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The Upper Mississippi and Illinois Rivers as Grain Transport Arteries: A Spatial Equilibrium Analysis

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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 to evaluate alternate grain routing necessitated by a catastrophic event at Lock and Dam 27 near St. Louis. Several scenarios are constructed to consider grain load capacity constraints in combination with alternative rail rate increases. The analysis suggests the annual value of the upper Mississippi and Illinois Rivers for grain transport ranges from $229 million to $806 million.

INTRODUCTION

There has been speculation about the likely impact of infrastructure failure on critical segments of the upper Mississippi and Illinois Rivers that may stem from a catastrophic or violent event. Further, 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. To offer perspective on these issues, analyses are made 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 made 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 north of 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, Lock and Dam 27 is a critical link in the system and the focus of the catastrophic analyses.

Spatial equilibrium models (quadratic programming) have been 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. Results indicate the planned and proposed infrastructure improvements would increase South American producers' grain revenues about $1 billion/year and increase annual exports about 3.28 million metric tons. In addition, 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. More recently, Wilson, DeVuyst, Koo, Dahl, and Taylor (2005) have developed for the U.S. Army Corps of Engineers a cost-minimizing spatial model of the world grain economy for purposes of estimating long-run grain movements on the Mississippi River.

OBJECTIVES AND PROCEDURES

The objectives of this study are to estimate the effect of a catastrophic event at Lock and Dam 27 near St. Louis on grain producer revenues in the Midwest who ship via the upper Mississippi and Illinois Rivers and to evaluate alternative grain transport routings that may become necessitated by such an event. In order to accomplish these objectives, spatial equilibrium models representing the international corn and soybean economies in the 2003-2004 crop year were developed. The

spatial models were validated by contrasting actual outcomes in 2003-2004 with solutions obtained using the constructed base models that represent 2003-2004. After validation of the base models, they were modified to include closing of the Mississippi River to barge traffic at all sites north of St. Louis, thus prohibiting export grain traffic on the upper Mississippi, Missouri, and Illinois Rivers. Then, three different scenarios that involve various capacity constraints on grain flows via alternate transport routings and port areas are introduced into the models along with three rail pricing responses. Capacity constraints focused on Pacific Northwest and Gulf grain ports and railroads serving these transportation corridors, the Great Lake ports, the Ohio River, and associated grain handling capacity, and the capacity of Mississippi River elevators to accommodate increased grain flows on the river segment south of St. Louis. Further, because of anticipated increases in railroad grain transportation demands as a result of closing the upper Mississippi and Illinois Rivers, scenarios are evaluated that include increases in railroad rates. The impacts on grain producer prices and revenues are measured by contrasting model solutions before river closure with those that feature river closure under three different scenarios.

MODEL DESCRIPTION

The models developed to accomplish research objectives are spatial, inter-temporal equilibrium models that feature the global corn and soybean sectors. The quadratic programming models generate interregional trade flows and prices that result from maximizing producer plus consumer surplus minus grain handling, storage, and transportation costs (Samuelson 1952, Takayama and Judge 1971). The models include considerable detail on 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; 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. A mathematical presentation of nearly identical models is in Fuller, Fellin, and Eriksen (2000).

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

Regional excess supply equations were obtained with (1) an estimate of the excess supply elasticity, (2) quantity exported from the 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 the excess demand elasticity, quantity imported into region, and a representative price (Shei and Thompson 1977).

Domestic own-price demand (E_d) and supply (E_s) elasticities were from econometric models developed by the Food and Agricultural Policy Research Institute (FAPRI) at the University of Missouri–Columbia (2005). Information on domestic corn and soybean production by crop reporting district (Q_p) was obtained from the USDA (2005h). The USDA (2006b, 2006c) provides national estimates of domestic corn use and soybean crush but no information regarding consumption by crop reporting district or any geographic unit. Therefore, corn consumption and soybean crush (Q_c) by crop reporting district was estimated. With these estimates of regional production and consumption, regional quantities exported (Q_e) and imported (Q_i) were calculated. And, with these data it was

possible to determine regional excess supply (E_{es}) and demand (E_{ed}) elasticities. The regional elasticities, in combination with associated exports (Q_e) and imports (Q_i), and regional prices, facilitated the mathematical derivation of the regional excess supply and demand relationships. See Fuller, Fellin, and Eriksen (2000) for an expanded presentation on mathematical derivation of excess supply and demand equations.

