ESTIMATED GRAIN BARGE DEMANDS FOR THE UPPER MISSISSIPPI AND ILLINOIS RIVERS: TENTATIVE FINDINGS

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Abstract: The lock and dam system on the upper Mississippi and Illinois Rivers is aged and in segments with comparatively high traffic levels, barge delay has become troublesome. The economic benefit from upgrading locks is conceptually based on the willingness of users to pay for the improvements. This study attempts to learn more about the demand for grain barge transportation on the upper Mississippi and Illinois Rivers. Tentative results suggest the grain barge demands on the upper Mississippi and Illinois Rivers are inelastic with foreign grain demand, and the winter season as important demand shifters. Variables measuring the effect of domestic grain consumption, competing transportation modes and ocean freight rates on quantity shipped by barge did not yield consistently robust results, hence additional research is required for a more complete understanding of these forces.

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EXECUTIVE SUMMARY

Low-cost grain barge transportation between grain surplus regions in north central United States and lower Mississippi River ports is facilitated by a system of locks and dams on the upper Mississippi and Illinois Rivers. Unfortunately, this lock and dam system is aged and in segments with comparatively high traffic, barge delay has become troublesome. Studies are underway to measure the benefits and costs of upgrading locks on selected segments of these transport arteries. Economic benefits from inland waterway improvements are conceptually based on users willingness to pay for infrastructure improvements. Selected areas under a barge demand schedule offer a measure of gross benefits associated with waterway improvements. For this reason, knowledge of grain barge demands on the upper Mississippi and Illinois Rivers is important. This study found the following regarding grain barge demands on these two waterways:

- The demand for grain barge transportation on the upper Mississippi and Illinois Rivers is inelastic. Six grain barge demand equations were estimated for each River and in all cases the estimated demands were found to be inelastic. The estimated demand elasticities on the upper Mississippi River averaged about –0.50 while the demand elasticities averaged about –0.20 on the Illinois River.

- Foreign grain demand, as measured by quantities of grain exported at lower Mississippi River ports, has an important influence on grain barge demands. The export grain demand elasticity was found to be elastic (1.2 to 1.6) for the upper Mississippi River and inelastic (0.7 to 0.9) for the Illinois River.

- As expected, the winter season is an important shifter of grain barge demands on both Rivers while floods have an important influence on grain barge demands on the upper Mississippi.

- Variables designed to measure the effect of domestic grain consumption, competing transportation modes, and ocean freight rates on grain barge demands did not yield consistently robust results that were statistically significant. Hence, additional research is required to develop a complete understanding of these forces.

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Introduction

The United States is the world's leading producer and exporter of corn, soybeans, and wheat, while Mexico and selected Asian countries (Japan, Taiwan, and South Korea) are the principal foreign importers of U.S. grain. Most export-bound grain movements are carried by maritime transportation from ports located in the lower Mississippi River and the Pacific Northwest. The lower Mississippi River ports dominate U.S. exports handling about 75 percent of the U.S.'s annual corn and soybean outflow. The importance of the lower Mississippi River port area is largely the result of an efficient barge transportation system that links the north central United States, an intense grain production region, to lower Mississippi River ports. This low-cost barge transportation linkage is facilitated by a system of locks and dams on the upper Mississippi and Illinois Rivers that are required to maintain adequate water depth for efficient barge transportation. Unfortunately, the lock and dam system is aged and in segments with comparatively high traffic levels, barge delay has become troublesome (Yu and Fuller, 2002; Yu, Fuller and Bessler, 2003). Greatest concern centers on the lower reaches of the upper Mississippi (locks 20, 21, 22, 24, and 25) and Illinois Rivers (Peoria and LaGrange locks) where traffic levels and congestion are greatest. Studies are underway to measure the benefits and costs of upgrading locks on selected segments of these transportation arteries.

Economic benefits from improving inland waterway transportation infrastructure are conceptually based on a demand schedule that relates barge companies willingness to pay for improved navigability of the waterway. A portion of the area under the demand relationship would offer a measure of the gross benefits from the infrastructure improvement. The net benefits from the navigation project could be viewed as the difference between the aggregate willingness to pay as measured by the area under the demand function and the sum of all appropriate costs. For this reason, knowledge of the demand characteristics for barge transportation on the upper Mississippi and Illinois Rivers is important. This study reports on the estimated demands for grain barge transportation on the upper Mississippi and Illinois Rivers. Grain represents about half of the commerce on these waterways. Hopefully, the information will be useful to grain producers, the barge industry, applied researchers, and policy makers.

Theoretical Foundation

In order to demonstrate the theoretical derivation of the demand for barge transportation, a two-region spatial equilibrium model is presented in Figure 1. Panel A depicts the supply (S_x) and demand (D_x) of grain (e.g., corn) in the north central United States while Panel C represents the rest-of-the-world's (ROW) excess demand for grain localized at lower Mississippi River ports. Panel B, the trade panel, includes the excess grain supply of the north central region ($ES_x = S_x - D_x$) and the excess demand of the foreign regions that purchase grain at lower Mississippi River ports ($ED_m = D_m - S_m$). The intersection of excess supply (ES_x) and excess demand (ED_m) relates the equilibrium price and quantity of grain traded between the north central U.S. and lower Mississippi River ports if no transportation costs were required to link the two regions. However, transportation costs are important in the transportation of grain and in Panel D the derived demand for grain transportation and the supply of grain transportation service are represented. The derived transportation demand is equal to the vertical distance between the

excess supply (ES_x) and excess demand (ED_m) in Panel B. Also shown in Panel D is the supply of transportation service linking the north central U.S. to lower Mississippi River ports. Since barges transport the majority of grain from the north central region to lower Mississippi River ports (+90 percent), it is reasonable to assume the supply is representative of the grain barge fleet operating on the upper Mississippi and Illinois Rivers. The intersection of the derived transport demand and supply determines the transportation rate linking the north central U.S to lower Mississippi River ports and the corresponding grain prices in the hinterland (P_x) and port area (P_m) (Panel B), where grain prices in the two regions (P_x and P_m) differ by the barge transport rate that link the two regions. Any force shifting the regional supply (S_x) and demand (D_x) of grain in the north central U.S. will shift the excess supply of grain (ES_x) and the derived transportation demand. Similarly, shifts in rest-of-the-world (ROW) excess demand and supply will also alter the derived demand for transportation. Therefore, the need to consider these forces when estimating the demand for grain barge transportation.

The partial equilibrium representation in Figure 1 is helpful in conceptualizing forces that may influence the demand for grain barge transportation; however, it fails to consider other important factors such as railroads and the competing transportation service they offer to barge transportation and alternative market outlets for grains in the north central region. Grain producers in Iowa or Minnesota may find Pacific Northwest ports (PNW) an alternative to lower Mississippi River ports. Therefore, grain demand at Pacific Northwest (PNW) ports and linking transportation rates between the upper Mississippi hinterland and the PNW may impact grain barge demand on the upper Mississippi and Illinois Rivers. In addition, the spread between ocean freight rates from the Pacific Northwest and lower Mississippi River ports to Asia may impact grain barge demand on these waterways.

Model Specifications

Based on the theory discussion above, we attempt to suggest important forces affecting grain barge demands on the upper Mississippi and Illinois Rivers. The dependent variable or the variable to be explained by the estimated grain barge demand equation is the quantity of the grain transportation service purchased by river grain shippers per unit of time. Most obviously, barge rates should be included as an explanatory variable. According to the law of demand, an inverse relationship should exist between barge demand and rate, that is, an increase in the grain barge rate will abate grain barge demand, *ceteris paribus*. The domestic supply and demand of grain in the north central region is presumably influential in determining grain barge usage. Regional grain supply is expected to affect the derived barge transport demand in a positive manner since an increase in local grain supply will shift the excess supply curve and the grain barge demand curve rightward. In contrast, an increase in regional grain demands will have a negative impact on grain barge transport demand due to the leftward shift in the excess grain supply and derived transport demand. Clearly, foreign grain demand would appear to have an important impact on the demand for grain barge transportation since 95+ percent of grain barge movements on the upper Mississippi and Illinois Rivers are to lower Mississippi River ports. An increase in foreign grain demand will shift the grain barge demand to the right, hence a positive relationship between foreign grain demand and the derived transportation demand. On the contrary, grain barge demand on the upper Mississippi and Illinois Rivers may decline when grain exports at other ports such as PNW or Great Lakes increase relative to the lower Mississippi River ports.

