Estimates of Grain Barge Demands for the Upper Mississippi and Illinois Rivers

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Abstract

The upper Mississippi and Illinois Rivers are important transportation resources for United States grain producers and exporters. Unfortunately, the lock and dam system on these Rivers is aged and barge delays have become troublesome in the lower portion of these Rivers. Studies are underway to measure the benefits and costs of upgrading locks on selected segments of these transportation arteries. Knowledge of demand characteristics for barge transportation on these Rivers is important since it is the key to measuring the economic benefits from infrastructure improvements. This paper reports on estimated demands for grain barge transportation on these two transport arteries. Results suggest the demand for grain barge transportation on the upper Mississippi and Illinois Rivers is inelastic. Foreign grain demand and winter season are shown to have an important influence on grain barge demands as do domestic grain consumption and supply.

Grain Barge Demands Estimates of the Upper Mississippi and Illinois Rivers

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.

Literature Review

Few studies have focused on estimation of grain barge demands on the upper Mississippi and Illinois Rivers. Exceptions include papers by Harnish and Dunn (1996) and Mijkovic et al. (2000). Harnish and Dunn (1996) estimated a reduced-form model to explore the determinants of grain barge rates on the Mississippi River in the short run. They selected eight segments of the River system and conducted an individual and pooled estimation. Their results suggested that grain exports, coal barge rates, input prices (fuel, labor), and distance influence grain barge rates. Since the independent variable was grain barge rate, their analysis generated the price flexibility instead of elasticity. Miljkovic et al. (2000) conducted a system estimation including both rail and barge transportation modes for export-bound grain movements. Supply and inverse demand equations associated with rail and barge markets that link Illinois to the Gulf of Mexico were evaluated using an econometric approach. Their findings suggest these two transportation modes were partial substitutes. In addition, the study found the export grain level did not have a statistically significant affect on the demand for either the barge or rail modes.

There are additional studies related to grain movements on inland waterways. Hauser, Beaulieu, and Baumel (1985) studied the impact of inland waterway user fees on grain flow patterns and the rail, barge and truck markets; and the implied grain barge demand elasticity. Babcock and German (1983) evaluated and forecasted the impact of the diesel fuel tax on the U.S. waterway traffic. Fellin and Fuller (1997) estimated the effect of the waterway user tax on U.S. agricultural and transportation markets. Oum (1979) formulated an intermodal network featuring rail, road and inland waterways in Canada for purposes of exploring intermodal competition. Beuthe et al. (2001) employed a detailed multimodal geographic information system (GIS) network model to assess direct and cross-elasticities for rail, road and waterway transportation in Belgium. In addition, several studies have focused on barge traffic forecasts for the U.S. inland waterway system (Wilson and Sander, 1982; Tang, 2001; Babcock and Lu, 2002). Jack Faucett Associates (1997, 2000) forecast future waterway traffic on the upper Mississippi and Illinois Rivers in order to estimate potential benefits from infrastructure improvements. Unfortunately, their study did not employ adequate methodology or appropriate assumptions, thus casting doubt on study findings. (Bitzan and Tolliver, 2000)

Previous studies failed to yield direct estimates of grain barge demands for the upper Mississippi and Illinois Rivers. Knowledge of grain barge demands on these transportation arteries is important to the barge industry, farmers and authorities that maintain and manage the lock and dam system on these Rivers. Further, it is critical because of the current controversies regarding the expansion of the lock system on these Rivers. The purpose of this paper is to estimate structural grain barge demands for the upper Mississippi and Illinois Rivers and to provide useful information to interest groups.

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 and 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.

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.

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 include 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 lower Mississippi ports (GEXPQ), (4) domestic grain demands (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.

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 total domestic corn consumption (TCDOM). 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] Railroad 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), (4) domestic grain supply (GSTOCKIL), (5) domestic grain demands (TCDOM, 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).

As in the upper Mississippi River model, grain exports at lower Mississippi River ports (GEXPQ) served as a proxy for export demand. 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/local grain demand for the Illinois River grain barge demand model included total domestic corn consumption (TCDOM) and an elevator corn price in central Illinois (CNILP). Since major grain-processing facilities are located in central Illinois, the elevator corn price, in addition to domestic corn consumption, is used to capture the domestic/local grain demand.