The USDA (2005d, 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. Another 5.80 billion bushels was used as animal feed and residual. The remaining was used as seed (USDA 2006b) (1 metric ton = 39.4 bushels (bu.) of corn and 37.7 bu. of soybean). To estimate food, alcohol, and industrial corn use by crop reporting district, a variety of information sources were utilized. Some information on corn use by geographic region (state) was obtained from the U.S. Census Bureau's Manufacturing-Industry Series (2004). This series offered useful information on wet corn millers, distilleries, breakfast cereal manufacturing, dry corn mills, snack food manufacturers, and breweries. Additionally, consultants, college professors, industry associations, and organizations, federal agencies, company websites, and state departments of agriculture and economic development provided useful information. Wet corn mills use of corn was based on the 24-hour grind capacity of each U.S. plant as provided by two industry consultants and numerous other trade related associations. Particularly helpful were the Corn Refiners Association (2004), North American Millers' Association (2004), Iowa Department of Agriculture and Land Stewardship (2004), Iowa Corn Growers Association (2004), Illinois Corn Growers Association (2004), and the Minnesota Department of Agriculture (2004). Dry corn mills use of corn by plant was based on information provided by an industry spokesman (Will Duesing), and a book authored by White and Johnson (2003) and data on plant capacity at Sosland's website. The estimated use of corn for ethanol production was based on plant capacity information provided at a trade association website (Renewable Fuels Association 2005). Corn masa flour mills use of corn was based on interviews with manufacturers and company websites (Azteca Milling 2005, Minsa 2005). Consultants indicated corn processor demands were constant year-round, hence this 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 from the 2003-2004 crop year. Corn consumption was estimated for beef cows, cattle on feed, broilers, layers, turkeys, milk cows, hogs, pigs, and 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 *Poultry-Production and Value* offered important information on animal 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. Utilizing monthly crush statistics provided by NOPA and a listing of soybean crushers' capacities and location, soybean crush was estimated by crop reporting district. Plant crush capacity information was obtained from researchers at the Universities of Minnesota and Illinois who had been involved in estimating regional crush capacity (Goldsmith, Li, Fruin, and Hirsch 2004). Domestic corn and soybean price by crop reporting district was based on 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 and/or countries were estimated with own-price demand and supply elasticities that were obtained from models developed by FAPRI (2005). In addition, data from the Production, Supply and Distribution (PS&D) database, which is compiled by the USDA (2005f), was an important source of information for estimation of excess

demand and supply parameters. These data includes information on each country's production, beginning stocks, imports, exports, feed, total disappearance, and ending stocks by crop year.

The FOB ship grain prices were obtained for many countries with the remainder estimated from available price data and ship rates. Argentina's average monthly FOB corn and soybean port prices were obtained from Secretaria de Agricultura, Ganaderia, Pesca y Alimentos (2005a), 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. Monthly price paid on Canada's imports of U.S. corn and soybeans came from Agriculture and Agri-Food Canada (2005). Attaché Reports produced by the Foreign Agricultural Service (USDA 2005e) offered useful background on prices of major corn and soybean trading countries and the monthly prices paid by U.S. exporters for corn and soybeans at major U.S. ports came from the USDA (2006a). Other corn prices came from Agrimarket Info (2005), a website including information on Ukraine, Argentina, French, and U.S. corn and soybean prices.

The temporal dimension of U.S. international corn and soybean trade was obtained from the USDA (2005g). In addition, 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 de 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 U.S. to various provinces came from Agriculture and Agri-Food Canada (2005). China's monthly corn exports and annual exports to major importers came from private communications with the USDA (2005i). The Foreign Agricultural Service's Attaché Reports (2005e) offered monthly/ quarterly exports and imports of selected corn and soybean exporting and importing countries.

Transportation and Logistics Network

The transportation and logistics network in the U.S. portion of the spatial model links 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. Many of the excess supply regions are linked to the river elevator sites by quarterly rail rates if the rail configuration lends itself to these routings. Similarly, all excess supply regions are linked by truck, and/or rail, to one, and likely two or three, port areas. For example, excess supply regions in Minnesota are linked by rail rates to Pacific Northwest ports, Great Lake ports, Gulf ports, excess demand regions in Canada and Mexico, and barge rates to Gulf ports. Further, Minnesota 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. Similar transportation linkages are applicable for all domestic excess supply regions in the developed spatial models, hence an extensive transportation network.

