Analyses of the Upper Mississippi and Illinois Rivers as Grain Transport Arteries: A Spatial Equilibrium Analyses

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Abstract

Grain is the primary commodity transported on the upper Mississippi and Illinois Rivers, comprising about half of the tonnage on the upper Mississippi and 40 percent of the Illinois River traffic. It is estimated these rivers annually originate about 36 million metric tons of corn and soybeans that are primarily destined for export at lower Mississippi River ports. Spatial models representing the international grain economy are developed to estimate the annual contribution of the upper Mississippi and Illinois Rivers to Midwest grain producer revenues and evaluate alternate grain routing necessitated by a catastrophic event at Lock and Dam 27 near St. Louis, a facility grain must pass on its route to lower Mississippi River ports. The analysis suggests the annual value of the upper Mississippi and Illinois Rivers for grain transport ranges from $233 to $799 million but based on the most likely scenario to range from $312 to $549 million. The catastrophic analyses examined the value of alternate routings and corridors given a violent event at Lock and Dam 27 and results show the segment of the Mississippi River immediately below St. Louis to be an attractive routing for grain from Illinois, Iowa, and Minnesota given closure of these rivers. Also of great importance as alternate routings was rail transportation on the Corn Belt to Gulf corridor, and grain shipments via the Ohio River and Great Lakes. The upper Mississippi and Illinois Rivers are important transport arteries for the Midwest grain economy and their value and the value of alternate grain transport corridors and routings is greatly dependent on pricing decisions by competing railroads.

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INTRODUCTION

Grain is the primary commodity transported on the upper Mississippi and Illinois Rivers, comprising about half of the tonnage on the upper Mississippi and 40 percent of the Illinois River traffic. It is estimated these rivers annually originate over 26 million metric tons (mmt) of corn and about 10 mmt of soybeans that are primarily destined for export at lower Mississippi River ports, a port area responsible for about two-thirds of U.S corn and soybean exports (USACE 2004). Exports are important to the U.S. grain economy since they make up about 20 percent of annual corn disappearance and 35 percent of soybean disappearance (USDA 2006b, 2006c).

There has been considerable debate regarding the upper Mississippi and Illinois Rivers and the desirability of infrastructure improvements to enhance navigation efficiency on these transport arteries. Further, there has been speculation about the likely impact of infrastructure failure on critical segments of these rivers that may stem from a catastrophic or violent event. To offer perspective on these issues, analyses are carried out to evaluate the contribution of these transport arteries to the Midwest grain economy and to offer insight on alternate grain routings in case of a catastrophic event. Analyses are carried out with international corn and soybean spatial equilibrium models, which include detail regarding grain transportation on U.S. inland waterways and the grain transport network. A particularly critical river segment in the upper Mississippi and Illinois River system is near St. Louis at Lock and Dam 27. The Illinois River empties into the upper Mississippi just above St. Louis while the Missouri River empties into the upper Mississippi at St. Louis. Hence, all grain originating on the upper Mississippi, Illinois and Missouri Rivers that moves to export at lower Mississippi River ports must traverse Lock and Dam 27, therefore a critical link in the system and focus of the catastrophic analyses.

Although spatial equilibrium models are generally unique as research tools to evaluate the worth or value of a transportation corridor and to carryout catastrophic analyses, earlier spatial models have been used to address similar questions. For example, spatial equilibrium models (quadratic programming) were recently employed by Fuller, Yu, Fellin, Lalor and Krajewski (2001) to evaluate improvements in South America's grain transportation infrastructure and its influence on competitiveness in world grain markets. Fuller, Fellin and Eriksen (2000) employed international spatial equilibrium models of the grain economy to examine the importance of the Panama Canal as a grain transport artery and to evaluate the effect of increasing Canal tolls on U.S. agriculture.

In the following section, study objectives and procedures are outlined. This section is followed by a description of the developed models, and model data needs and sources. In addition, information on model validation is related as is information on transportation/port corridors that may reach capacity constraints given closure of the upper Mississippi and Illinois Rivers. Finally, the results offer information on likely declines in Midwest grain producer revenues if rivers were closed, and the value of alternate routes and corridors in case of a catastrophic event at Lock and Dam 27.

OBJECTIVES AND PROCEDURES

The objectives of this study are to (1) estimate the contribution of the upper Mississippi and Illinois Rivers to grain producers' revenues in Midwest regions and (2) evaluate alternative grain transport routing that may be necessitated by a catastrophic event at Lock and Dam 27 near St. Louis. To carry out the objectives of the study, spatial equilibrium models representing the international corn and soybean economies in the 2003-2004 crop year are developed.

After construction of the spatial models, they will be validated by contrasting actual outcomes in 2003-2004 with solutions obtained with the models. After satisfactorily completing the recalibration and validation of the 2003-2004 base models, analysis will commence. Study objectives will be resolved by modifying the base models and then contrasting the modified models solutions with base model outcomes. To accomplish objectives 1 and 2, the base models will be modified to include closing of the Mississippi River to barge traffic at all sites above St. Louis (Lock and Dam 27), thus prohibiting any river traffic on the upper Mississippi and Illinois Rivers. The solutions from the base models will be contrasted with solutions from modified models that prohibit all grain traffic on the upper Mississippi and Illinois Rivers above St. Louis. Attention will focus on producer prices and revenues, and grain shipment patterns before and after river closure. Closing the upper Mississippi and Illinois Rivers to grain traffic will likely modify regional grain flows and alter demands for transportation services and infrastructure on competing corridors, hence the need to include in the modified models upper bound capacity estimates on grain flows via alternate routings and port areas. Capacity considerations focus on Pacific Northwest and Gulf grain ports and railroads serving these transportation corridors, Great Lake ports, the Ohio River and its grain handling capacity, and the capacity of Mississippi River elevators to accommodate increased grain flows below St. Louis. Further, because of anticipated increases in railroad grain transportation demands that result from closing the upper Mississippi and Illinois Rivers, scenarios are evaluated that include increases in railroad rates. To accomplish Objective 2, focus is on shadow prices that result from constraints on alternate transport routings and port areas.