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

The grain barge demand model for both upper Mississippi and Illinois Rivers is estimated by ordinary least square (OLS).[5] 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 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 estimated grain barge demand equation 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. In addition to the explanatory variables discussed in the previous section, the lagged dependent variables ($BQUM_{t-1}$, $BQUM_{t-2}$) were included in the model to capture dynamics associated with grain barge travel. The optimal length of the lags was determined by the Schwarz criterion.

Both lagged dependent variables ($BQUM_{t-1}$, $BQUM_{t-2}$) have positive signs indicating a positive relationship between quantities transported by barge in previous months and the quantity transported this month. However, only the one-lag variable ($BQUM_{t-1}$) is statistically significant. The expected negative relationship between barge rate (BRNI) and the quantity of grain moved by barge on the upper Mississippi River is observed. The own-price elasticity associated with the grain barge rate is –0.582, indicating grain barge demand is inelastic. The own-price elasticity is significant at the 5 percent level. The quantity of grain exported at lower Mississippi River ports (GEXPQ) affects grain barge demand in a positive manner and it is significant. The estimated elasticity, 1.164, implies that a one percent increase in export grain demand will generate slightly more than a one percent increase in grain barge demand. The variable representing domestic corn demand (TCDOM), is negative, as expected, and is statistically significant at the 10 percent level. The elasticity associated with the TCDOM variable is –0.586 indicating that a one percent increase in total domestic corn consumption will reduce upper Mississippi River grain barge demand by about 0.6 percent. As expected, there is a positive relationship between grain stocks in Minnesota and Iowa (GSTOCKUM) and grain barge demand on the upper Mississippi River: the GSTOCKUM variable was statistically significant at the 10 percent level. The associated elasticity for the GSTOCKUM variable was 0.340 indicating a one percent increase in grain stocks would increase upper Mississippi River grain barge demand about one-third of a percent.

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. However, the influence of railroad rate on grain barge demand is not statistically significant at usual levels. 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 ten percent level. The estimated elasticity on the RRMR variable is about –0.683 indicating that a one percent increase in RRMR will lower quantity of grain transported on the upper Mississippi about two-thirds of a percent.

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; however, it was not significant at usual levels. The lack of statistical significance implies that the influence of the ocean freight rate spread may be modest. 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 flood variable (FLOOD), a dummy variable, is used to evaluate the impact of upper Mississippi River floods on grain barge demand. As expected, it has a negative sign and is significant at the 10 percent level.

Illinois River

Estimated grain barge demand equations for the Illinois River are presented in Table 4. As in the upper Mississippi model, the lagged dependent variable is included. For the Illinois River model, the Schwarz criterion shows the optimal length of lag is one.

Interestingly, a negative, statistically-significant (5 % level) relationship is observed between the current traffic level and traffic in the previous month. As expected, a negative relationship between barge rate (BRSP) and grain barge demand is observed. Further, the own-price elasticity is –0.127 and significant at the five percent level. Therefore, a one percent increase in the south of Peoria grain barge rate will diminish grain barge demand about 0.12 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 and to have an elasticity of 0.724.

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 on this variable: the CNILP variable was found significant at the ten percent level with an elasticity of –0.241. Total domestic corn consumption (TCDOM) has the anticipated negative impact on grain barge demand and it is significant at the 10 percent level. The elasticity associated with the TCDOM variable is about –0.2 percent. Grain stocks in Illinois (GSTOCKIL) are included as a proxy for grain supply in the estimated equation. The grain stocks variable has the anticipated positive sign and the variable is highly significant with an elasticity of 0.288.

Railroad transportation of grain from Illinois origins to lower Mississippi River ports is thought to substitute 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. The expected positive sign was estimated for the RRGF variable and it was statistically significant at the 5 percent. It shows a one percent increase in the railroad rate (RRGF) will increase grain barge demand on the Illinois River about 0.3 percent. The influence of the U.S. Gulf-to-Japan ocean freight rate (OCEAN) is included into the equation and, unexpectedly, the sign on the OCEAN variable is positive and statistically significant. The reason(s) for the positive sign are unknown.

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 increases during the winter period.

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.

Results show the dynamics of the grain barge travel existing in both grain barge demand models for upper Mississippi and Illinois Rivers. Additional findings indicate that 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 0.12 percent (own-price elasticity of –0.12). And, on the upper Mississippi River a one percent increase in the grain barge rate will lower quantity transported by barge an estimated 0.6 percent (own-price elasticity of –0.58). These findings suggest the grain barge demands on the upper Mississippi and Illinois Rivers are inelastic.[6]

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 (1.16) for upper Mississippi River grain barge demand models and inelastic (0.72) for Illinois River grain barge demand models.