Other transportation modes may also impact grain barge traffic on the upper Mississippi and Illinois Rivers. For instance, a north-south railroad (e.g., Illinois Central Gulf which is now the Canadian National) linking the north central region to lower Mississippi River ports may offer strong competition to the grain barge fleet operating on the upper Mississippi and Illinois Rivers. Similarly, selected railroads (Burlington Northern and Union Pacific) operating in Minnesota and Iowa may compete with the barge industry through their links to Pacific Northwest ports. Potentially, a(n) reduction (increase) in linking rail rates will increase (decrease) rail grain shipments to the Pacific Northwest, therefore, reducing (increasing) the amount of grain shipped by barge on the inland waterways. Railroads and trucks may also complement barge transportation since they are typically used to transport grain to the Rivers. If the rate associated with complementary rail or truck grain carriage increases, it is likely that the quantity of grain shipped to the River will diminish. Accordingly, the demand for grain barge traffic would decrease or shift to the left. Conceptually, maritime transportation rates may also influence grain barge demand on the upper Mississippi and Illinois Rivers. A relatively high ocean freight rate linking lower Mississippi River ports to world importing regions may adversely affect grain barge demand on the upper Mississippi and Illinois Rivers, whereas comparatively low ship rates may increase grain barge demand.

Obviously, floods and droughts impact the navigability of the inland waterway. When a flood or drought occurs, barge demand may be weakened. Similarly, grain barge demand may be influenced by seasonal factors. During the grain harvest season, the demand for grain barge service may increase. In the winter season, the upper Mississippi River is typically not navigable so the grain barge demand will be virtually nonexistent. In contrast, the Illinois River is generally navigable during the winter and may experience an increase in grain barge traffic because of the closure of the upper Mississippi River.

It is thought that the specified grain barge demand model can be appropriately represented with a single equation, that is, an endogeneity problem is unlikely to exist. Regardless, tests for endogeneity will be carried out to determine the appropriateness of a single equation specification.

Data

This section offers a brief discussion of selected variables used to measure grain barge demands on the upper Mississippi and Illinois Rivers. Data to estimate these relationships is monthly and extends from 1992 through 1999. Table 1 relates the definition of variables included in the study. The descriptive statistics for continuous variables are presented in Table 2. The upper portion of both tables includes variables used in the estimation of the upper Mississippi River's grain barge demand while the middle portion includes variables used in the estimation of the Illinois River's model. The variables listed in the lower portion of the table are included in both Rivers' grain barge demand equations. Following is a discussion of variables included in the upper Mississippi and Illinois River's grain barge demand equations.

Upper Mississippi River

Variables to estimate the upper Mississippi River's grain barge demand equations included the following: (1) quantity of grain shipped by barge per month (BQUM), (2) grain barge tariff rate (BRNI), (3) export grain demand at various ports (GEXPQ, PEXPQ), (4) domestic grain demands (HCPR, TCDOM), (5) regional grain supply (GSTOCKUM), (6) rates of competing

and complementary transportation modes (OCEANS, RRMR, RRPNW), and (7) dummy variables (WINTER, FLOOD). BQUM represents the quantity of grain shipped per month from the upper Mississippi River to the lower Mississippi River port area. It is grain that originated on that segment of the Mississippi River extending from Minneapolis to Lock 24. These data were generated by the Tennessee Valley Authority (TVA) and provided by the Agricultural Marketing Service (AMS), U.S. Department of Agriculture (USDA)[1] Corn and soybeans are the primary grains shipped by barge on the upper Mississippi River. Figure 2 shows monthly grain shipments on the upper Mississippi River over the study period: peak flows typically occur during the spring and fall seasons. The north Iowa grain barge rate (BRNI) was adopted as a proxy for barge rates linking the upper Mississippi River to lower Mississippi River ports. It is a spot grain barge rate collected by AMS, USDA by surveying barge industry personnel.[2] The BRNI rate is not available in the winter since the River is usually frozen. The upper Mississippi River grain barge rate shows some seasonality with the peak rate often occurring in the harvest season (Figure 3). The average north Iowa grain barge rate is $10.40 per ton, and grain shipments on the upper Mississippi average 1.7 million tons per month (Table 2).

Grain exports at lower Mississippi River ports (GEXPQ) served as a proxy for foreign grain demand: the AMS, USDA made these data available.[2] Lower Mississippi River grain exports show no trend during the study period, however, there is seasonality in exports with peak outflow in the harvest season (Figure 4). The average quantity of grain exported per month at lower Mississippi River ports is 4.6 million tons (Table 2). Corn is the primary grain produced in the Corn Belt and it is exported in greatest quantity to lower Mississippi River and Pacific Northwest ports. Corn and soybean exports serve as a proxy for export demand at Pacific Northwest ports (PEXPQ).[2] Over the study period about 0.87 million tons of corn and soybeans were exported per month via Pacific Northwest (PNW) ports (Table 2).

Grain stocks in Minnesota and Iowa (GSTOCKUM) represent regional grain supplies. These data were obtained from the Economic Research Service (ERS), USDA.[3] Grain stocks are recorded quarterly, hence the need to interpolate the quarterly statistics for purposes of generating monthly values. The mean grain stock levels in Minnesota and Iowa were about 52.5 million tons per month (Table 2). Domestic demand for corn and soybeans was represented in the estimated grain barge equation by the U.S. hog-corn price ratio (HCPR) and total domestic corn consumption (TCDOM). The hog-corn price ratio is defined as the number of bushels of corn that are equal in value to 100 pounds of live market hogs: this ratio is a measure of hog production profitability. Domestic corn consumption (TCDOM) represents all corn consumed in the United States.[3]

Transportation rates of complementary and competing transportation modes are also included in the grain barge demands. The spread or difference in the U.S. Gulf-to-Japan and the PNW-to-Japan ocean grain freight rates (OCEANS) is included and is calculated by subtracting the PNW rate-to-Japan from the U.S. Gulf-to-Japan rate.[2] In addition, railroad rates from Minnesota origins to upper Mississippi River elevators (RRMR) and from west Minnesota to the PNW (RRPNW) are included. Data on grain ship rates came from the AMS, USDA while the annual Carload Waybill Sample was the source of railroad rates.[4] Rail service from Minnesota origins to the upper Mississippi River elevators is viewed as complementary to barge transportation (RRMR) while railroad rates from west Minnesota to the PNW (RRPNW) offer competition to grain barge transportation.

Illinois River

Variables in the Illinois River grain barge demand equation include the following: (1) quantity of grain shipped by barge per month (BQIL), (2) grain barge tariff rate (BRSP), (3) export grain demand at various ports (GEXPQ, LEXPQ), (4) domestic grain supply (GSTOCKIL), (5) domestic grain demands (HCPR, TCDOM, FSI, CNILP), and (6) rates of other transportation modes (OCEAN, RRGF). BQIL is the monthly quantity of grain shipped by barge on the Illinois River: these data were prepared by TVA and provided by the AMS, USDA.[1] During the study period, no trend was evidenced regarding Illinois River grain flow, however, seasonality was observed with peak shipments occurring during the fall and winter seasons. An average of 1.3 million tons of grain were transported per month by barge on the Illinois River during the study period. The south of Peoria grain barge rate (BRSP) is used as a proxy of grain barge rates on the Illinois River. The grain barge rate data were collected and made available by AMS, USDA.[2] The south of Peoria barge rate did not show a trend during the study period; however, seasonality in rate was displayed (Figure 6). Plots of the south of Peoria barge rate (BRSP) and the north Iowa barge rate (BRNI) show they moved in a parallel manner during the study period (Figures 3 and 6), however, the average north Iowa barge rate was about one-third greater than the south of Peoria rate (Table 2).