MODEL DESCRIPTION

The quadratic programming models developed for this study generate interregional trade flows and prices that result from maximizing regional producer plus consumer surplus minus grain handling, storage and transportation costs (Samuelson 1952) (Takayama and Judge 1971). Models include regional excess demands and supplies, and transportation, storage and grain handling rates/charges in the United States. Other trading countries are treated as an excess supply or excess demand region except for Canada and Mexico.

Mexico includes five excess demand regions and Canada two excess demand regions. Output from the spatial equilibrium models identifies each geographic region's grain production, consumption and price; trade flows between all domestic and foreign regions by quarter; and the geographic routing of trade between trading regions and the responsible transport mode at each link in the logistics and transportation network that participates in the interregional grain flow.

An excess supply region's production plus carry-in stocks exceed estimated consumption while an excess demand region's consumption exceeds production and carry-in. Each excess supply region is represented by a positively-sloped linear relationship (ES_i) that is conceptually obtained by subtracting region demand (D_i) from region supply (S_i) ($S_i - D_i = ES_i$), while each excess demand region is represented by a negatively-sloped linear relationship (ED_i) that may be mathematically obtained by subtracting region supply from region demand ($D_i - S_i = ED_i$). Domestic excess supply regions include country elevator grain price while foreign excess supply regions include FOB ship grain prices. Equivalence is maintained in the foreign and domestic components of the models by including in the domestic portion all grain handling, storage and transportation charges associated with moving grain from country elevators to ports.

Grain supply is generated in the fall quarter (northern and southern hemisphere) and carried forward into subsequent quarters incurring storage charges in the domestic and foreign portion of the models. Grain handling costs are incurred at country elevators in domestic regions and intermodal transfer facilities. Domestic trade is facilitated by a transportation network that links domestic excess supply regions with barge-loading sites, domestic excess demand regions and ports via grain handling and storage charges, and quarterly truck, rail and barge rates. Grain barge loading sites on the inland waterways are linked to barge unloading elevators at Gulf ports, and barge unloading elevators on the lower Mississippi and Tennessee River by quarterly barge rates. The barge unloading elevators at Gulf ports incur charges associated with receiving the grain and loading the grain to ocean vessels, while barge-unloading facilities on the lower Mississippi and Tennessee Rivers incur costs of receiving and loading grain to truck and rail modes. The truck and rail modes connect the river's barge unloading elevators to nearby excess demand regions by quarterly rates. Domestic excess supply regions are also linked directly to excess demand regions and all U.S. ports by truck and rail modes via grain loading (supply region) and unloading charges (excess demand region or port) and quarterly transportation rates. And, selected domestic excess supply regions are linked to foreign excess demand regions in Mexico and Canada by quarterly truck and rail rates. Mexico may also import grain via an ocean port at Veracruz, which is linked by truck and rail rates to the five Mexican excess demand regions.

Foreign excess supply regions (countries) are represented by upward sloping linear relationships (excess supplies) whose grain price is FOB ship. Domestic and foreign ports are linked to foreign excess demand regions by quarterly ship rates that connect representative ports in each region.

The domestic or U.S. portion of the spatial models includes 73 excess corn supply regions and 106 excess soybean supply regions, and 72 excess corn demand regions and 35 excess soybean demand regions. Each geographic region in the domestic portion of the models is a crop reporting district or aggregated crop-reporting districts: a crop reporting district typically includes ten to twenty counties. The foreign component of the spatial models includes six corn excess supply regions (exporting countries) and 29 excess corn demand regions (importing countries). Foreign corn suppliers include the Black Sea region (Moldova, Ukraine), South Africa, India, Thailand, China and South America, which includes Argentina, Brazil, Paraguay and Uruguay. Two of the foreign excess corn demand regions are in Canada, five are in Mexico and in the European Union (EU-25) which is divided into two regions. Japan, Taiwan and Korea are each represented as an excess corn demand region while remaining excess corn demand regions are groups of contiguous countries.

India, Canada and South America (Argentina, Brazil and Paraguay) are foreign excess supply regions in the soybean model. Twenty-three regions are identified as foreign soybean excess demand regions. China, Japan, Korea and Taiwan are each represented as an excess demand region, Mexico is divided into five excess demand regions, Canada is represented as two regions, and European Union (EU-25) is represented as two regions.

Included in the U.S. portion of the model is a transportation/logistics network that links excess supply regions to river barge loading elevators, ports and excess demand regions with applicable transportation, storage and grain handling charges. Grain storage occurs in the excess supply region until shipped via the transportation/logistic network to applicable locations. The barge loading elevators are linked to barge unloading elevators on rivers near excess demand regions and applicable ports by quarterly barge rates. Included in the model are 40 barge loading/unloading sites on the upper Mississippi (11), Illinois (3), Missouri (6), Arkansas (3), Ohio (4), lower Mississippi (7), Cumberland (1), White (1) and Tennessee (4) Rivers. The upper Mississippi River elevators are closed above St. Louis during the winter because of river freezing.