Truck rates in the spatial model were estimated with a regression that was based on data included in the USDA's *Grain Transportation Report* (2005a). The truck rate function estimates per mile costs by quarter for the north and southern portions of the U.S. when transported in trucks with cargoes of about 950 bushels (80,000 lbs. gross vehicle weight). See authors for more information regarding the truck rate equation.

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. If linking rates could not be isolated in the waybill data set, regression analysis was used to estimate linking rates. Overland rail rates to Canada were estimated with the Carload Waybill data. Railroad rates that link

US-Mexico border-crossing sites (Brownsville, Laredo, Eagle Pass, El Paso, Nogales) to Mexico's five excess demand regions were estimated from rate data supplied by Transportacion Ferroviaria Mexicana and Ferrocarril Mexicana, both Mexican railroads. The Transportacion Ferroviaria Mexicana (2005) also provided rate data that linked the Mexican port at Veracruz to interior excess demand locations in Mexico.

Grain barge export rates that link the upper Mississippi, mid-Mississippi, lower Mississippi, Illinois, and Ohio Rivers to lower Mississippi River ports are collected by the USDA (2005c). This weekly barge rate data was averaged by quarter to obtain export barge rates and, for barge movements to the Tennessee River, the available rates were adjusted in accordance with mileage and tow size.

International grain ship rate data were obtained from the USDA (2004h), however, the data were originally compiled by Baltic Exchange. These data relate originating world region, originating port, destination world region, destination port, date of shipment, shipment terms, size of cargo, and rate. Miles of haul between origin port and destination port was measured for each observation and included in an estimated rate equation as was fuel price, originating world region, destination world region, shipment terms, quarter, and grain cargo size. See authors for more information regarding the ship rate equation.

Grain Handling and Storage Charges

In the U.S. portion of the spatial models, grain-handling charges at country elevators 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. Receiving and loading charges at country elevators were estimated at $0.10/bushel while the receiving charge (from truck or rail) at barge-loading sites was estimated at $0.0275/bushel. Barge loading charges at these sites were also estimated at $0.0275/bushel. At barge unloading sites, the estimated charge to unload was estimated at $0.03/bushel while charges of loading to truck and rail modes were $0.02 and $.03/bushel, respectively. Storage charges in the domestic and foreign portion of spatial models were estimated to be $0.001/bushel/day. Charges at U.S. ports averaged about $0.105/bushel while foreign port charges ranged from $0.10 to $0.21/bushel of grain handled. Data on U.S. charges were obtained via phone conversations with grain shippers and firm websites that offered information on tariffs (Blue Water Shipping Website 2005).

COMPARISON OF HISTORICAL AND MODEL-PROJECTED FLOWS

Because the analysis focuses on the upper Mississippi and Illinois River waterways, special attention is given to these arteries and their carriage of corn and soybeans 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 but archived and forwarded by Chrisman Dager of the Tennessee Valley Authority (2006).

Information in Table 1 contrasts historic and model-determined quantities of corn and soybeans entering the upper Mississippi and Illinois Rivers. Information on the Mississippi River is for segment 1 (mile 1 to 242) which extends from near Cairo, Illinois, to Winfield, Missouri; segment 2 which extends from near Winfield, Missouri, to McGregor, Iowa (mile 243 to 634); and segment 3 extending from McGregor, Iowa, to Minneapolis/St. Paul, Minnesota (mile 635 to 860). The model-projected quantities of corn entering segment 1 of the upper Mississippi is somewhat underestimated (15%) for 2003-2004 but all corn and soybean flows to remaining segments of the upper Mississippi and Illinois Rivers closely approximate historic quantities in 2003-2004 crop year. In general, model-projected quantities of soybeans transported via each river approximate actual quantities.

