Specifying and Estimating a Regional Agricultural Railroad Demand Model

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In recent years there have been few railroad demand studies. Also, no study has investigated the possibility of regional differences in railroad demand. The objective of the paper is to estimate railroad demand functions for wheat, corn, sorghum, and soybeans for the United States as well as the east and west regions. A two-region spatial equilibrium model is employed to specify the empirical model in which railroad tons originated is the dependent variable. The explanatory variables include railroad price per ton, crop production, and barge price per ton. The theoretically expected sign is negative for rail price. Alternatively, the expected sign is positive for crop production and barge rate. Results include estimates of railroad own-price elasticities and cross price elasticities relative to barge transport. The estimates also reveal regional differences in railroad grain demand.

INTRODUCTION

The last three decades have witnessed tremendous change in the U.S. rail freight industry. The Staggers Rail Act of 1980 led to major restructuring of the industry. The act gave railroads the ability to set any rate between variable cost and 80% above variable cost, without regulatory review. The act prohibited railroads from discussing local rates in rate bureaus establishing the conditions for intrarailroad price competition. Railroads were given the ability to enter into rail/shipper contracts that contributed to increases in rail market shares. The Staggers Act accelerated the decision process for abandonment and merger decisions to promote railroad cost reductions.

In 1980 there were 40 Class I railroads, which has declined to seven in 2011. Thus there have been numerous consolidations and mergers that have restructured the industry. Both shippers and railroads benefit from end-to-end mergers (mergers of railroads that previously served different territories). Shippers experience reduced inventory and stockout costs due to reduced transit times as the merged railroad is able to ship commodities over longer distances without having to interchange freight with other railroads. Shippers also benefit from direct access to more markets and fewer record-keeping costs. Railroads benefit from end-to-end mergers by gaining access to a larger territory, fostering more differential pricing opportunities. Railroads also reduce costs as a result of the economies of scale resulting from a merger.

Miles of track owned by Class I railroads fell from 270,623 miles in 1980 to 161,926 miles in 2010, a 40.2% decline (AAR 2011). Some of the 108,697 miles of track were abandoned, but a large share of these lines were sold to Class II (regional railroads) and Class III (local railroads). The Association of American Railroads (2011) defines regional railroads as line-haul railroads below the Class I revenue threshold ($398.7 million in 2011) operating at least 350 miles of road and/or earning annual revenue between $40 million and the Class I revenue threshold. Local railroads are line-haul railroads below the regional criteria, and switching and terminal railroads. The number of regional railroads fell from 27 in 1987 to 21 in 2010 (a 22% decrease) while the number of local railroads rose from 457 (1987) to 537 (2010), a 17.5% increase (ASLRRA 2012). Thus the total number of Class II and III railroads increased from 484 (1987) to 558 (2010) a gain of 15.3%. In 2010, regional and local railroads accounted for 31% of U.S. track miles and 10.3% of U.S. rail industry employment (AAR 2011).

The U.S. freight railroad industry has achieved tremendous advances in labor productivity. Freight revenue ton miles per employee rose from 2.1 million in 1980 to 11.2 million in 2010, a

433% gain (AAR 2011). Freight revenue ton-miles per employee hour increased from 863 in 1980 to 4505 in 2010, a 422% increase (AAR 2011).[1]

The productivity gains have contributed to improved financial condition of the Class I railroad industry. Net railway operating income rose from $1,338.6 million in 1980 to $9,959.2 million in 2010, a 644% increase (AAR 2011). The rate of return on net investment rose from 4.22% in 1980 to 10.36% in 2010, while the rate of return on shareholders' equity increased from 6.01% (1980) to 11.23% (2010) (AAR 2011).