Domestic excess supply regions are also linked by quarterly truck and rail rates to the following port elevator locations in the spatial models: lower Mississippi River, east Gulf, north Texas, south Texas, Puget Sound, Columbia River, north Atlantic , south Atlantic, Duluth/Superior, Chicago, and Toledo. The Great Lakes ports (Duluth/Superior, Chicago, Toledo) may ship directly to foreign excess demand regions via ocean-going vessels (salties) or via vessels (lakers) that shuttle grain between Great Lake port elevators and the lower St. Lawrence River elevators. The three Great Lake ports are closed during the winter months due to freezing while lower St. Lawrence River ports are open year-round.

The U.S ports can ship grain to representative ports in foreign excess demand regions (importers) by quarterly ship rates as can representative ports associated with foreign excess supply regions (exporters). Odessa, Ukraine was the selected export site for Ukraine and Moldovia corn exports; Durban, South Africa for corn exports from South Africa; Madras, India for corn exports of that country; Bangkok, Thailand for corn exports from Thailand; Dalian, China for corn exports from China, and Sao Paulo, Brazil for exports of Argentina, Brazil, Paraguay and Uruguay. In the soybean portion of the model, Sao Paulo was identified as the representative port for Argentina, Brazil, Paraguay and Uruguay exports. Canada was allowed to export soybeans through its west coast ports (Vancouver) and St. Lawrence River ports (Quebec), while India shipped soybeans via Madras. .

MODEL DATA

The spatial model was constructed with estimates of domestic and foreign excess demand and supply equations; grain handling and storage charges; and railroad, truck, barge and ship rates.

Excess Supply and Demand Equations

Region excess supply equations were obtained with (1) an estimate of the excess supply elasticity (2) quantity exported from region and (3) representative price. These data facilitate the mathematical estimation of the slope and intercept terms of an inverse excess supply equation. In a similar manner, an inverse excess demand was estimated with (1) an estimate of excess demand elasticity (2) quantity imported into region and (3) a representative price. Region excess supply elasticity was derived from demand and supply price elasticities and estimated quantities produced, consumed and exported. Region excess demand elasticity was mathematically obtained with information on own-price demand and supply elasticities, quantity consumed in region, quantity produced in region, and imports (Shei and Thompson, 1977).

Domestic own-price demand and supply elasticities were from econometric models developed by Food and Agricultural Policy Research Institute (FAPRI) at the University of Missouri (2005). Information on domestic corn and soybean production by crop reporting district was obtained from the USDA (2005h). The USDA (2006b, 2006c) provides national estimates of domestic corn use and soybean crush, however, no information regarding consumption by crop reporting district or any geographic unit. Therefore, corn consumption and soybean crush by crop reporting district had to be estimated. With these estimates of regional production and consumption, regional quantities exported and imported were calculated. And, with these data it was possible to determine regional excess supply and demand elasticities. The regional elasticities in combination with associated exports and imports, and regional prices facilitated the mathematical derivation of the regional excess supply and demand relationships.

The USDA (2006b) estimated domestic corn use in 2003-2004 at 8.34 billion bushels. An estimated 2.55 billion bushels was used for food, alcohol and industrial uses, and 5.80 billion bushels as feed and residual, and the remaining as seed (USDA 2006b). To estimate food, alcohol and industrial corn use by crop reporting district, a variety of information sources were employed. Some information on corn use by geographic region was obtained from the U.S. Census Bureau's Manufacturing-Industry Series (2004): this series offered information on wet corn millers, distilleries, breakfast cereal manufacturing, dry corn mills, snack food manufacturers, and breweries. Wet corn mills use of corn was based on 24-hour grind capacity of each U.S. plant as provided by two industry consultants and several state-level trade associations. Dry corn mills use of corn by plant was primarily based on information provided by an industry spokesman and a trade organization. The estimated use of corn for ethanol production was based on plant capacity information provided by a trade association and several states' economic development agencies. Masa corn mills use of corn was based on interviews with several manufacturers and company websites (Azteca Milling 2005) (Minsa 2005). Consultants indicated corn processor demands were constant year-round, hence demand was assumed to be equal in each quarter.

Domestic corn consumption by livestock, poultry, and dairy was estimated with population data and representative rations for the 2003-2004 crop year. Corn consumption was estimated for beef cows, cattle on feed, broilers, layers, turkeys, milk cows, hogs, pigs, sheep and lambs. The 2002 Census of Agriculture (USDA 2004a) provided information on county populations, which were subsequently adjusted by state data for 2003-2004. Documents titled *Cattle on Feed*, *Cattle, Sheep and Goats*, *Hogs and Pigs*, *Chickens and Eggs*, and *Chicken Production and Value* offered information on populations (USDA 2004b, 2004c, 2004d, 2004e, 2004f, 2004g). The Iowa State University Extension Service (2005) was the source of rations that were adjusted for selected states based on counsel with animal scientists.

Domestic soybean crush was estimated in 2003-2004 to be 1.53 billion bushels (USDA 2006c). Based on information from the National Oilseed Processors Association (NOPA) (2005) and estimated plant crush capacities, soybean crush was estimated by crop reporting district.

Domestic corn and soybean price by crop reporting district was estimated from a data set of daily prices paid by elevators, terminals and processors across the United States. These data were obtained from CashGrainBids.com (2006).

Excess supply and demand elasticities for foreign regions (countries) was estimated with own-price demand and supply elasticities from models developed by FAPRI at the University of Missouri (2005). In addition, data from the PS&D file maintained by the USDA (2005f) was a data source for estimation of foreign elasticities.