Increases in total domestic corn consumption were negatively related to quantities of grain transported by barge on the upper Mississippi and Illinois Rivers. The domestic demand elasticity was more elastic in the upper Mississippi model (-0.58) than in the Illinois model (-0.21). In general, domestic grain consumption levels were found to be an important explainer of grain barge demands. Additionally, 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.

Competing and complementary transportation modes may have an affect on upper Mississippi and Illinois River grain barge demand. 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 the estimated grain barge demand model. In addition, 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 Illinois River model the estimated coefficient was of the wrong sign and statistically significant. The reasons for this outcome are unknown.

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 rates, foreign grain demands localized to lower Mississippi River ports, domestic grain supply and demand, and the winter season are factors that influence grain barge demands on the upper Mississippi and Illinois Rivers. Railroad rates linking Minnesota origins to upper Mississippi River elevators (complementary relationship) in the upper Mississippi model and railroad rates linking Illinois origins to lower Mississippi River ports (substitute relationship) in the Illinois River demand were statistically significant with the expected signs.

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] Two-stage least square (2SLS) estimation was also carried out for grain barge demand models on both the upper Mississippi and Illinois Rivers. Since it is a demand equation, the barge rate, theoretically, is the endogenous variable on the RHS. The selected instrument variables included diesel price, wage rate for transportation and warehouse industry, exchange rate between Japan Yen and U.S. dollars (Yen/$US), and number of empty barges available on the upper Mississippi and Illinois Rivers. Applying Hausman's specification test (1978), we found the OLS and 2SLS estimates are statistically invariant given the model specification and the choice of instruments.

[6] The barge demand elasticities presented in Tables 3 and 4 are viewed as short-run elasticities. By using the estimated coefficients of the lagged dependent variables, long-run grain barge demand elasticities were obtained for both Rivers by following the procedure forwarded by Davidson and MacKinnon (1993). The short-run own-price elasticity for the upper Mississippi was estimated to be about –0.58 while the calculated long-run elasticity was –0.81. For the Illinois River, the short-run elasticity was –0.12 while the long-run elasticity was 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)
$GSTOCKUM_i$	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)
$GSTOCKIL_i$	Quantity of grain stocks in Illinois 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)
$TCDOM_i$	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
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
GSTOCKIL	1,000 tons	25,223.92	12,870.73	2,737.90	53,651.90
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
TCDOM	1,000 tons	16,113.98	4,089.74	8,393.51	24,702.31

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

Variables[1, 2]	Coefficient	t-Statistic
$BQUM_{t-1}$	0.251	4.444*
$BQUM_{t-2}$	0.034	0.567
$BRNI_t$	-0.582	-2.018*
$GEXPQ_t$	1.164	3.040*
$TCDOM_t$	-0.586	-1.822**
$GSTOCKUM_t$	0.340	1.886**
$RRPNW_t$	0.629	0.807
$RRMR_t$	-0.683	-1.752*
$OCEANS_t$	-0.053	-0.350
WINTER	-2.826	-13.485*
FLOOD	-0.564	-1.798**
C[1]	-0.131	-0.024
Obs (N)	94	
Adj. R^2	0.76	
Schwarz criterion	2.33	

[1] See Table 1 for definition of variables.
[2] All variables are in natural log form.
*Significant at the 5% level, **significant at the 10% level

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

Variables[1, 2]	Coefficient	t-Statistic
$BQIL_{t-1}$	-0.222	-2.915*
$BRSP_t$	-0.127	-1.292***
$GEXPQ_t$	0.725	5.501*
$CNILP_t$	-0.241	-1.748**
$TCDOM_t$	-0.208	-1.666**
$GSTOCKIL_{t-1}$	0.289	5.898*
$RRGF_t$	0.282	2.172*
$OCEAN_t$	0.239	1.928**
WINTER	0.459	6.864*
C	1.592	1.228
Obs (N)	95	
Adj. R^2	0.74	
Schwarz criterion	0.14	

[1] See Table 1 for definition of variables.
[2] All variables are in natural log form.
*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.