Table 1: Historic and Model-Projected Quantities of Corn and Soybeans Entering Upper Mississippi and Illinois Rivers, 2003-2004 Crop Year (thousands of metric tons)

River	Historic Corn Quantities (1,000mt)	Historic Soybean Quantities (1,000mt)	Model-Projected Corn Quantities (1,000mt)	Model-Projected Soybean Quantities (1,000mt)
Upper Mississippi				
[1]Segment 1	4,772	1,883	4,067	1,759
[2]Segment 2	6,769	1,876	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 Mississippi River and Ohio River (Cairo, Illinois) to near Winfield, Missouri, at 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 Minnespolis and St. Paul, Minnesota. (Mile 635-Mile 860)

Historic quantities provided by Tennessee Valley Authority, Christopher Dager.

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 to Mexico where model-projected quantities exceed actual quantities by 55% in 2003-2004. The reason for the divergence between actual and estimated shipments may have been due to undocumented changes in Mexican import restrictions or quality standards.

Table 2: Historic and Model-Projected Quantities of Corn and Soybeans Exiting Via U.S. Port Areas, 2003-2004 Crop Year (thousands of metric tons)

Port Areas	Historic Corn Quantities (1,000mt)	Historic Soybean Quantities (1,000mt)	Model-Projected Corn Quantities (1,000mt)	Model-Projected Soybean Quantities (1,000mt)
Lower Mississippi River	34,916		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	1,094	1,178
Overland	2,436	1,537	2,670	2,387
Total	48,787		48,790	24,086

Historic quantities taken from USDA, Agricultural Marketing Service, *Grains Inspected and/or Weighted for Export by Region and Port Area.*

ESTIMATED TRANSPORTATION AND GRAIN HANDLING CONSTRAINTS

Closure of the upper Mississippi and Illinois Rivers is estimated to divert about 27 million metric tons (mmt) of corn and soybeans (Segments 2 and 3, and Illinois River described in Table 1) from these transport arteries, which undoubtedly would have an important effect on regional grain flows and the routing of export-destined grain. Important quantities of corn and soybeans are currently rail-transported from Minnesota, Nebraska, North and South Dakota, and Iowa to Pacific Northwest ports for export. If the upper Mississippi and Illinois Rivers were closed, it seems likely that increased quantities of corn and soybeans would be transported to Pacific Northwest ports and possibly attempt to move in quantities that exceed that corridors' capacity. Currently, the Pacific Northwest ports rank second in grain export volume behind lower Mississippi River ports (USDA 2005b). In addition, the Great Lakes ports would most likely receive additional corn and soybeans given their proximity to excess supplies in Minnesota, Illinois, and Ohio, and possibly Atlantic Coast ports would receive increased quantities even though comparatively small quantities of corn and soybeans now exit via this port region. Further, if the upper Mississippi were closed near St. Louis, grain originally destined to the upper Mississippi and Illinois rivers would likely be routed to river elevators south of St. Louis for barge movement to the lower Mississippi River. However, it is possible river elevator capacity constraints would be reached. In addition, railroads would likely be used to transport increasing quantities to lower Mississippi River ports from Illinois, Iowa, and other states bordering the upper Mississippi and Illinois rivers. With closure of these rivers, however, constraints on rail capacity and rail-receiving capacity at Gulf ports may represent bottlenecks since barges have historically assembled from 90 to 95% of all grain exported from lower Mississippi River ports. Finally, additional quantities of corn and soybeans may be shipped to the Ohio River for barge transport to lower Mississippi River ports. This grain could be originated in increasing quantities from the river's current market area (Ohio, Indiana, Illinois, and Kentucky) or transported from other regions to the Ohio River.

In summary, it is thought that closure of the upper Mississippi and Illinois Rivers may increase grain flows to ports in the Pacific Northwest, Great Lakes, and Atlantic Coast, and increase rail-transport of grain to Gulf ports, as well as increase grain flows to Mississippi River elevators south of St. Louis and to the Ohio River. In view of the likely changes in regional flow patterns, efforts were made to gain insight on port and transportation capacities on various corridors. Because of the impossibility of obtaining precise estimates on corridor constraints, three scenarios are developed and evaluated with the spatial models. Because the analyses are viewed as short-run (one year in duration), it is assumed existing infrastructure capacity cannot be substantially altered and new infrastructure capacity cannot be constructed. Further, it was important that developed constraints for corn and soybeans take into consideration other grains that also require transportation and handling services. Table 3 summarizes the evaluated port and transportation constraints that were included into the analyses. Scenario 1 is the most highly constrained scenario while Scenario 3 is the least constrained.