Export FOB ship grain prices were obtained for selected countries with the remainder estimated from available price data and ship rates. Argentina's monthly FOB corn and soybean port price was obtained from Secretaria de Agricultura, Ganaderia, Pesca y Alimentos (2005), and Brazil's monthly soybean export price from its Ministerio da Agricultura, Pecuaria e Abastecimento (2005). A USDA economist (2005i) provided unpublished monthly data on China's FOB port corn price, and price paid for Canada's imports of U.S. corn and soybeans came from Agriculture and Agri-Food Canada (2005). Attache Reports (2005e) offered background on prices of major corn and soybean trading countries and the prices paid for corn and soybeans at major U.S. ports came from USDA (2006a). Additional foreign corn prices came from Agrimarket Info (2005).

Data on Argentina's monthly exports of corn and soybeans to trading partners was obtained from the Secretaria de Agricultura, Ganaderia, Pesca y Alimentos (2005b), and Brazil's monthly exports of soybeans to individual countries was supplied by its Ministerio da Agricultura, Pecuaria e Abastecimento (2005). Mexico's Secretaria de Agricultura, Ganaderia, Desarrollo Rural, Pesca Y Alimentacion (2005) provided data on monthly imports of corn and soybeans via overland and maritime sources, while Canada's monthly imports of corn and soybeans from the U.S. to various provinces came from Agriculture and Agri-Food Canada (2005). China's corn exports to major importers came from a private communication with a USDA economist (2005i). The Attache Reports (2005e) offered monthly/quarterly exports and imports of selected corn and soybean trading countries.

Transportation and Logistics Network

The transportation and logistics network in the U.S. portion of the spatial model links the excess supply regions to barge loading facilities, ports and excess demand regions by applicable modes by quarter. Virtually every excess supply region (crop reporting district) within 200 miles of the upper Mississippi and Illinois Rivers are linked to barge-loading locations on the upper Mississippi (11) and Illinois Rivers (3) by quarterly truck rates and many of the excess supply regions are linked to the river elevator sites by quarterly rail rates. Similarly, all excess supply regions are linked by truck and/or rail to two or three port areas. For example, excess supply regions in Minnesota are linked by rail rates to Pacific Northwest ports, Great Lake ports, and Gulf ports and to excess demand regions in Canada and Mexico, as well as by barge rates to Gulf ports. Further, Minnesota’s excess supply regions are linked by truck and/or rail rates to domestic excess demand regions in Arkansas, Arizona, California, Colorado, Idaho, Illinois, Iowa, Kansas, Mississippi, Oklahoma, Texas and Washington.

Truck rates in the spatial model were estimated with a regression that was based on data included in the *Grain Transportation Report* (2005a). The truck rate function estimates per mile costs by quarter for various regions of the United States.

Railroad rates were taken from the 2003 and 2004 Carload Waybill Samples that were obtained from USDOT (2005). The waybill was segregated by quarter and then used to estimate rates between excess supply regions and ports, barge loading sites, and excess demand regions. Overland rail rates to Canada were estimated with the waybill data, and rates to Mexico's excess demand regions were estimated from rate data supplied by Transportacion Ferroviaria Mexicana (2005) and Ferrocarril Mexicana (2005). The Transportacion Ferroviaria Mexicana also provided rate data that linked the Mexican port at Veracruz to interior excess demand locations in Mexico.

Grain barge rates are collected for grain movements from the upper Mississippi, mid-Mississippi, lower Mississippi, Illinois and Ohio Rivers to lower Mississippi River ports by the USDA (2005c). These data were used to obtain model parameters and, for barge movements to the Tennessee River the USDA rates were adjusted to reflect appropriate mileages.

International grain ship rate data were obtained from the USDA (2004h), however, the data were originally compiled by Baltic Exchange. A ship rate equation was estimated with these data and used to estimate quarterly ship rates between trading regions/ports. Miles of haul between origin port and destination port was measured for each ship rate observation and included in the estimated rate equation as was fuel price, originating world region, destination world region, shipment terms, quarter, and grain cargo size.

Grain Handling and Storage Charges

In the U.S. portion of the spatial model, grain handling charges at country elevators in production regions were included as were intermodal transfer charges at barge loading and unloading sites, and ports. In addition, storage charges were included in both the domestic and foreign portions of the model. Data on charges were obtained via phone conversations with grain shippers and firm websites that offered information on tariffs (Blue Water Shipping 2005).

MODEL VALIDATION

Because the analysis focuses on the upper Mississippi and Illinois waterways, special attention is given to these arteries and their carriage of corn and soybean in the validation process. The following tables contrast model-determined quantities of corn and soybeans entering various segments or sections of these rivers with historical data collected by the U.S. Army Corps of Engineers for the 2003-2004 crop year.

As shown in Table 1, model-projected quantities of corn entering segment 1 of the upper Mississippi (mile 1 to mile 234) are somewhat underestimated for 2003-2004 but all corn and soybean flows to remaining segments of the upper Mississippi and Illinois Rivers closely approximate historic quantities. In general, model-projected quantities of soybeans transported via each river approximate actual quantities. In the analysis that follows, it is assumed that closure of the upper Mississippi and Illinois Rivers prohibits grain entering segments 2 and 3, and the Illinois River (Table 1).