Grain exports at lower Mississippi River ports (GEXPQ) served as a proxy for export demand. An additional proxy of foreign demand was grain exports from Great Lakes ports (LEXPQ), which was provided by the AMS, USDA.[2] Because Illinois borders on a portion of the Great Lakes (Chicago) it was viewed as a possible export location for Illinois corn and soybeans. The average monthly quantity of grain exported at Great Lakes ports was about 290 thousand tons, which is about 6 percent of the exported quantity at Gulf ports (Table 2).

Grain stocks in Illinois (GSTOCKIL) represent the regional supply of grain in that state. It is recorded quarterly by the ERS, USDA and was converted to a monthly series for purposes of carrying out this study.[3] The average stock of grain in Illinois during the study period was about 25 million tons (Table 2). Proxies for domestic and local grain demand for the Illinois River grain barge demand model included the hog-corn price ratio (HCPR), total domestic corn consumption (TCDOM), corn usage for food, seed, and industry (FSI), and an elevator corn price in central Illinois (CNILP). The hog-corn price ratio (HCPR) measures the profitability of hog production while total domestic consumption (TCDOM) is a measure of total corn consumption. Corn used for food, seed, and industrial uses (FSI) was included because of the concentration of grain processing activities in Illinois. Ethanol production has become an increasingly important outlet for corn production during the 1990s because of environmental issues. On average, about 3.9 million tons of corn are used nationally per month for food, seed, and industrial (FSI) purposes which is almost three times the quantity of grain shipped on the Illinois River per month (Table 2). Data on grain consumption was made available by the ERS, USDA.[3]

Transportation rate information on other modes was also included in the Illinois River grain barge demand models. These included the ocean grain freight rate from the U.S. Gulf to Japan (OCEAN) and railroad rates associated with corn and soybean traffic from Illinois origins to lower Mississippi River ports (RRGF). Ocean grain freight data came from AMS, USDA while railroad rate data was from the annual Carload Waybill Sample.[2,4]

Methodology and Results

To determine the proper specification for the grain barge demand model (single equation versus multi-equation system), a Hausman test was carried out (Hausman, 1978). For the upper Mississippi River, the north Iowa barge rate was examined as a potential endogenous variable. The instrument variables included in this test were a one-period lag of the barge rate, number of empty barges operating on the upper Mississippi, barge delay in the lower segment of the River, and other exogenous variables in the barge demand equation. In addition, the rail rate from west Minnesota to Pacific Northwest ports was evaluated as a potential endogenous variable. The instrument variables in this test featured a one-period lag in the rail rate linking west Minnesota to the Pacific Northwest ports, quantity of grain shipped by rail to Pacific Northwest ports, corn export price at Pacific Northwest ports and other variables in the grain barge demand equation. A similar test was conducted for the Illinois River barge demand equation. For both barge demand equations, the Hausman test indicated there was no endogeneity problem when using a single equation specification, hence the appropriateness of estimating the relationship with ordinary least square (OLS).

Several econometrics tests were conducted to examine the quality of the ordinary least square (OLS) results (Quantitative Micro Software, 1994). The residual tests, including correlograms of squared residuals, normality test, serial correlation Lagrange Multiplier (LM) test, autoregressive conditional heteroskedasticity (ARCH) LM test, and White's heteroskedasticity test were carried out for the upper Mississippi and Illinois River's grain barge demand models. In addition, specification and stability tests consisting of the Chow breakpoint test, Ramsey RESET test, and CUSUM of squares test were applied. In general, the estimated grain barge demand equations for the Illinois River performed satisfactorily in all tests while the estimated upper Mississippi River equations did not perform as well in the residual test, the specification test, and the stability test. The closing of the River during December, January, and February and the absence of rate and shipment data complicate the estimation of the upper Mississippi River grain barge demand equations during this time period. Thus, the likely reason for the inferior results associated with the upper Mississippi River grain barge demand equations.

The adjusted R-square for the estimated upper Mississippi River grain barge demand models was about 0.67 indicating that 67 percent of the variation in grain barge demand was explained by the estimated models. The Durbin-Watson statistic indicated AR(1) serial correlation could not be determined with certainty for the upper Mississippi River grain barge demands. The explanatory power of the Illinois River grain barge models ranged from 0.545 to 0.639. Based on the Durbin-Watson statistic, AR(1) serial correlation was not evidenced in any estimated Illinois River grain barge demand equations (Baltagi, 2002).

The linear-log functional form was employed in the estimation of all grain barge demand equations. Grain barge demand results are summarized in Table 3 for the upper Mississippi River and Table 4 for the Illinois River.

Upper Mississippi River

Table 3 includes regression results associated with the grain barge demand equations for the upper Mississippi River. The estimated coefficient associated with each variable, except the dummy variable, is an elasticity. The elasticity measures the percent change in the dependent variable (quantity of grain transported by barge on the upper Mississippi River) associated with a

one percent change in a right-hand side or explanatory variable. There are six models presented with different combinations of explanatory variables included in each equation. It was necessary to alter selected explanatory variables in the various equations because of inadequate degrees of freedom if all variables were included in a single equation. Selected variables were included in all equations. They include the following: North Iowa grain barge rate (BRNI), export grain demand at lower Mississippi River ports (GEXPQ), railroad rate from Minnesota to Pacific Northwest ports (RRPNW), ocean freight rate spread between the U.S. Gulf-to-Japan and the Pacific Northwest-to-Japan rates (OCEANS), grain stocks in Iowa and Minnesota (GSTOCKUM) and a dummy variable for the winter season (WINTER).

The expected negative relationship between barge rate (BRNI) and the quantity of grain moved by barge on the upper Mississippi River is observed in all six equations. The magnitude of elasticity associated with the grain barge rate ranges from –0.326 to –0.635, indicating grain barge demand is inelastic with respect to grain barge rate. BRNI is significant at the 20 percent level in models 1M and 2M, while statistically insignificant in the remaining four models. The quantity of grain exported at lower Mississippi River ports (GEXPQ) affects grain barge demand in a positive manner and is significant at the five percent level in all models. The estimated elasticities range from 1.231 to 1.665; implying that a one percent increase in the export grain demand will generate more than a one percent increase in the grain barge demand. The positive relationship between railroad rates from Minnesota to Pacific Northwest ports (RRPNW) and grain barge demand is as expected: it suggests that a higher railroad rate to the PNW will divert grain export flows from the PNW to the upper Mississippi River barge fleet. The influence of railroad rate on grain barge demand is not statistically significant at usual levels.

An increase in the spread between the U.S. Gulf-to-Japan and the Pacific Northwest-to-Japan ocean freight rates (OCEANS) will conceptually make grain exports from lower Mississippi River ports less competitive than exports from the PNW. Consequently, the demand for grain barge transportation on the upper Mississippi River could be reduced with a widening in this ship rate spread, hence a negative sign is expected on the OCEANS variable. A negative sign is found on the OCEANS variable in two models (Models 1M and 2M) and positive signs in four models; however, in no case was the OCEANS variable significant at usual levels. The lack of statistical significance implies that the influence of the ocean freight rate spread may be modest. As expected, there is a positive relationship between grain stocks in Minnesota and Iowa (GSTOCKUM) and grain barge demand on the upper Mississippi River and, in two models, the GSTOCKUM variable was statistically significant at the 20 percent level. The associated elasticity for the GSTOCKUM variable was about 0.20 indicating that a one percent increase in grain stocks would increase upper Mississippi River grain barge demand about 0.20 percent. In general, the upper Mississippi River is not navigable in December, January, and February. As a result, the grain barge demand would be expected to dramatically decline in this period. Results confirm this expectation. The WINTER variable is highly significant (five percent level) and the magnitude of its coefficient is large with a value near –3 in all estimated equations.