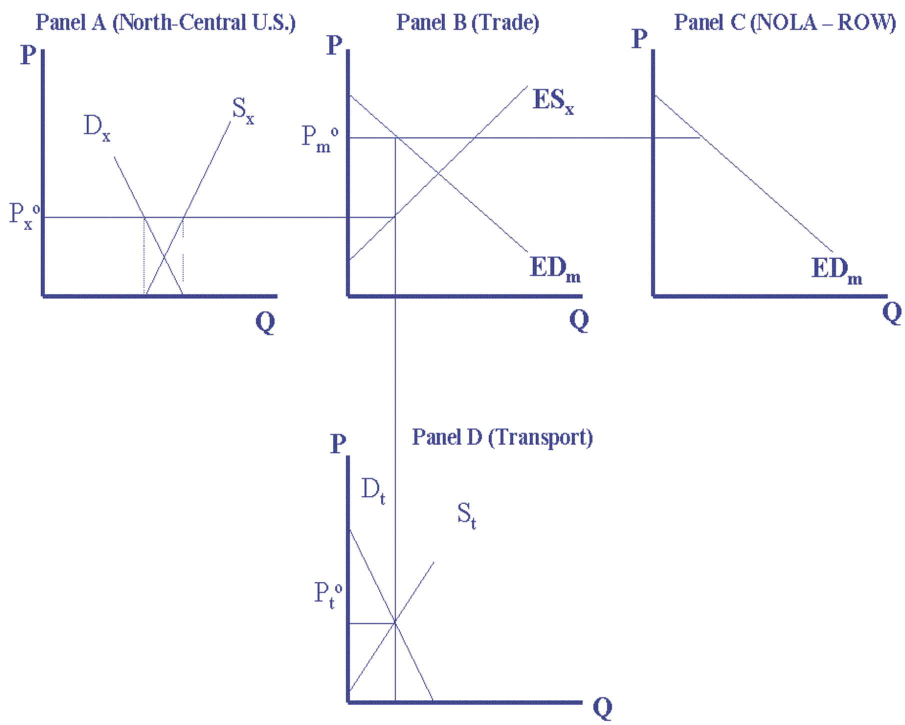

Figure 2: Quantity of Corn and Soybeans Moved by Barge on the Upper Mississippi River, 1000 tons.