Table 1: Historic and Model Projected Quantities of Corn and Soybeans Entering Upper Mississippi amd Illinois Rivers, 2003-2004 Crop Year

River	Historic Corn Quantities 1000 mt	Historic Soybeans Quantities 1000 mt	Model-Projected Corn Quantities 1000 mt	Model-Projected Soybean Quantities 1000 mt
Upper Mississippi				
[1]Segment 1	4,772	1,883	4,067	1,759
[2]Segment 2	6,769	1876	6,800	1,718
[3]Segment 3	4,401	760	4,556	798
Illinois	10,960	2,265	10,927	2,049

[1] **Segment 1** extends from juncture of Mississppi River and Ohio River to near Winfield, Missouri or Lock 25 (Mile 1 to Mile 243).
[2] **Segment 2** extends from Lock 25 through McGregor, Iowa near the Iowa Minnesota border. (Mile 243-Mile 634)
[3] **Segment 3** extends from McGregor, Iowa through Minnepolis, St. Paul, Minnesota. (Mile 635-860)

Table 2 contrasts model-projected quantities of corn and soybeans exiting the U.S. via alternative port areas with historic quantities in 2003-2004. The projections are comparatively close to historic quantities with the exception of overland soybean shipments where model-projected quantities exceed actual quantities in 2003-2004. Based on the presented outcomes in Tables 1 and 2 and other grain flow patterns, the developed models were judged adequate to carryout the analyses.

Table 2: Historic and Model-Projected Quantities of Corn and Soybean Exiting Via U.S. Port Areas 2003-2004 Crop

Port Areas	Historic Corn Quantities 1000 mt	Historic Soybeans Quantities 1000 mt	Model-Projected Corn Quantities 1000 mt	Model-Projected Soybean Quantities 1000 mt
Lower Mississippi River	34,916	15,141	33,940	14,727
Other Gulf	341	1,442	305	1,190
Pacific Northwest	10,103	4,515	10,781	4,531
Atlantic	84	499	0	73
Great Lakes	907	961	1,904	1,178
Overland	2,436	1,537	2,669	2,387
Total	48,787	24,095	48,789	24,086

ESTIMATED TRANSPORTATION AND GRAIN HANDLING CONSTRAINTS

Closure of the upper Mississippi and Illinois Rivers above St. Louis would divert about 27 mmt of corn and soybeans from these transport arteries (segments 2 and 3, and Illinois River shown in Table 1), which undoubtedly would have an important affect on regional grain flows and the routing of export-destined grain. After a review of selected data, it was thought closure of the upper Mississippi and Illinois Rivers could increase grain flows to ports in the Pacific Northwest, Great Lakes, Atlantic Coast, and increase rail-transport of grain to Gulf ports, as well as increase grain flows to Mississippi River elevators below St. Louis and grain elevators on the Ohio River. In view of potential changes in regional flow patterns, efforts were made to gain insight on likely port and transportation capacities on affected corridors. Because of the impossibility of obtaining precise estimates on corridor constraints, three scenarios are developed and evaluated with the spatial models.

In scenario development, it was assumed existing infrastructure capacity could not be substantially altered and new infrastructure capacity could not be constructed because of the short-run time period featured in the analysis. To gain insight on potential capacity constraints, a variety of data sources were reviewed. Historical monthly grain flows of corn and soybean through port areas was available from USDA (2005b). The St. Lawrence Seaway Traffic Reports (2006) provided increased detail on grain exports via Great Lake ports. Information on possible railroad capacity constraints are collected by the Association of American Railroads (AAR) and USDA. In particular, the AAR collects information on weekly and annual number of grain carloads originated by each Class I carrier: these data and information on port area rail deliveries (carloads) appear in the *Grain Transportation Report* (2005a). In addition, a study by The Louis Berger Group, Inc. (2005) provided information on river grain elevators handling capacity in the

St. Louis area. Handling capacity of other river elevators in the mid- and lower Mississippi River and Ohio River, and U.S. port elevators were obtained from data presented by Sosland Publications (2006). The U.S. Army Corps of Engineers, Rock Island District, (2006) has detailed historic information on monthly quantities of various commodities transiting each lock and dam in the U.S. waterway system: this information offered perspective on potential waterway constraints.

Three scenarios were developed that had estimated constraints for corn and soybeans on various corridors and routings (Table 3). The developed constraints for corn and soybeans took into consideration other grains that also required transportation services on virtually all of the corridors. Scenario 1 is the most highly constrained scenario while Scenario 3 is the least constrained of the evaluated scenarios.

Table 3. Estimated Capacity Constraints on Selected Corn and Soybean Transportation Corridors and Routings

	Mississippi River Segment [1] (1000 mt)	Great Lakes[2] (1000 mt)	Gulf Ports[3] (1000 mt)	Ohio River[4] (1000 mt)	Pacific Northwest[5] (1000 mt)
Scenario 1	6,500	4,800	9,000	10,700	18,000
Scenario 2	9,500	4,800	12,500	12,500	20,000
Scenario 3	12,000	4,800	14,000	13,400	20,000

1. Based on estimated grain receiving capacities of river elevators in Mississippi River segment extending from St. Louis to Cairo, Illinois.

2 Represents historic maximum corn and soybean export volumes from Great Lakes.

3. Based on Gulf ports rail-receiving capacity, availability of rail capacity and historic rail carload statistics on unloads.

4 Based on historic volumes transported from Ohio River origins to lower Mississippi River ports and river elevator barge loading capacities.

5 Based on historic rail carload statistics on unloads.

RESULTS

Value of Upper Mississippi and Illinois Rivers as Grain Transport Arteries

The three scenarios outlined in Table 3 are analyzed to gain information on the value of the upper Mississippi and Illinois Rivers as grain transport arteries. Analysis focuses on the contribution of these two transport arteries to Midwest producers' annual grain revenues. All scenarios involve closure of the Mississippi River above St. Louis, which is approximated by segments 2 and 3, and Illinois River presented in Table 1. Closing the river will divert important quantities of grain, which would likely increase railroad grain demands and rates. For this reason, railroad rates are adjusted upward by 5, 10, and 15 percent on export grain corridors in each of the scenarios.