The hog-corn price ratio (HCPR) is a measure of domestic grain demand and is included in models 1M, 2M, 5M, and 6M. Theoretically, the higher the ratio, the greater the profitability of expanding hog production and the lower grain barge demand. The expected negative sign is not found in any estimated equation; however, in no case was the HCPR variable significant at usual levels. The other variable representing domestic corn demand, total domestic corn consumption (TCDOM), is included in models 3M and 4M. Interestingly, the TCDOM variable is negative,

as expected, and is statistically significant at the 20 percent level. The elasticity associated with the TCDOM variable is about –0.700 indicating that a one percent increase in total domestic corn consumption will reduce upper Mississippi River grain barge demand by 0.7 percent. The variable which measures railroad rate from Minnesota origins to upper Mississippi River elevators (RRMR) is a complement to grain barge transportation on the upper Mississippi River. The RRMR variable has the expected negative sign and is significant at the five percent level (Models 1M and 2M). The estimated elasticity on the RRMR variable is about –1.0 indicating that a one percent increase in RRMR will lower quantity of grain transported on the upper Mississippi by one percent.

The Pacific Northwest corn exports (PEXPQ) were included as a measure of Pacific Northwest corn demand. Presumably higher corn exports from the Pacific Northwest will, *ceteris paribus*, unfavorably affect grain barge demand on the upper Mississippi River. As expected, the coefficient on the PEXPQ variable was negative in all models (Models 3M, 4M, 5M, and 6M), but in no model was the variable statistically significant at usual levels. The flood variable (FLOOD), a dummy variable, is used to evaluate the impact of upper Mississippi River floods on grain barge demand. As expected, the FLOOD variable has a negative sign in all equations (2M, 4M, and 6M), and is significant at the 20 percent level in all estimated models.

Illinois River

Estimated grain barge demand equations for the Illinois River are presented in Table 4. Five key variables were included in all six models. They include: south of Peoria grain barge rate (BRSP), export grain demand at lower Mississippi River ports (GEXPQ), railroad rate from Illinois origins to lower Mississippi River ports (RRGF), corn price in central Illinois (CNILP), and a dummy variable representing the winter period (WINTER).

Results show, as expected, a negative relationship between barge rate (BRSP) and grain barge demand in all estimated models. Further, the own-price elasticity is consistently near –0.22 (between –0.211 and –0.268) and significant in all equations at the five percent level. Therefore, a one percent increase in the south of Peoria grain barge rate will diminish grain barge demand about 0.22 percent, hence an inelastic relationship between barge rate and quantity of grain transported on the Illinois River. As expected, increasing grain export levels at lower Mississippi River ports (GEXPQ) were found to increase grain barge demand. The GEXPQ variable was found to be statistically significant in all equations and to have associated elasticities ranging from 0.745 to 0.914.

Railroad transportation of grain from Illinois origins to lower Mississippi River ports substitutes for barge transportation on the Illinois River. Therefore, a positive relationship is expected between railroad rates from Illinois origins to lower Mississippi River ports (RRGF) and grain barge demands on the Illinois River. A positive cross-price elasticity is shown in all six models; however, the variable is statistically significant in only one equation (Model 5I). It shows that a one percent increase in the railroad rate (RRGF) will increase grain barge demand on the Illinois River about 0.3 percent. The central Illinois corn price (CNILP) was included as a proxy for local grain demand. An increase in CNILP is expected to attract grain to the local grain market and correspondingly reduce grain barge demand on the Illinois River. The expected negative sign is observed in all models with elasticities ranging from –0.272 to–0.535: the CNILP variable was found significant at either the five or ten percent level in all estimated equations.

Because the Illinois River is navigable year-round, its grain traffic in the winter season is expected to be comparatively high due to the closure of the upper Mississippi River in that time period. Results show the winter season variable (WINTER), a dummy variable, to be positive and significant at the five percent level. Thus, statistical results confirm that the Illinois River grain barge demand shifts to the right or increases during the winter period.

The estimated coefficients on the hog-corn price ratio variables (HCPR) have the anticipated negative signs in all models (Models 1I, 3I, and 6I) and are statistically significant in two models (Model 3I and 6I). The estimated elasticities range from –0.277 to -0.351 and suggest that increased profitability of hog production reduces grain barge demand on the Illinois River. Total domestic corn consumption (TCDOM) is included in two models and has the anticipated negative impact on grain barge demand; however, the TCDOM variable is not significant in either model. The FSI variable measures corn consumed for food, seed, and industrial purposes. The coefficient on the FSI variable has an unanticipated positive sign, however, it is not statistically significant at usual levels.

The influence of the U.S. Gulf-to-Japan ocean freight rate (OCEAN) is evaluated in four models. Unexpectedly, the sign on the OCEAN variable is positive and statistically significant in all estimated equations. The reasons for the positive signs are unknown. Grain stocks in Illinois (GSTOCKIL) are included as a proxy for grain supply in two equations (Models 5I and 6I). The grain stocks variable has the anticipated positive sign, however, the variable is not significant in either equation. Conceptually, grain exports through Great Lake ports (LEXPQ) may, *ceteris paribus*, reduce grain barge demand on the Illinois River. The estimated coefficient on the LEXPQ variable has the anticipated negative sign, but is not significant at usual levels.

Conclusions

The upper Mississippi and Illinois Rivers are critical arteries in the U.S. inland waterway system and of great importance to U.S. agriculture. Unfortunately, the lock and dam system on both Rivers is aged and, in segments with comparatively high traffic levels, barge delay has become troublesome. Studies are underway to measure the benefits and costs of upgrading and extending locks in selected sections of these Rivers. Economic benefits from inland waterway transportation improvements should be based on demand schedules representing the willingness to pay for improved navigability of the waterway. The areas under the demand function measure the gross benefits from waterway improvement. The purpose of this study is to estimate grain barge demands for the upper Mississippi and Illinois Rivers and develop an improved understanding of forces impacting these demands.

In general, the analyses have noteworthy findings. Barge rates have a negative affect on grain barge demand or the quantity of grain transported by barge from upper Mississippi and Illinois River origins to lower Mississippi River ports. On average, a one percent increase in the Illinois River barge rate will reduce quantity of grain transported by barge to lower Mississippi ports by about 0.20 percent (own-price elasticity of –0.20). And, on the upper Mississippi River a one percent increase in the grain barge rate will lower quantity transported by barge an estimated 0.3 to 0.6 percent (own-price elasticity of –0.30 to –0.60). These findings suggest the grain barge demands on the upper Mississippi and Illinois Rivers are inelastic.[5]

Foreign grain demand, as measured by quantities of grain exported at lower Mississippi River ports, has an important influence on grain barge demands. This is reasonable since grain barge

demand is a derived demand that depends on excess demands associated with the international grain market. The export demand elasticity was found to be elastic (1.2 to 1.6) for upper Mississippi River grain barge demand models and inelastic (0.7 to 0.9) for Illinois River grain barge demand models.

Competing and complementary transportation modes may have an affect on upper Mississippi and Illinois River grain barge demand; however, the results of this study are not robust or consistently significant regarding these forces. For example, lowering railroad rates linking Minnesota origins to Pacific Northwest ports was associated with reductions in grain transport on the upper Mississippi; however, the influence was not statistically significant. A similar, relationship was found between barge-transported quantities on the Illinois River and railroad rates linking Illinois origins to lower Mississippi River ports. This finding was statistically significant in only one estimated grain barge demand model. In contrast, the railroad rate linking Minnesota origins to upper Mississippi River elevators was found to be a statistically important shifter of upper Mississippi River grain barge demands, with increasing railroad rates associated with reduced grain barge movements on the upper Mississippi River. In general, ocean grain freight rates were not statistically important explainers of grain barge demands on the inland waterways. However, in several models the estimated coefficients were of the wrong sign and statistically significant. The reasons for this outcome are unknown.

Increases in total domestic corn consumption were negatively related to quantities of grain transported by barge on the upper Mississippi and Illinois Rivers, however, this study did not find the influence to be statistically significant in most estimated barge demand models. In general, domestic grain consumption levels were not found to be an important explainer of grain barge demands. However, inland corn price, a variable included into the analyses as a proxy for local grain demand in Illinois, was found to be significant and with the expected negative sign, i.e., higher inland corn prices in Illinois reduced the quantities of grain transported by barge on the Illinois River.