The objective of the paper is to examine the demand for railroad grain transportation over this period of change to obtain own price and cross price elasticities, and to determine if rail demand differs between east and west regions, which has rarely been investigated. Major grain crops (wheat, corn, sorghum, and soybeans) are a good case study commodity for railroad demand because of the large gains in railroad tonnage. Collectively, farm products accounted for 8.6% of total Class I railroad tons originated in 2010, which was only exceeded by chemicals and coal (AAR 2011).[2] Between 1970 and 2011, total railroad tons originated of the four above named crops collectively increased by 48.3%, with most of the gains occurring in corn and soybeans (AAR 2012).

The measurement of railroad grain transportation demand is important to railroads, grain exporters, grain marketing companies, and barge operators. Railroads need grain demand model forecasts as an input to equipment planning and staffing decisions. Price elasticities obtained from the demand models can indicate which markets offer the best opportunities for increased revenue as a result of specific price changes. Cross price elasticities with respect to barge prices reveal the impact on railroad demand of competitive price changes instituted by water carriers. Grain exporters and grain marketing companies could use information from railroad grain demand models as an input to their logistics system planning. Barge operators need to know railroad grain demand to formulate competitive strategy.

LITERATURE REVIEW

Miklius, Casavant, and Garrod (1976) apply a logit model to estimate the price elasticities and cross elasticities for freight transport service. The model is applied to a sample of cherry and apple shipments. The cherry shipments are from Washington, Oregon, and Montana, and the apple shipments originated in Washington. The authors selected cherries because of their high perishability. Thus, quality of service would be expected to be a major factor in mode selection. Apples are storable for longer time periods; thus, modal selection would be expected to be responsive to modal rate differences.

The authors specify a binary choice model where the shipper choice is a function of rail and truck rates, transit times, and transit time dependabilities. Elasticities for own-price and cross price elasticities are calculated for both rail and truck. Most of the coefficients of both the cherry and apple models have the theoretically expected sign and are statistically significant.

The authors found that in the cherry model the demand for both rail and truck service was relatively elastic, not only for its own price and transit time but also with respect to those of the competing mode. For cherries, the choice of transport mode was much more sensitive to transit time than rates.

The authors concluded the results for the apple model were less satisfactory than the cherry model. The apple model had an unexpected sign for rail transit time, and the coefficient for truck transit time was statistically insignificant.

Oum (1979) formulated a demand model for intercity freight transport as an intermediate input to the production and distribution sectors of the economy, and to estimate the price elasticities and the elasticities of substitution between the major freight modes (rail, truck, and water).

The author used a twice continuously differentiable production function relating the gross output to capital, labor, and freight transport. The data are from the Canadian economy 1945-1974 and were transformed using a price index for each mode to calculate the revenue per ton mile.

The author found that the demand for railway freight services is only slightly responsive to the change in railway freight rates; but the own-price elasticity has been increasing in absolute value over time. Also, railway and motor carriers exhibited a complementary relationship until 1955 when they started competing heavily with one another. There is also a highly competitive relationship between rail and water carriers that can be seen throughout all years of data, but it has been decreasing slightly over time.

Friedlaender and Spady (1980) analyzed the demand for freight transportation with freight being a productive input in the firm that should be treated like any other input, and the full costs of transportation should include inventory costs as well as shipping and storage. The authors derive an explicit freight demand equation from a general cost function recognizing the interrelationship between rates and inventory cost through shipment characteristics. The demand equation was generated from a cost function that uses labor, capital, materials and energy, rail transportation, and truck transportation to produce an aggregate output.

The authors find that commodities such as iron and steel products, electrical machinery, and food appear to have an elastic demand. By region, the demand for rail service in the southern region appeared to be elastic. The cross price elasticities between rail and truck service were low in absolute value across all goods in all areas, suggesting a large amount of independence between the two modes. The authors note that this was reasonable since most of the data for trucks they used were for LTL shipments, which are not a strong competitor for rail service.

Winston (1981) noted that previous work in freight transportation has focused on the aggregate approach without considering the underlying behavior of the firms responsible for actually making the mode-choice decision. The author examined these choices as they apply to intermodal competition. This was done by developing a random expected utility model that was suitable for econometric analysis comparing both regulated and unregulated motor freight and rail.