Results show closure of the upper Mississippi and Illinois Rivers would have an important affect on regional grain prices and flows. In scenario 1 (Table 4), corn prices in those Illinois, Iowa, and Minnesota regions adjacent to the upper Mississippi and Illinois Rivers decline up to $7.75/metric ton (mt) ($.20/bu.) while more distant locations in these states experience a reduction in corn price that ranges from about $1.25/mt ($.03) to $4.50/mt ($.115/mt). As expected, soybean prices also decrease with river closure. In those regions adjacent to the upper Mississippi and Illinois Rivers (Illinois, Iowa, Minnesota) soybean prices decline up to $6.95/mt ($.19/bu.) but typically decline from $1.38/mt ($.037/bu) to $6.15/mt ($.17/bu.). Corn and soybean prices also decline similarly in nearby excess demand regions, which increase domestic corn and soybean consumption. Annual corn and soybean producer revenues decline an estimated $646 million with closure of the upper Mississippi and Illinois Rivers while revenue losses increase further to $673 million with a 5% increase in export rail rates, and to $738 million and $799 million with a 10% and 15% increase in export rail rates.

Table 4. Scenario 1: Estimated Effect of Closing Upper Mississippi and Illinois Rivers on Port Area Grain Flows (Corn, Soybean) and Grain Producer Revenues With Export Railroad Rate Increases (5%, 10%, 15%)

Port Area	Scenario 1 (1000 mt)	Scenario 1-5% (1000 mt)	Scenario 1-10% (1000 mt)	Scenario 1-15% (1000 mt)
Lower Mississippi	36,680	36,743	36,889	37,320
Other Gulf	1,319	1,317	1,622	1,617
Pacific Northwest	18,019	17,514	17,194	16,729
Atlantic	2,069	1,998	1,781	1,384
Great Lakes	4,800	4,800	4,800	4,800
Overland	5,164	5,177	5,194	5,210
Total	68,051	67,549	67,480	67,060
Producer Revenue Losses	$ 646 million	$673 million	$738 million	$799 million

In Scenario 1, corn and soybean exports decline approximately 4.8 mmt or nearly 7 percent and grain flow patterns are altered. Exports via lower Mississippi River ports decline nearly 12 million metric tons (mmt), and export capacity constraints are reached on the Pacific Northwest transport corridor (18 mmt), Great Lakes (4.8 mmt), Ohio River (10.7 mmt), rail-transported quantities to Gulf ports (9 mmt), and the Mississippi River segment below St. Louis (6.5 mmt). In the eastern corn belt, increasing quantities of corn are transported to Atlantic Coast ports, Ohio River, and Great Lake ports while in Illinois, rail shipments to Gulf ports increase as do truck and rail shipments to Great Lake ports (Chicago) and to Ohio River barge loading facilities in the lower reaches of that river (Evansville, Indiana and below). In addition, Illinois shippers route increased corn exports to the Mississippi River segment below St. Louis. River closure increases Illinois corn shipments to the export market and lowers its shipments to the important southeast U.S. market. As a result, corn in northwest Illinois, eastern Iowa and southeast Minnesota is increasingly routed to the southeast U.S market to replace the diverted Illinois shipments. Iowa increases its shipments to the south and southwest U.S. (primarily Texas) market, while Minnesota, South Dakota, Iowa and Nebraska increase shipments to the Pacific Northwest ports. Corn surplus regions in southeast Missouri, western Kentucky and Louisiana increasingly route corn to lower Mississippi River ports by barge and railroads.

River closure also reroutes soybeans with the most important changes involving an increase in flows to Great Lake ports, the Pacific Northwest ports and to the Ohio River for barge shipment to the lower Mississippi River port area. In addition, there is an increase in soybean flows from Illinois origins to that segment of the Mississippi River immediately below St. Louis. Increased shipments to the Great Lakes primarily originate in Minnesota and Wisconsin and are shipped to the Duluth/Superior port. Much of the increased flow to the Ohio River originates in Illinois: these soybeans are transported to the lower reaches of the Ohio River. The increased shipments to the Pacific Northwest originate in Minnesota, and North and South Dakota.

In scenario 2, capacity on selected routes and corridors was allowed to increase (Table 5). Annual grain-handling capacity of river elevators in that segment of the Mississippi River below St. Louis is increased to 9.5 mmt, and the Ohio River grain transportation capacity increases to12.5 mmt as does the capacity of the rail corridor linking the Corn Belt to Gulf ports. In addition, the capacity of the Pacific Northwest corridor increases to 20 mmt.

Table 5. Scenario 2: Estimated Effect of Closing Upper Mississippi and Illinois Rivers on Port Area Grain Flows (Corn, Soybean) and Grain Producer Revenues With Export Railroad Rate Increases (5%, 10%, 15%)

Port Area	Scenario 2 (1000 mt)	Scenario 2-5% (1000 mt)	Scenario 2-10% (1000 mt)	Scenario 2-15% (1000 mt)
Lower Mississippi	42,186	43,267	44,307	44,808
Other Gulf	1,621	1,431	1,452	1,263
Pacific Northwest	17,363	15,803	13,538	13,010
Atlantic	206	70	16	15
Great Lakes	4,800	4,800	4,800	4,800
Overland	5,088	5,111	5,146	5,169
Total	71,264	70,482	69,259	69,065
Producer Revenue Losses	$312 million	$367 million	$482 million	$549 million

As a result of the expanded route and corridor capacities in scenario 2, corn and soybean export levels are reduced more modestly than in scenario 1, declining 1.6 mmt as compared to the 2003-2004 base (Table 5). Exports via lower Mississippi River ports decline about 6.5 mmt as compared to the base and capacity constraints are reached on the Ohio River (12.5 mmt), Great Lakes (4.8 mmt), segment of Mississippi River below St. Louis (9.5 mmt) and rail corridor linking Corn Belt to Gulf ports (12.5 mmt). The 20 mmt constraint on the Pacific Northwest corridor was not reached.