As expected, floods and the winter season have statistically important impacts on upper Mississippi and Illinois River grain barge demands. Floods on the upper Mississippi reduce grain barge demand, as does the winter season when the River is generally impassable. In contrast, grain barge demand increases on the Illinois River during the winter season. This is presumably a result of the upper Mississippi River being closed to navigation during this period and the transfer of grain demands to the Illinois River, a transport artery that is typically navigable year-round.

In summary, grain barge demands on the upper Mississippi and Illinois Rivers are influenced by barge rates, foreign grain demands localized to lower Mississippi River ports, the winter season, and floods. In general, remaining evaluated forces did not yield consistently robust findings that were statistically significant.

Footnotes

[1] Tennessee Valley Authority made information available on monthly quantities of corn and soybeans entering pools on the upper Mississippi and Illinois Rivers and months when floods occurred on the upper Mississippi.

[2] U.S. Department of Agriculture, Agricultural Marketing Service made information available on weekly grain barge rates on the upper Mississippi and Illinois Rivers, ocean grain freight rates, corn and soybean exports at lower Mississippi River, Pacific Northwest and Great Lakes ports, and regional grain prices.

[3] U.S. Department of Agriculture, Economic Research Service was the source of information on grain stocks and measures of domestic grain consumption. These data may be found at their website. (www.ers.usda.gov/Data/)

[4] Data on all railroad rates came from the Carload Waybill Sample.

[5]The barge demand elasticities presented in Tables 3 and 4 are viewed as short-run elasticities. By restructuring the models to feature lag(s) of the dependent variable, long-run grain barge demand elasticities were obtained for both Rivers (Davidson and MacKinnon, 1993). Short-run elasticities for the upper Mississippi ranged from about -0.50 to –0.75 while the calculated long-run elasticities ranged from about –0.70 to –1.03. For the Illinois River, the short-run elasticities ranged from -0.20 to –0.35 while the long-run elasticities were virtually identical.

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Table 1: Definition of Variables in Grain Barge Demand Equations for Upper Mississippi and Illinois Rivers.

Variables	Definitions
For Mississippi River	
$BQUM_i$	Quantity of grain entering segment of upper Mississippi River that extends through Iowa and Minnesota in month *i* (1,000 tons)
$BRNI_i$	North Iowa grain barge rate in month *i* ($/ton)
$PEXPQ_i$	Quantity of grain exported at Pacific Northwest ports in month *i* (1,000 tons)
$GSTOCKUM_i$	Quantity of grain stocks at Minnesota and Iowa in month *i* (1,000/tons)
$OCEANS_i$	Spread in ocean freight rates between Mississippi Gulf and Pacific Northwest to Japan in month *i* ($/ton)
$RRMR_i$	Rail rate for Minnesota-originated grain shipped to upper Mississippi River elevators in month *i* ($/ton)
$RRPNW_i$	Rail rate for grain to Pacific Northwest ports in month *i* ($/ton-mile)
FLOOD	Dummy variable for river closure caused by flood: flood = 1; no flood = 0.
For Illinois River	
$BQIL_i$	Quantity of grain entering Illinois River in month *i* (1,000 tons)
$BRSP_i$	South of Peoria grain barge rate in month *i* ($/ton)
$CNILP_i$	Central Illinois corn price in month *i* ($/ton)
FSI_i	Domestic corn consumption used for food, seed and industrial purposes in month *i* (1,000 tons)
$GSTOCKIL_i$	Quantity of grain stocks in Illinois in month *i* (1,000 tons)
$LEXPQ_i$	Quantity of grain inspected at Great Lakes in month *i* (1,000 tons)
$RRGF_i$	Rail rate for grain shipped from Illinois to Mississippi Gulf in month *i* ($/ton)
$OCEAN_i$	Ocean grain freight rate from Mississippi Gulf to Japan in month *i* ($/ton)
For Both Rivers	
$GEXPQ_i$	Quantity of grain exported at Mississippi Gulf ports in month *i* (1,000 ton)
$HCPR_i$	Number of bushels of corn equal in value to 100 pounds of all hogs, live weight, in month *i* (bushels)
$TCDOM_i$	Total domestic corn consumption in month *i* (1,000 tons)
WINTER	Dummy variable for winter quarter: December, January, February =

	1; others = 0.

Table 2: Statistical Summary of Variables included in Grain Barge Rate Equations.

Variables	Unit	Mean	Standard Deviation	Minimum	Maximum
For Mississippi River					
BQUM	1,000 tons	1,738.65	1,057.13	1.85	3,504.92
BRNI	$ / ton	10.40	3.33	5.51	19.26
PEXPQ	1,000 tons	871.18	500.92	33.89	2005.99
GSTOCKUM	1,000 tons	52,493.78	23,202.22	6,674.90	10,3231.90
OCEANS	$ / m. ton	9.56	3.11	0.91	15.95
RRMR	$ / ton-mile	0.038	0.008	0.026	0.077
RRPNW	$ / ton-mile	0.014	0.001	0.011	0.018
For Illinois River					
BQIL	1,000 tons	1,364.49	589.02	293.50	3,324.55
BRSP	$ / ton	7.85	2.77	3.94	14.90
CNILP	$ / ton	90.56	23.28	61.07	173.57
FSI	1,000 tons	3,902.50	298.91	3,380.74	4,443.05
GSTOCKIL	1,000 tons	25,223.92	12,870.73	2,737.90	53,651.90
LEXPQ	1,000 tons	290.28	307.62	0.00	1,131.09
OCEAN	$ / m. ton	22.87	5.36	12.51	35.47
RRGF	$ / ton	9.52	1.80	6.32	17.43
For Both Rivers					
GEXPQ	1,000 tons	4,615.70	1,158.33	2,287.21	7,310.14
HCPR	bu. of corn	17.40	3.10	7.50	24.30
TCDOM	1,000 tons	16,113.98	4,089.74	8,393.51	24,702.31

Table 3: Summary of Grain Barge Demand Equations for Upper Mississippi River.

Variables[1, 2]	Model 1M	Model 2M	Model 3M	Model 4M	Model 5M	Model 6M
$BRNI_t$	-0.635*** (0.415)[3]	-0.607*** (0.417)	-0.337 (0.399)	-0.326 (0.397)	-0.489 (0.391)	-0.463 (0.389)
$GEXPQ_t$	1.396* (0.409)	1.259* (0.406)	1.665* (0.470)	1.511* (0.470)	1.392* (0.451)	1.231* (0.440)
$RRPNW_t$	0.584 (0.956)	0.582 (0.954)	0.760 (0.964)	0.795 (0.962)	0.461 (0.953)	0.471 (0.947)
$OCEANS_t$	-0.162 (-0.134)	-0.156 (0.139)	0.069 (0.169)	0.080 (0.171)	0.062 (0.165)	0.057 (0.165)
$GSTOCKUM_t$	0.028 (0.149)	0.076 (0.154)	0.154 (0.147)	0.196*** (0.143)	0.154 (0.163)	0.206*** (0.161)
WINTER	-2.983* (0.325)	-3.002* (0.327)	-3.060* (0.374)	-3.087* (0.377)	-3.029* (0.370)	-3.051* (0.373)
$HCPR_t$	0.346 (0.449)	0.445 (0.474)	--	--	0.177 (0.455)	0.309 (0.487)
$TCDOM_t$	--[4]	--	-0.678* (0.229)	-0.678* (0.222)	--	--
$RRMR_t$	-1.047* (0.514)	-0.988* (0.533)	--	--	--	--
$PEXPQ_t$	--	--	-0.126 (0.114)	-0.122 (0.110)	-0.088 (0.113)	-0.085 (0.109)
FLOOD	--	-0.420** (0.255)	--	-0.456** (0.237)	--	-0.509* (0.245)
C[1]	-4.428 (4.857)	-3.944 (4.709)	3.345 (4.892)	4.290 (4.695)	-2.586 (5.135)	-2.161 (4.975)
Obs (N)	96	96	96	96	96	96
Adj. R^2	0.685	0.686	0.679	0.681	0.670	0.672
D-W statistic	1.627	1.651	1.626	1.632	1.661	1.679

[1] See Table 1 for definition of variables.
[2] All variables are in natural log form.
[3] Number in parenthesis is the standard error associated with the coefficient.
[4] "--" indicates not included in the model
*Significant at the 5% level, **significant at the 10% level, ***significant at the 20% level.

