Intercept	6.15269 (7.08)	3.47841 (3.98)	6.69748 (6.03)
Total Distance	0.01440 (11.61)	0.01923 (13.76)	0.01727 (10.20)
Total Distance^2	-0.00000618 (-1.09)	-0.00000348 (-5.07)	-0.00000031 (-0.43)
Distance to Nearest Barge	0.0031 (1.55)	0.00262 (2.89)	0.00358 (4.71)
ln(trend)	-1.03531 (-3.69)	-0.23765 (-0.84)	-0.70702 (-1.95)
E2	1.83036 (2.29)	2.42205 (3.40)	-4.27459 (-4.31)
E3	8.86272 (12.70)	5.60938 (8.23)	1.05385 (1.05)
E5	0.35193 (0.40)	2.49947 (2.51)	3.19947 (3.18)
E6	1.57449 (0.92)	1.21379 (0.80)	-0.53889 (-0.46)
E7	3.69626 (5.14)	2.73210 (4.05)	-2.84382 (-3.09)
EB1	0.56765 (0.75)	0.92125 (1.32)	-0.08614 (-0.10)
EB2	1.11607 (1.30)	2.07723 (2.13)	3.72586 (2.86)
EB3	1.65583 (1.51)	3.48158 (3.45)	4.61321 (4.20)
EB4	0.89131 (1.10)	3.51914 (3.45)	1.54986 (0.57)
EB5	1.40329 (1.27)		
RMSE	5.09711	4.66810	6.97211
R^2	0.75	0.74	0.69

* t values in ( ).

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