Table 3: Estimated Capacity Constraints on Selected Corn and Soybean Transportation Corridors and Routings (thousands of metric tons)

	Mississippi River Segment [1] (1,000 mt)	Great Lakes[2] (1,000 mt)	Gulf Ports[3] (1,000 mt)	Ohio River[4] (1,000 mt)	Pacific Northwest[5] (1,000 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 near 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 corn and soybean unloads and port area exports.

A study by The Louis Berger Group, Inc. for the Institute of Water Resources, U.S. Army Corps of Engineers (USACE 2005), offered information on river grain elevators handling capacity in the St. Louis area and was the primary source of the constraint information identified in Table 3 as the Mississippi River Segment. Scenario 1 represented quantities normally handled by these facilities; the quantity associated with Scenario 2 was thought feasible by adding labor shifts and extending the receiving season, while Scenario 3 was believed possible if harvest season (weather-determined) and a variety of other forces were to converge in an optimal manner.

The constraint on Great Lakes shipments was based on the annual traffic reports of the St. Lawrence Seaway Development Corporation that identified quantities of grain originating at U.S. ports (SLS various issues). Because of disinvestment in grain handling and transportation infrastructure (laker vessels) on the Great Lakes, the capacity constraints of each scenario were identical and represented the maximum quantity handled by these facilities in recent years (Table 3).

Information for the Gulf port constraints came from a study by Wilson, Devuyst, Koo, Dahl, and Taylor (2005) which estimated the annual rail-receiving capacity at lower Mississippi River ports to be about 6.5 mmt, and USDA reports that relate grain exports by port region (USDA 2005b) and rail car grain deliveries by port area (USDA 2005a). Because of declining grain exports at Texas Gulf ports (Beaumont, Houston, Galveston, and Corpus Christi) in recent years and an underutilized grain port facility in Mobile, Alabama, it was assumed additional corn and soybeans would be routed to these facilities by railroads. Excess capacity at Texas Gulf facilities and the Mobile, Alabama, facility was approximated by contrasting export levels at Gulf port areas in peak years with recent export levels while historic rail car delivery data offered insight on rail-receiving capacities and abilities to accommodate rail traffic in various port areas. Scenario 1 featured a 6.5 mmt constraint on lower Mississippi River ports and a 2.5 mmt constraint at other Gulf ports. Scenario 2 constraint was estimated to be 12.5 mmt which included 6.5 mmt of capacity at lower Mississippi River ports and 6.0 mmt of capacity at other Gulf ports, while Scenario 3 featured 6.5 mmt of capacity at lower Mississippi River ports and 7.5 mmt of capacity at other Gulf ports (Table 3).

Constraints associated with transportation of soybeans and corn on the Ohio River were based on U.S. Army Corps of Engineers data (USACE 2006) on down bound grain movements transiting lock 53 (near juncture of Ohio and Mississippi Rivers) and information on Ohio River elevators' hourly barge-loading capacities (Sosland Publications 2006). Corn and soybean tonnage transiting lock 53 is primarily destined for export at lower Mississippi River elevators (Table 3). Scenario 1 reflected maximum grain tonnage transiting lock 53 in recent years which was obtained from U.S.

Army Corps of Engineers (USACE 2006). The collective barge-loading capacities of Ohio River elevators implied greater tonnage could move on the Ohio River than indicated by quantities of grain transiting lock 53, hence Scenarios 2 and 3 were developed. Scenarios 2 and 3 feature conservative estimates of additional grain that could move on the Ohio River based on hourly barge-loading capacity of Ohio River elevators (Table 3). It was assumed that closure of the upper Mississippi and Illinois rivers would facilitate adequate barge-transportation capacity to accommodate additional grain transportation demands on the Ohio River.