Table 4: Summary of Grain Barge Demand Equations for Illinois River.

Variables[1, 2]	Model 1I	Model 2I	Model 3I	Model 4I	Model 5I	Model 6I
$BRSP_t$	-0.213* (0.117)[3]	-0.220* (0.109)	-0.268* (0.107)	-0.229* (0.109)	-0.211** (0.126)[3]	-0.211** (0.124)
$GEXPQ_t$	0.871* (0.149)	0.815* (0.134)	0.745* (0.120)	0.783* (0.122)	0.914* (0.171)	0.749* (0.120)
$RRGF_t$	0.135 (0.193)	0.230 (0.179)	0.186 (0.167)	0.198 (0.184)	0.264** (0.158)	0.175 (0.167)
$CNILP_t$	-0.272** (0.148)	-0.423* (0.160)	-0.535* (0.161)	-0.386* (0.153)	-0.406* (0.135)	-0.462* (0.177)
WINTER	0.482* (0.146)	0.508* (0.067)	0.493* (0.066)	0.510* (0.067)	0.461* (0.075)	0.444* (0.083)
$HCPR_t$	-0.134 (0.175)	--	-0.351* (0.175)	--	--	-0.277*** (0.189)
$TCDOM_t$	--[4]	-0.086 (0.150)	--	--	-0.130 (0.135)	--
FSI_t	--	--	--	0.002 (0.441)	--	--
$OCEAN_t$	--	0.317* (0.129)	0.439* (0.141)	0.314* (0.133)	0.295* (0.104)	0.373* (0.154)
$GSTOCKIL_{t-1}$	--	--	--	--	0.042 (0.091)	0.039 (0.063)
$LEXPQ_t$	-0.010 (0.040)	--	--	--	--	--
C	1.453 (1.529)	1.817 (1.545)	2.884* (1.359)	1.168 (4.069)	0.904 (1.602)	2.052 (1.658)
Obs (N)	81	96	96	96	95	95
Adj. R^2	0.545	0.611	0.627	0.610	0.639	0.618
D-W statistic	2.020	2.020	2.137	2.038	2.085	2.214

[1] See Table 1 for definition of variables.
[2] All variables are in natural log form.
[3] Number in parenthesis is the standard error associated with the coefficient.
[4] "--" indicates not included in the model
*Significant at the 5% level, **significant at the 10% level, ***significant at the 20% level.

Figure 1: Two-region Spatial Equilibrium Model and Derived Transportation Market.

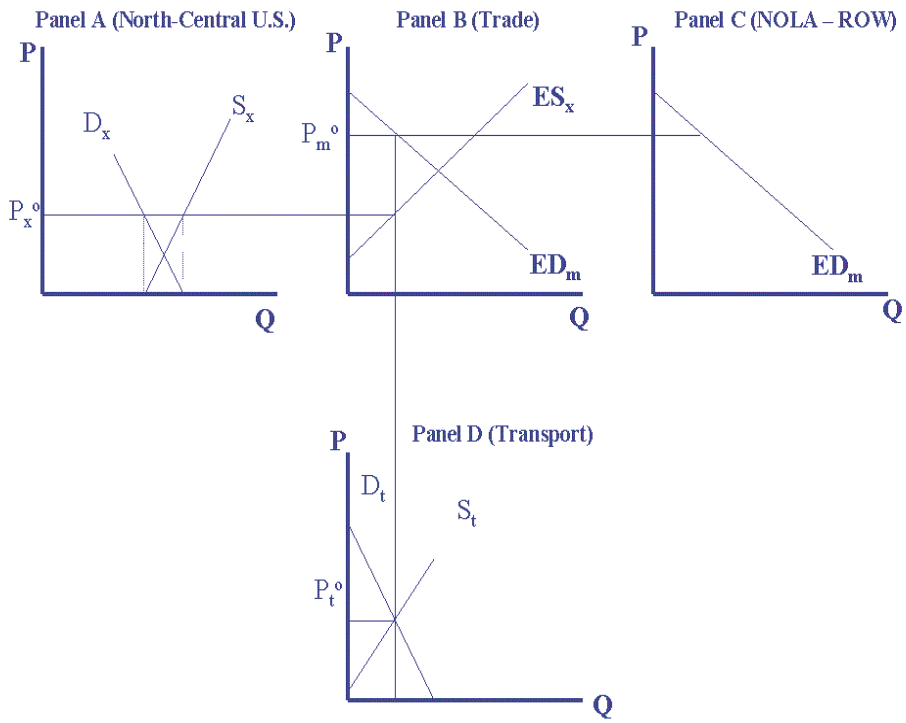

Figure 2: Quantity of Corn and Soybeans Moved by Barge on the Upper Mississippi River, 1000 tons.

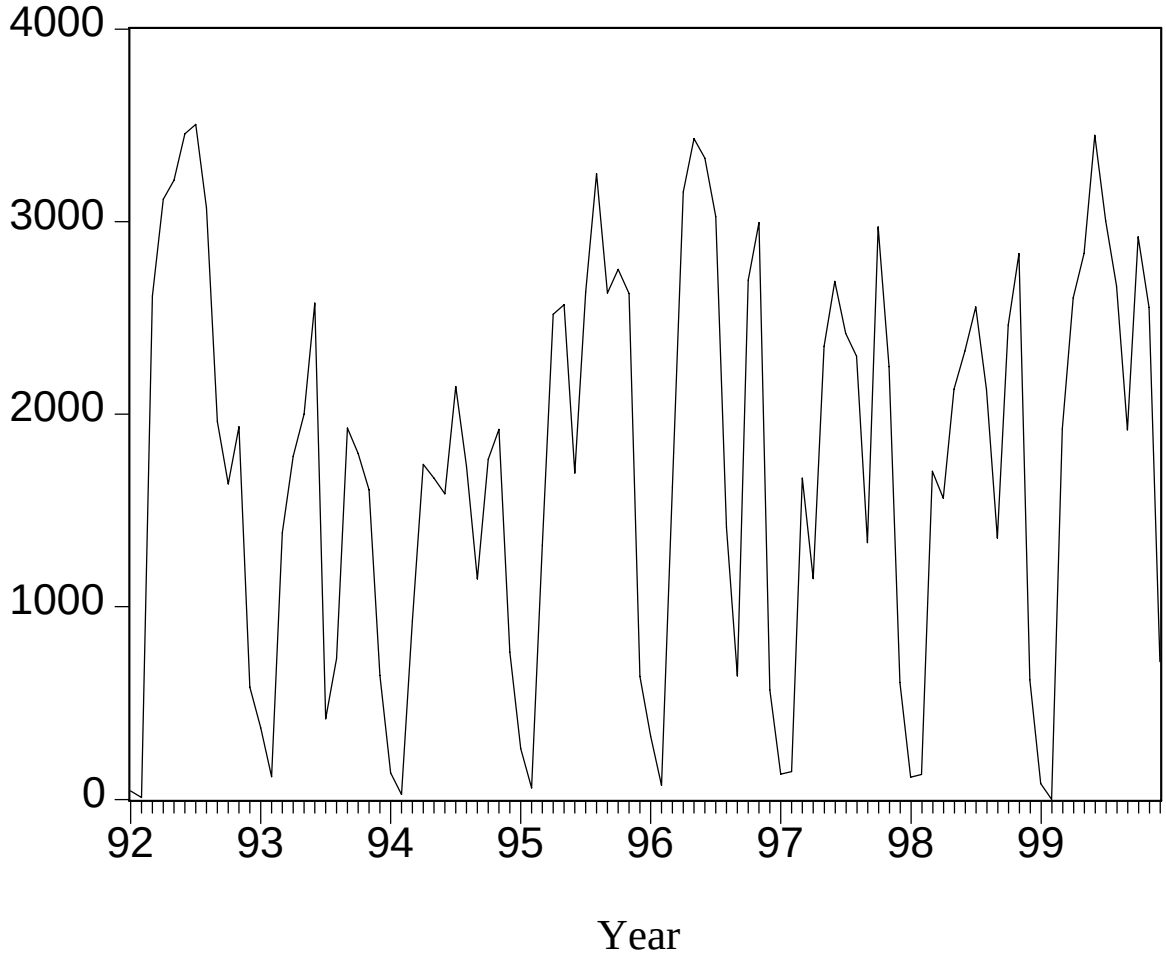

Figure 3: North Iowa Grain Barge Rate on the Upper Mississippi River, dollars/ton.