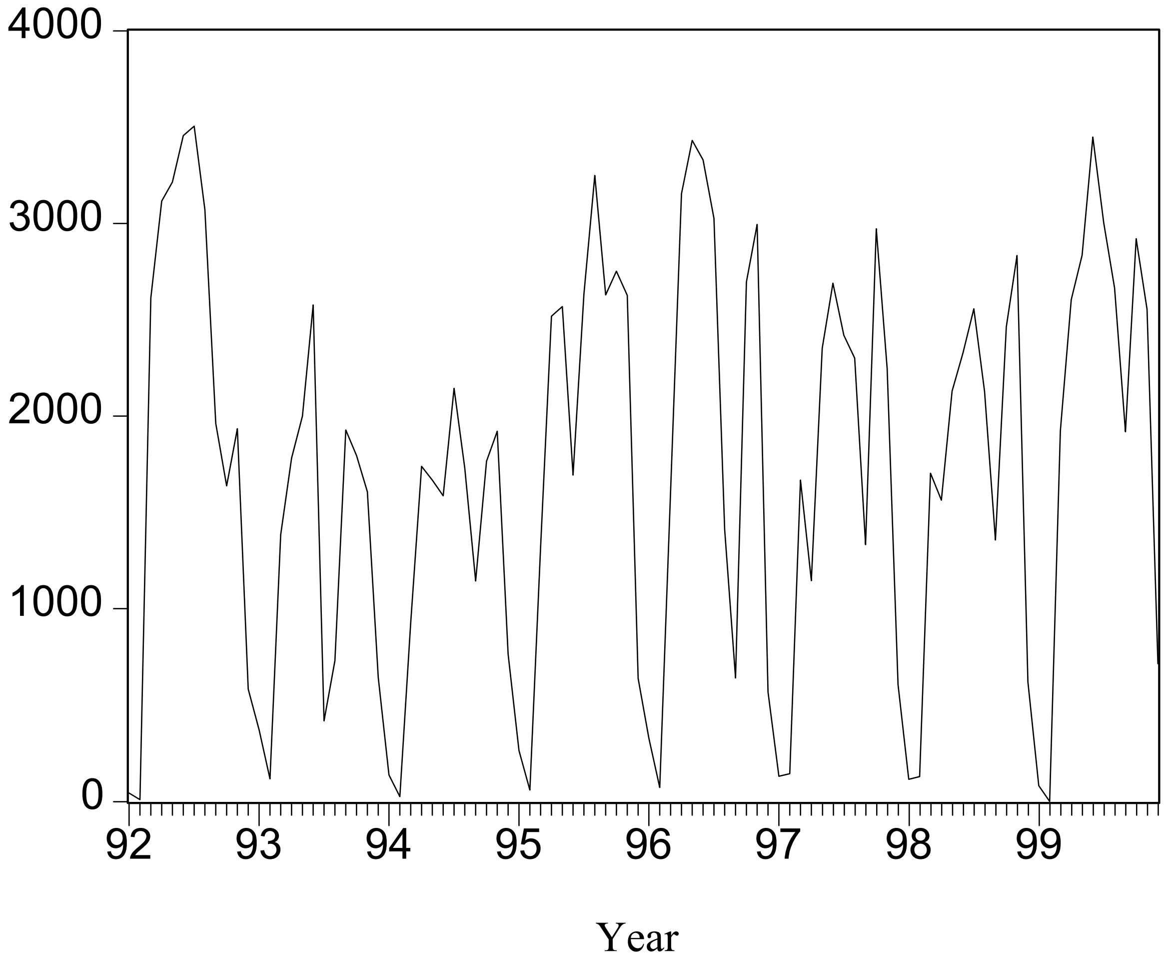

Figure 3: North Iowa Grain Barge Rate on the Upper Mississippi River, dollars/ton.