Constraints on Pacific Northwest corn and soybean exports were based on historical exports of corn, soybeans, and wheat from the Pacific Northwest port area (USDA 2005b), and railcar delivery data by port area (USDA 2005a). Historical data on corn and soybean exports by port area offered perspective on rail-delivered quantities of corn and soybeans at Pacific Northwest ports since the 2003 and 2004 Carload Waybill indicated most of these grains are transported to these ports by railroad from origins in north central states. Further, these data showed nearly all wheat exported from Pacific Northwest ports exit via Columbia River ports. These data and historical data on corn and soybean exports at Pacific Northwest ports provided perspective on total railcar receipts of grain at Pacific Northwest ports by grain type. The maximum historical quantities of corn and soybeans exported from Pacific Northwest ports gave rise to Scenario 1. The constraint associated with Scenarios 2 and 3 is identical and was based on an extrapolation of estimated railcar deliveries during the first nine months of 2006, a period of heighted export activity at Pacific Northwest ports (Table 3).

RESULTS

In all evaluated scenarios it is impossible for corn and soybeans to be transported by barge from upper Mississippi and Illinois River origins in Illinois, Minnesota, Iowa, Wisconsin, and portions of Missouri (approximated by segments 2 and 3) to lower Mississippi River ports or domestic river sites such as those on the Tennessee River. Further, export grain barge transportation on the Missouri River is also impossible since this river's confluence with the upper Mississippi is north of river closure at St. Louis. Closing the river will divert important quantities of grain, which would likely increase railroad grain demands and rates. For this reason, railroad rates were adjusted upward by 5%, 10%, and 15% on export grain corridors in the three scenarios. Knowledge of railroad grain demand elasticities on various corridors would have allowed adjustment of rail rates in a manner that may have approximated railroad behavior. However, this information was unavailable.[1]

Effect of River Closure on Grain Flows

In Scenario 1, corn and soybean exports from Gulf ports decline from 50.16 mmt to 38.31 mmt (Table 4) while exports via remaining port areas increase but overall this scenario yields a net decline in exports of 4.96 mmt (72.88 mmt – 67.92 mmt = 4.96 mmt). In the eastern Corn Belt, increasing quantities of corn and soybeans are transported to Atlantic Coast ports where exports increase from .07 to 1.65 mmt (Table 4), an export level approximated in recent years. Illinois and Minnesota truck and rail shipments of corn and soybeans to Great Lakes ports increase from 2.27 to 4.80 mmt, the projected capacity level of Great Lake ports, and Illinois increasingly ships corn and soybeans to Ohio River barge loading facilities in the lower reaches of that river. Rail shipments of Illinois corn to Gulf ports increase as do rail and truck shipments of corn and soybeans to the Mississippi River segment below St. Louis. River closure increases Illinois corn shipments to export markets but lowers its shipments to the important southeast U.S. market.[2] As a result, corn in northwest Illinois, eastern Iowa, and southeast Minnesota is increasingly routed to the southeast U.S. corn market to replace the diverted Illinois corn shipments. Further, Iowa increases its corn shipments to the south and southwest U.S. (primarily Texas) market, while Minnesota, South Dakota, Iowa, and Nebraska increase corn and soybean shipments to the Pacific Northwest ports where exports

increase from 15.31 mmt to 18.00 mmt (Table 4). In addition, corn surplus regions in southeast Missouri, western Kentucky and Louisiana increasingly route corn to lower Mississippi River ports by barge and railroad, and the analyses suggest a modest increase in soybean export flows on the Arkansas River.

Table 4: Estimated Effect of Closing Upper Mississippi and Illinois Rivers on Port Area Grain Flows (Corn, Soybean) for Base Model and Scenarios 1, 2 and 3, and Grain Producer Revenue Losses (thousands of metric tons)

Port Area	2003-2004 Base (1,000 mt)	Scenario 1 (1,000 mt)	Scenario 2 (1,000 mt)	Scenario 3 (1,000 mt)
Gulf	50,162	38,306	43,625	45,853
Pacific Northwest	15,312	18,000	17,326	15,890
Atlantic	73	1,652	127	72
Great Lakes	2,272	4,800	4,800	4,800
Overland	5,057	5,164	5,079	5,071
Total	72,876	67,922	70,957	71,686
Producer Revenue Losses		$ 645 million	$ 296 million	$ 229 million

Importantly, the spatial models offer perspective on those corridors and routes whose constraints are most critical. In Scenario 1, the capacity constraint on river elevators' barge-loading capacity in that segment of the Mississippi River immediately south of St Louis is most critical. A unit increase in loading capacity (1,000 mt of additional capacity) on this segment of the river would increase producer and consumer welfare $11.11/1,000 mt. Relieving the constraint on rail transportation handling capacity at Gulf ports ranked second in terms of welfare improvement ($9.91/1000 mt), while the Great Lakes ranked third ($8.61/1000 mt), followed by the Ohio River constraint ($7.39/1,000 mt), and the Pacific Northwest corridor constraint ($5.20/1,000 mt).