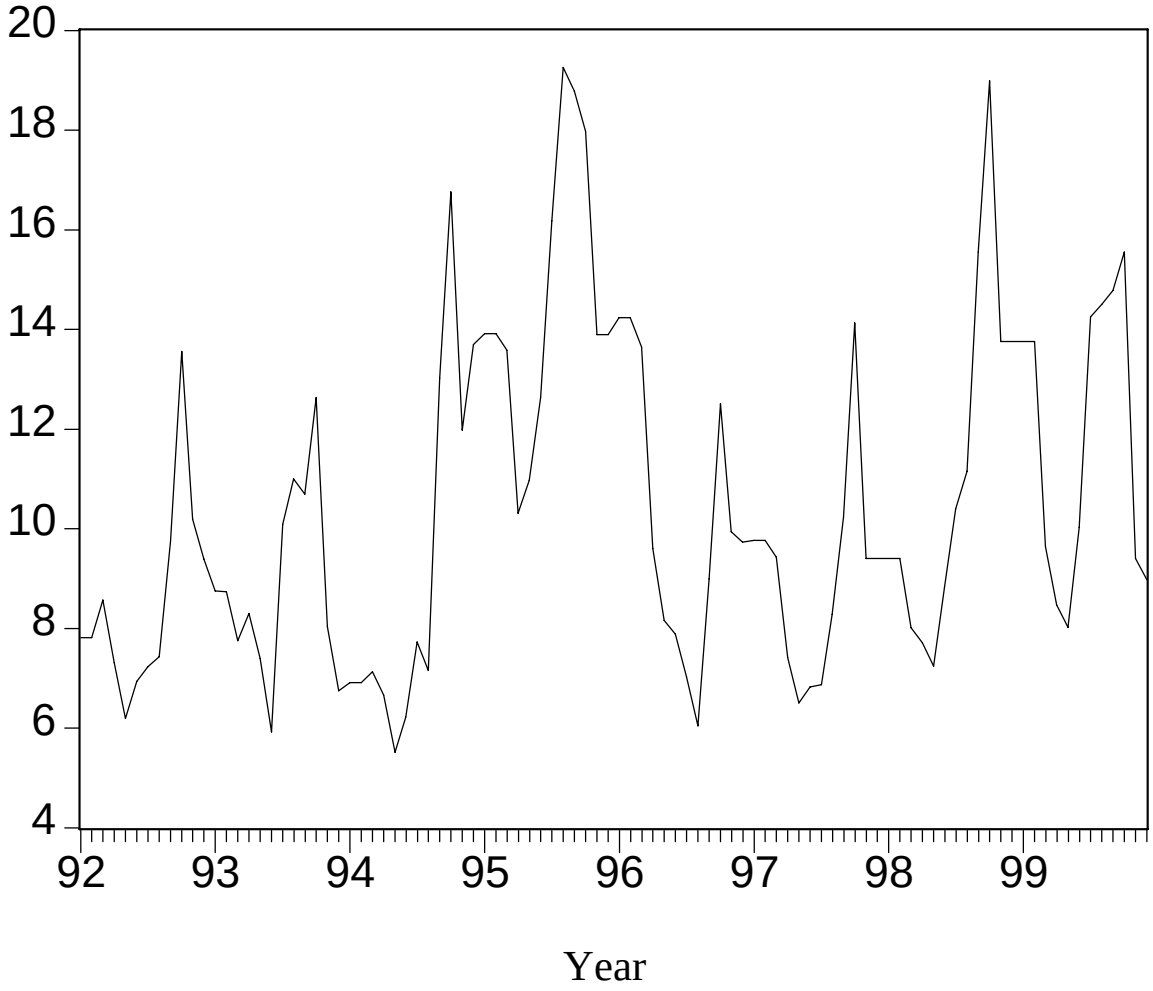

Figure 4: Corn and Soybeans Inspected for Export at the Lower Mississippi River Ports, 1000 tons.

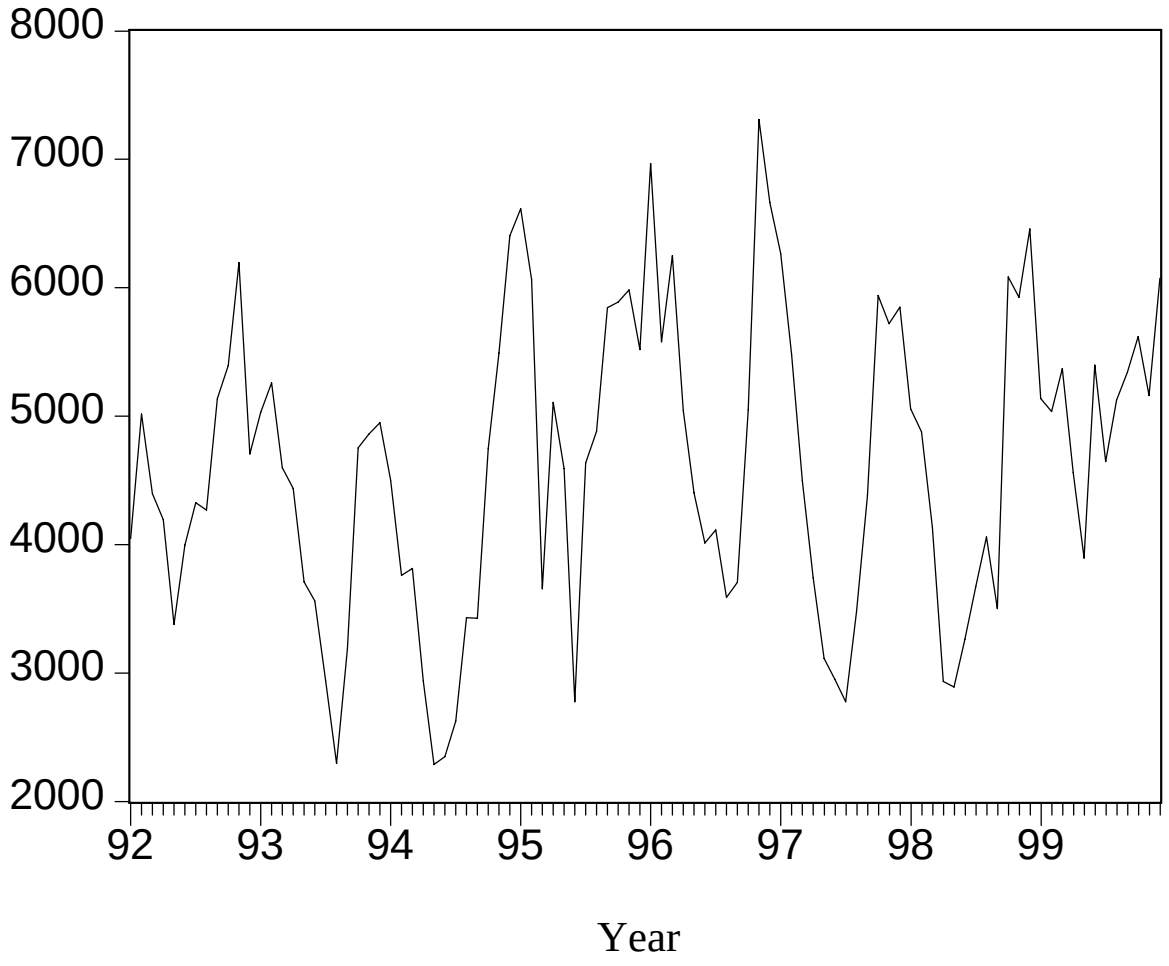

Figure 5: Quantity of Corn and Soybeans Moved by Barge on the Illinois River, 1000 tons.