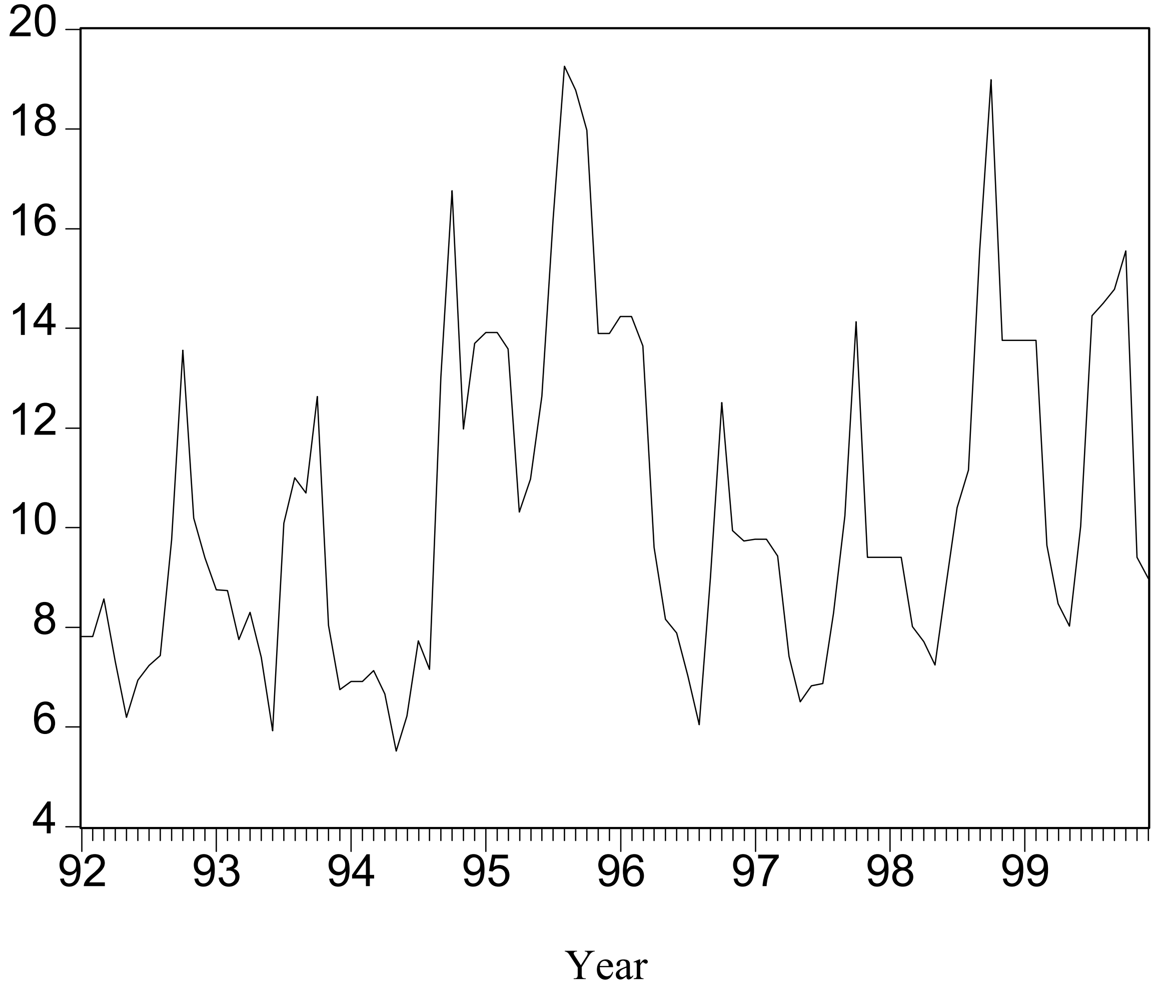

Figure 4: Corn and Soybeans Inspected for Export at the Lower Mississippi River Ports, 1000 tons.

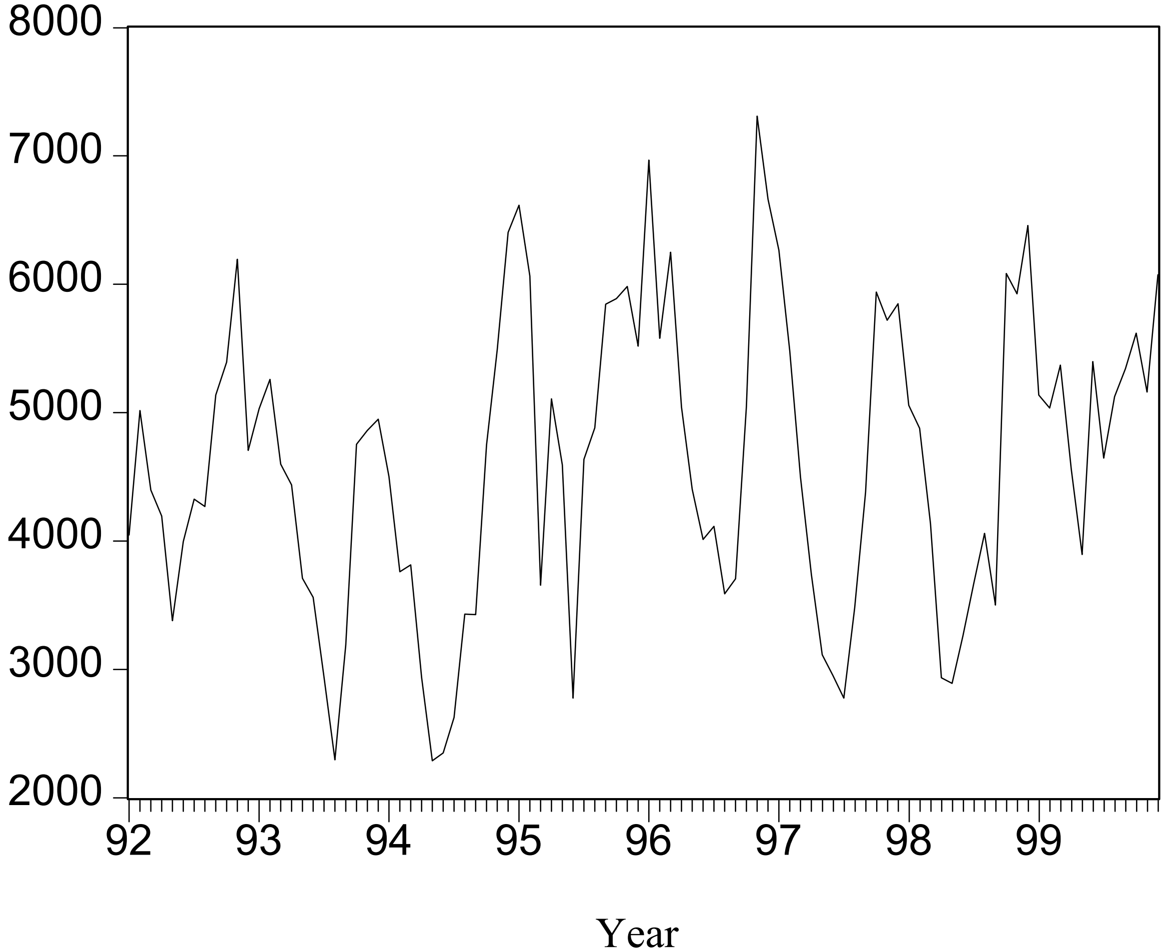

Figure 5: Quantity of Corn and Soybeans Moved by Barge on the Illinois River, 1000 tons.