As a result of the expanded route and corridor capacities in scenario 2, corn and soybean exports increase at Gulf ports by 5.32 mmt (Table 4) (43.63 mmt – 38.31 mmt = 5.32 mmt) as compared to Scenario 1 but decline at other port areas by a collective 2.28 mmt except Great Lakes ports where exports are unchanged. Total exports in Scenario 2 (70.96 mmt) (Table 4) increase by 3.03 mmt as compared to Scenario 1, but are less than the 2003-2004 base by 1.92 mmt.

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 Mississippi River segment south of St. Louis, thus expanding this segments geographic market area to include a region in southeast Minnesota. Similarly, expansion of Ohio River elevator capacity increased grain flows from Illinois and Indiana origins to this river, while increasing the capacity constraint at Gulf ports increased Iowa and Illinois rail shipments to this port area. Expansion of river elevator capacity south of St. Louis, and increasing capacity on the Ohio River and at Gulf ports increased Gulf port region corn and soybean exports 5.32 mmt as compared to Scenario 1.Analysis of Scenario 2 shows the constraint on Great Lakes grain shipping capacity to be most critical, with an additional unit of Great Lakes shipping capacity increasing producer and consumer welfare by $8.09/1,000 mt. This outcome is expected since capacity on all analyzed routings and corridors in Scenario 2 was expanded except Great Lakes export capacity. Other routing and corridor constraints of importance are Mississippi River elevators south of St. Louis ($4.63/1,000 mt), Gulf port corridor ($3.96/1,000 mt), and the Ohio River routing ($1.45/1,000 mt).

Corn and soybean exports increase from 70.96 mmt in scenario 2 to 71.69 mmt in scenario 3 (Table 4), but as compared to the 2003-2004 base model, exports are reduced by 1.19 mmt. As capacity constraints on various routings and corridors are expanded in Scenario 3, the geographic

market areas tend to increase. For example, when the estimated grain handling capacity of Mississippi River elevators south of St. Louis increase 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 grain surplus regions. Similarly, rail-carried exports from Iowa and Illinois increase with expansion of capacity on the Gulf port corridor from 12.5 mmt (Scenario 2) to 14 mmt (Scenario 3), and additional grain flows to the Ohio River from Indiana and Illinois as this river's carrying capacity increases from 12.5 to 13.4 mmt. As a result of the increase in capacity, Gulf port exports increase from 38.31 mmt in Scenario 1 to 43.63 mmt in Scenario 2, and to 45.85 mmt in Scenario 3.

Because of the expansion in route and corridor capacities in Scenario 3, there is a decline in the value of an additional unit of capacity in the capacitated logistics system. For example, an additional unit of capacity on the Great Lakes routing had an estimated value of $7.01/1,000 mt in Scenario 3, which is reduced from $8.09/1,000 mt and $8.61/1,000 mt in Scenarios 2 and 1, respectively. If the grain-handling capacity of Mississippi River elevators in the segment south of St. Louis were increased one unit in Scenario 3, economic surplus would increase $2.77/1,000 mt, while an additional unit of Gulf port capacity had a value of $2.51/1,000 mt. The value of adding an additional unit of capacity to the Ohio River was near zero in Scenario 3.

Effect of River Closure on Producer Prices and Revenues

Annual corn and soybean revenues of producers decline an estimated $645 million with closure of the upper Mississippi at St, Louis when rail export rates are unchanged from the 2003-2004 base and grain flow capacity constraints of Scenario 1 are included (Table 5). Producer revenues decline a more modest $296 million and $229 million in Scenarios 2 and 3 (Table 5) when rail export rates remain at 2003-2004 levels. However, as export rail rates increase, projected prices and revenues of corn and soybean producers decline. For example, with constraints associated with Scenario 1, a 5% increase in export rail rates is expected to annually reduce producer revenues $673 million while a 10% and 15% increase in rail export rates reduce producer revenues an estimated $738 and $806 million, respectively (Table 5). As expected, elevated rail export rates generate more modest producer revenue losses in Scenarios 2 and 3 where route capacity has been expanded.