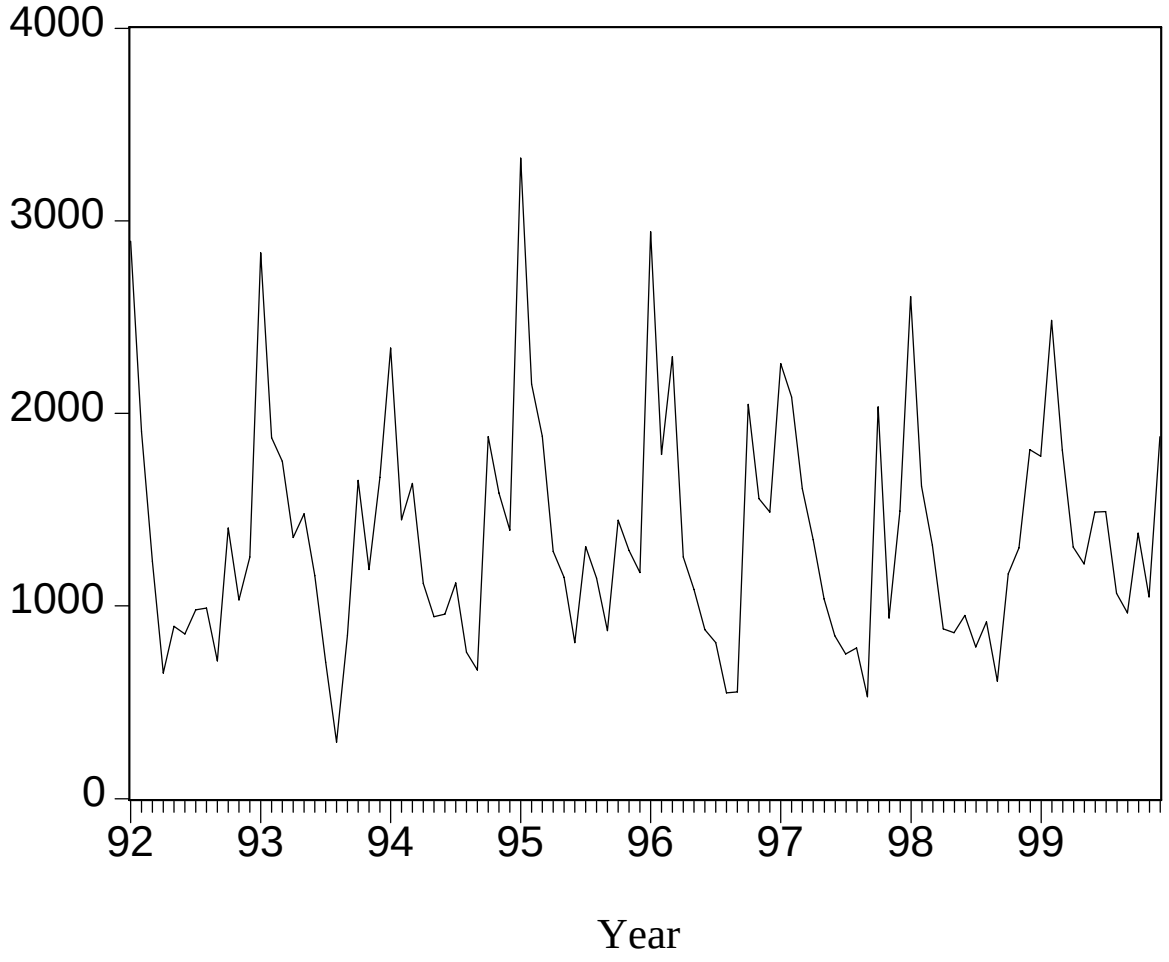
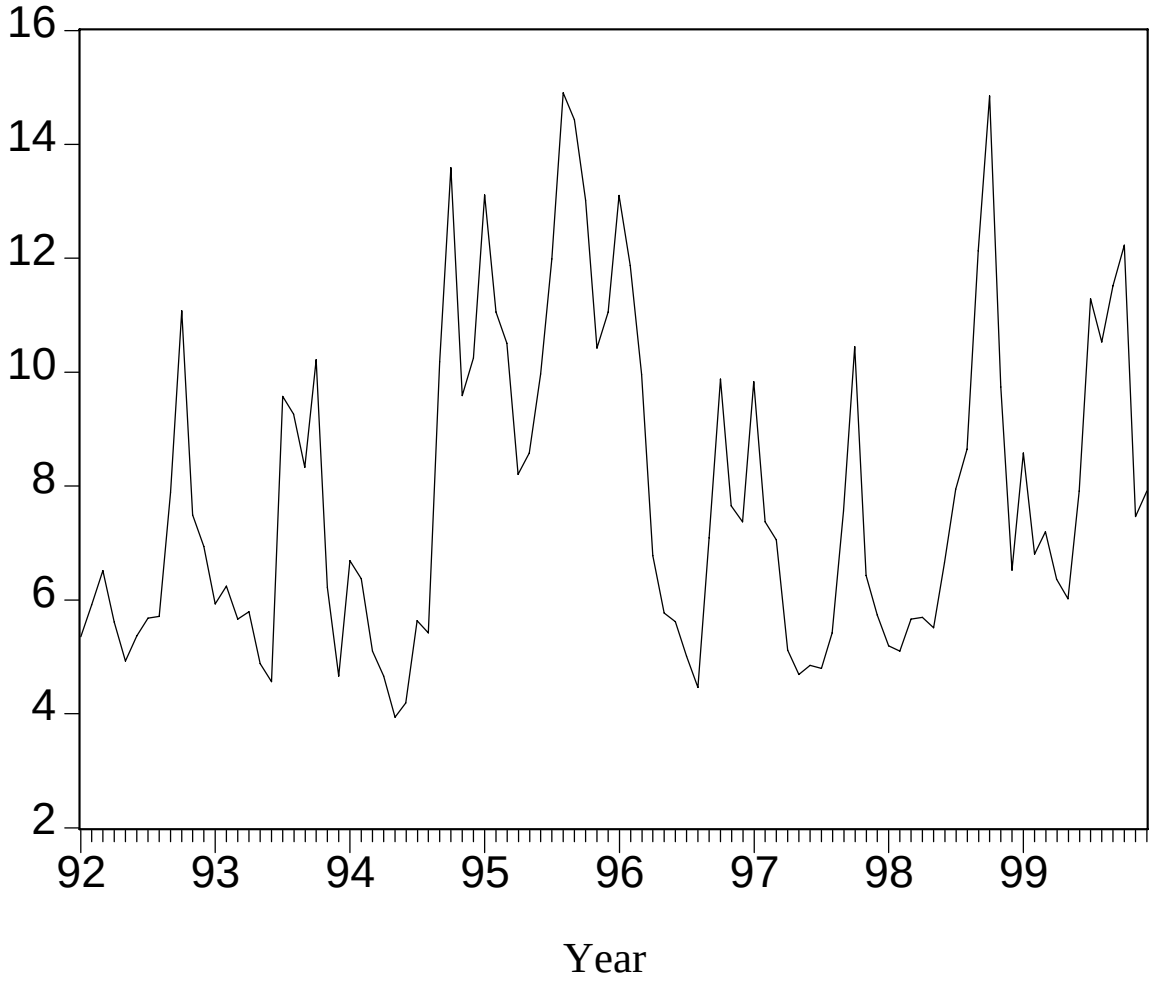
Figure 6: South of Peoria Grain Barge Rate on the Illinois River, dollars/ton.