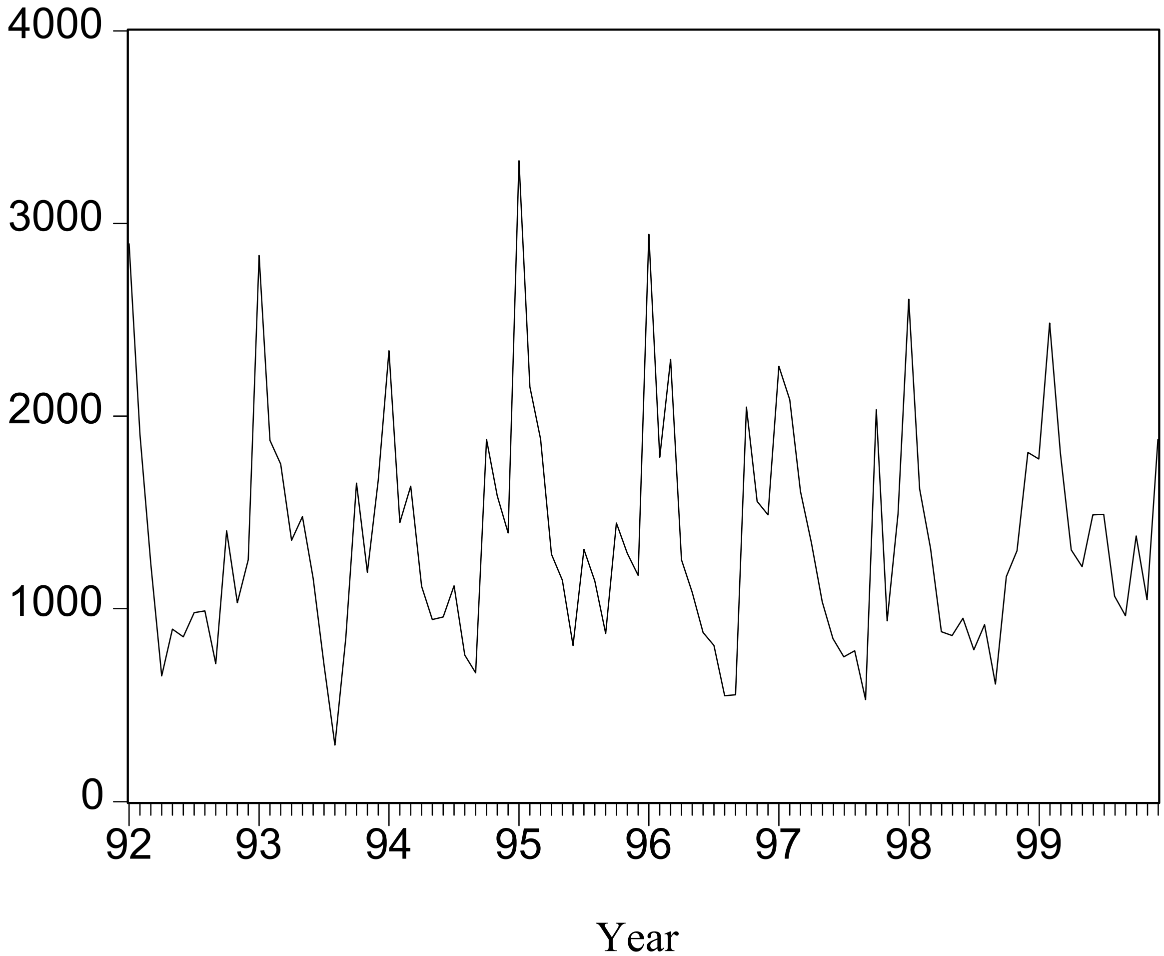

Figure 6: South of Peoria Grain Barge Rate on the Illinois River, dollars/ton.