Table 5: Estimated Annual Effect of Closing Upper Mississippi and Illinois Rivers on Grain Producer Revenue Losses With 0%, 5%, 10% and 15% Export Railroad Rate Increases (millions of dollars)

Scenario	0% Rate increase ($ millions)	5% Rate increase ($ millions)	10% Rate increase ($ millions)	15% Rate increase ($ millions)
Scenario 1	$645	$673	$738	$806
Scenario 2	$296	$369	$509	$599
Scenario 3	$229	$310	$396	$484

In Scenario 1, corn prices in Illinois, Iowa, and Minnesota regions adjacent to the upper Mississippi and Illinois rivers decline up to $7.75/mt ($.20/bu.) while more distant locations in these states experience a reduction in corn price that ranges from about $1.25/mt ($.03/bu.) to $4.50/mt ($.115/bu.). And, as expected, in Scenarios 2 and 3, corn prices decline more modestly. For example, in Scenario 2, corn prices in Iowa, Illinois, and Minnesota regions that are adjacent to the Mississippi and Illinois Rivers decline up to $5.28/mt ($.13/bu), but generally the price reductions ranges from $2.67/mt ($.07/bu) to $4.34/mt ($.11/bu). In Scenario 1, soybean prices in those regions adjacent to the upper Mississippi and Illinois Rivers (Illinois, Iowa, and Minnesota) decline up to $6.95/mt ($.19/bu.) but under Scenario 2 soybean prices decline a more modest $5.28/mt ($.14/bu.).

Minnesota grain prices are less affected by river closure than regions in Iowa and Illinois. This is a result of Minnesota's more direct transportation links to the Pacific Northwest ports, and the importance of the Asian market. As suggested by economic logic, Asian grain prices increase with closure of the upper Mississippi and Illinois Rivers since the transportation rates linking the Corn Belt to world markets adjust upward. The higher prices in the Asian market result in higher prices at Pacific Northwest ports, which favorably affect grain prices in western Minnesota, a location that ships large quantities directly to this port area. As an example, in west central Minnesota (Wilmar, Minnesota) corn prices increase about $.21/mt with closure of the upper Mississippi and Illinois rivers. However, as export rail rates increase, the positive influence of river closure on price is negated and corn prices in Wilmar, Minnesota, decline about $1.60/mt ($.04/bu) when export rates are increased 5%.

SUMMARY

The analyses shows the upper Mississippi and Illinois Rivers to be important transportation arteries whose annual value to the Midwest grain economy may vary over a wide range. Because of incomplete information on various logistical 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 $645 million if no rail rate increases were to occur but annual revenue losses of $806 million if rail export rates increase 15%. In contrast, the scenario including least constraints (Scenario 3) showed annual revenue losses of $229 million without rail rate increases, but revenue losses of $484 million when railroads increase export rates 15 %. Therefore, these analyses suggest the annual value of the upper Mississippi and Illinois rivers for grain transport ranges from $229 million to $806 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. Results show the segment of the Mississippi River immediately south of St. Louis to be an attractive routing for Illinois, Iowa, and Minnesota grain given closure of the upper Mississippi and Illinois Rivers. Also of great importance as alternate corridors and routings was rail transportation from the Corn Belt to Gulf ports, 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 their value and the value of competing grain transport corridors and routings is largely dependent on pricing decisions by competing railroads.

Endnotes

1. Bessler and Fuller (2000) show railroad export grain rate markets are linked in varying degrees. Some are nearly independent but many interact with and to rates in other regions. Results suggest rate setting in a particular region is a function of action by the dominant railroad, an expected outcome in an oligopolistic market.

2. The southeastern U.S. region is an important producer of poultry and hogs and its grain demands exceed region grain production. North and South Carolina, Georgia, Alabama, Florida, and Mississippi produced 50% of U.S. broilers in 2005 and if Texas and Arkansas are included, the southeastern region produced 70% of all U.S. broilers. In addition, North Carolina is the second most important producer of slaughter hogs in the United States (USDA 2007).

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