Corn prices in Iowa, Illinois and Minnesota regions that are adjacent to the upper Mississippi and Illinois Rivers decline up to $5.28/metric ton (mt) ($.13/bu) but generally the price reduction ranges from $2.67/mt ($.07/bu) to $4.34/mt ($.11/bu). Regions in Illinois, Iowa and Minnesota that are more distant from the river experience corn price declines ranging from $.40/mt ($.01/bu) to $2/mt ($.05/bu). In those states adjacent to the upper Mississippi and Illinois Rivers (Illinois, Iowa, Minnesota) soybean prices decline up to $5.28/mt ($.14/bu.) but typically decline from $.54/mt ($.015/bu) to $4.76/mt ($.13/bu.). In scenario 2, annual corn and soybean producer revenues decline an estimated $312 million with closure of the upper Mississippi and Illinois Rivers with revenue reductions increasing to $367 million with a 5% increase in export rail rates, and to $482 million and $549 million with a 10% and 15% increase in export rail rates.

Minnesota grain prices are less affected by river closure than regions in Iowa and Illinois. This appears to be a result of Minnesota's more direct link to the Pacific Northwest port and the Asian market. Asian grain prices increase with closure of the upper Mississippi and Illinois Rivers since the transportation rates linking the Corn Belt, a major international corn supplier, to foreign markets increase. The higher prices in the Asian market affect higher prices at Pacific Northwest ports, which favorably affects grain prices in western Minnesota, a location that ships important rail-transported quantities directly to this port area.

Flow patterns in scenario 2 generally reflect patterns exhibited in scenario 1, however grain flows increase on those routes and corridors that are most critical and this often expands geographic market areas. As an example, those regions near the closed portion of the upper Mississippi River increase shipments to elevators in the river segment below St. Louis, thus expanding this segments geographic market area to include a region in southeast Minnesota. Similarly, expansion of Ohio River capacity increased grain flows from Illinois and Indiana origins to this river, while expansion of rail handling capacity on the Corn Belt to Gulf port corridor increased Iowa and Illinois rail shipments to the Gulf. Expansion of river elevator capacity below St. Louis, and increasing capacity on the Ohio River and the rail corridor linking the Corn Belt to Gulf ports increased Gulf port region corn and soybean exports about 5.5 mmt as compared to scenario 1, which subsequently produced a decline in shipments to Pacific Northwest ports.

In scenario 3, capacities on selected routes and corridors are increased above those in either scenario 1 or 2 (Table 6). Grain-handling capacity in that portion of the Mississippi River below St. Louis is increased from 9.5 mmt to 12.0 mmt, and rail capacity linking the Corn Belt to Gulf ports increases from 12.5 to 14.0 mmt. Grain handling capacity of Ohio River infrastructure increases from 12.5 mmt to 13.4 mmt while capacities on remaining routes are as in scenario 2.

Corn and soybean exports decline an estimated .8 mmt in scenario 3 as compared to the base model representing the 2003-2004 crop year (Table 6). Constraints are reached on Great Lake exports (4.8 mmt), corridor linking Corn Belt to Gulf ports (13.4 mmt), and the Mississippi River segment below St. Louis (12 mmt).

In the Iowa, Illinois and Minnesota regions that are adjacent to the river, the decline in corn prices range up to \$4.64/mt (\$.12/bu) but are generally from \$1.03/mt (\$.03) to \$4.57/mt (\$.11/bu). In other regions in these states, price declines range from \$.27/mt (\$.006/bu) to \$1.26 (\$.03/bu). Soybean prices decline an estimated \$5.08/mt (\$.14/bu) in a northwest Illinois region in scenario 3, but most price declines in Illinois, Iowa and Minnesota range from \$.36/mt (\$.01/bu) to \$4.44/mt (\$.12/bu). In scenario 3, annual corn and soybean revenues decline an estimated \$233 million and with 5%, 10% and 15% increases in export rail rates, producer revenue losses increase to \$300, \$364, and \$458 million, respectively (Table 6).

Table 6. Scenario 3: Estimated Effect of Closing Upper Mississippi and Illinois Rivers on Port Area Grain Flows (Corn, Soybean) and Grain Producer Revenues With Export Railroad Rate Increases (5%, 10%, 15%)

Port Area	Scenario 3 (1000 mt)	Scenario 3-5% (1000 mt)	Scenario 3-10% (1000 mt)	Scenario 3-15% (1000 mt)
Lower Mississippi	44,544	45,824	46,924	47,071
Other Gulf	1,620	1,458	1,449	1,263
Pacific Northwest	15,940	13,885	12,124	11,228
Atlantic	72	70	16	16
Great Lakes	4,800	4,800	4,800	4,800
Overland	5,076	5,101	5,130	5,165
Total	72,052	71,138	70,443	69,543
Producer Revenue Losses	$233 million	$300 million	$364 million	$458 million

Corn prices in regions with direct access to foreign markets increase modestly in scenario 3 as a result of closing the Mississippi River above St. Louis. As an example, in west central Minnesota (Wilmar, Minnesota) corn prices increase about $.21/mt with river closure. This occurs because west central Minnesota ships large quantities of corn by rail to Pacific Northwest ports and when the rivers are closed, foreign grain prices tend to increase since the transportation costs linking the Corn Belt to foreign markets increase. As a result of increasing prices in Asia and it positive influence on Pacific Northwest port price, corn prices in Wilmar, Minnesota also increase. However, as export rail rates increase (5%, 10%, 15%) the positive influence of river closure on corn price is negated and prices in Wilmar, Minnesota decline about $1.60/mt ($.04/bu) rather than modestly increase.

As capacity constraints on various routings and corridors are expanded, the geographic market areas tend to increase. For example, when the estimated grain handling capacity of river elevators below St. Louis increases from 9.5 mmt in scenario 2 to 12 mmt in scenario 3, the market area shipping to this river segment expands to include additional Missouri, Iowa and Illinois corn and soybean shipments. Similarly, rail carried exports from Iowa and Illinois increase with expansion of capacity on the Corn Belt to Gulf port corridor and additional grain flows to the Ohio River from Indiana and Illinois as this rivers grain carrying capacity is increased. As a result of these increased capacities, lower Mississippi River exports increase from 36.7 mmt (Scenario 1) to 42.2 mmt in scenario 2, to 44.5 mmt in scenario 3.

Value of Alternate Grain Routings and Corridors

If a catastrophic event were to occur that disabled Lock and Dam 27 at St. Louis and this subsequently prevented grain barge transportation on the upper Mississippi and Illinois Rivers, alternate corridors and routings become of increased interest. Importantly, the spatial models developed for these analyses offer perspective on the value of alternate grain corridors and routings through calculation of shadow prices. In scenario 1, shadow prices indicate the capacity constraint on river elevators' barge-loading capacity in that segment of the Mississippi River immediately below St. Louis is most critical. The estimated parameter shows a unit increase in loading capacity (1 metric ton (mt) of additional capacity) on this segment of the Mississippi River would increase producer and consumers welfare by $11.10/mt. The constraint on the corridor linking the Corn Belt to Gulf ports ranked second in terms of welfare improvement ($9.81), while the Great Lakes ranked third ($8.61), followed by the Ohio River constraint ($7.38) and the Pacific Northwest corridor constraint ($5.19). As expected, the relative importance of various corridor constraints and routings was changed with the 5%, 10% and 15% increase in export rail rates. Those routes that are highly dependent on export rail shipments had their importance diminished, while routes less dependent on export rail shipments increased in importance. For example, with the 15% increase in export rail rates, the shadow price associated with the river elevator constraint on the upper Mississippi segment below St. Louis increased from $11.10 to $12.51 while the shadow price associated with Pacific Northwest corridor, a rail-transport corridor,declined from $5.19 to $0.64.

Although the calculated shadow price for each corridor and routing decrease as capacity constraints increase in scenarios 2 and 3, the implications offered by the results in scenario 1 tend to hold. In particular, the handling capacity of river grain elevators in that segment of the Mississippi River immediately below St. Louis is most critical. Expanding quantities of Illinois, Iowa and Minnesota grain originally routed to the upper Mississippi and Illinois Rivers is directed to this segment as its capacity is expanded suggesting the efficiency of this route in the second-best solution. Also, important is the rail capacity on the corridor linking the Corn Belt to Gulf ports, the capacity of Ohio River infrastructure and the Great Lakes capacity. In part, Great Lake shadow prices remained comparatively large because capacity on this routing was unchanging in the three scenarios. Although, the Pacific Northwest corridor is an important link, its ability to successfully attract grain from interior Corn Belt locations was not suggested by the analyses. Further, the analyses suggested that rail-dependent corridors such as the Pacific Northwest and the Corn Belt to Gulf corridor to a lesser extent are vulnerable to railroad pricing decisions in a catastrophic event.

SUMMARY

The analyses shows the upper Mississippi and Illinois Rivers to be important transportation arteries whose annual value to the Midwest grain economy could range up to $799 million. Because of incomplete information on transportation corridor and routing constraints and the reaction of railroads to reduced barge competition it is difficult to offer a precise estimate. The scenario including greatest constraints (scenario 1) indicated annual producer revenue losses of $646 million and when railroads increased export rates 15 percent, losses grew to $799 million. Whereas, the scenario including least constraints (scenario 3) showed annual revenue losses of $233 million but when railroads increased export rates 15 percent, producer revenue losses grew to $458 million. Hence, the analysis suggests the annual value of the upper Mississippi and Illinois Rivers for grain transport ranges from $233 to $799 million but based on the most likely scenario (scenario 2) to range from $312 to $549 million.

The catastrophic analyses examined the value of alternative routings and corridors given a violent event at Lock and Dam 27 near St. Louis and the inability to transport grain to lower Mississippi River ports from upper Mississippi and Illinois River origins. Analyses focused on shadow prices obtained from spatial model solutions. Results show that segment of the Mississippi River immediately below St. Louis to be an attractive routing for Illinois, Iowa, and Minnesota grain given closure of the upper Mississippi and Illinois Rivers but current river elevator capacity would constrain movements to this segment. Also of great importance as alternate corridors and routings was rail transportation on the Corn Belt to Gulf corridor, and grain shipments via the Ohio River and Great Lakes.

In summary, the upper Mississippi and Illinois Rivers are important transport arteries for the Midwest grain economy and its value and the value of competing grain transport corridors and routings is greatly dependent on pricing decisions by competing railroads.

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