The author made expected utility a function of modal attributes, and commodity and firm characteristics that were divided into two different elements: observed and unobserved parts. This was further disaggregated into the observed part and a stochastic term representative of a random parameter, modal attributes, and an independent identically distributed disturbance.

It was found that the commodity groups most sensitive to service quality are perishable products or inputs to perishable products. Conversely, the commodity groups that are least sensitive to service quality are neither perishable nor likely to have storage problems such as high storage costs or unstable demand. Generally, freight charges and location had the most explanatory power, with tangible shipping costs tending to play a dominant role in mode choice decisions.

Babcock and German (1982) forecast national and regional rail demand for selected agricultural commodities including wheat, corn, sorghum, and soybeans. The forecasting models are single equation regression employing annual data from the 1958-1980 period. Each model is estimated for the United States and for the east, south, and west regions.

The dependent variable for each of the crop models was rail tons originated of the commodity. Independent variables for each model included crop production, crop exports, and a time trend. The corn model also had cattle on feed in addition to the above mentioned variables. The soybean model also contained the barge share of combined rail and barge tonnage.

The empirical results of the model were good with high R^2s and no autocorrelation. The exception was the soybean equations, which had significant autocorrelation and was corrected using the Cochrane-Orcult method. The explanatory variables generally had the theoretically expected sign and are highly significant.

The authors obtained 1985 forecast values for each of the explanatory variables to forecast 1985 railroad crop demand.

Babcock and German (1983) forecasted 1985 railroad market shares for 12 intercity manufactured goods freight markets. The authors noted that the railroad share of these markets declined in the 1955-1980 period while the truck share rose. One of the principal objectives of the Staggers Rail Act of 1980 was to arrest the decline of rail market shares. Whether this would occur was the primary question addressed by this paper.

The authors employed a model in which railroad market share (measured by ratio of a rail tonnage index to an index of industrial production) is made a function of the ratio of the rail rate to the truck rate, the prime interest rate, and the ratio of truck service to rail service. Truck service was measured by interstate highway miles as a percent of total highway miles. Rail service was measured by an index of average daily freight car miles. The authors found the potential forecast performance of the estimated rail share equations to be excellent.

The authors also found that rail market shares would continue to decline in about half of the 12 markets if truck service improved relative to rail service. If the decline in rail service relative to truck service was arrested, railroad market shares increased in all 12 markets. The principal conclusion of the paper was that the secular decline of railroads was ending in most transport markets by the middle 1980s.

The purpose of the Wilson, Wilson, and Koo (1988) paper is to analyze the market for transport services and the behavior of modal rates, and to identify critical parameters affecting rail market power they estimate modal demand and supply functions from time series data.

The theoretical model is a dominant firm (the railroad) price leadership model with differentiated services. Price-taking motor carriers form the competitive fringe. Thus, the transport market consists of two highly interdependent submarkets, one for rail and the other for trucks. They form demand functions in which truck and rail demand are functions of truck and rail price. The rail decision process includes some conjecture on the market response of trucks. Thus, the rail demand includes the rail price and the competitive price response of trucks.

In the empirical model, a recursive system is specified with two blocks. One describes rail pricing and the other a system of structural equations and equilibrium conditions. The second block includes structural equations for intermodal competition and simultaneously determines equilibrium values of modal outputs and truck rates. The rail demand function is $QRD_t = f(PR_t, PT_t, C_t, U_t)$ where QRD is rail shipments, PT is truck rates, PR is rail rates, C is an index of railcar availability (reflects service quality), and U is a dummy variable equal to 1.0 after multi-car shipments were introduced. Truck demand is a function of the same variables.

The equation was estimated for wheat from North Dakota to Minneapolis and Duluth from 1973 to 1983 in monthly frequency. All the explanatory variables had the theoretically expected sign and were statistically significant. The equation had a good fit and there was no autocorrelation.

The authors found that in the pre-Staggers period, the rail own-price elasticity of demand was -1.18 and the cross price elasticity was 2.30. In the post-Staggers period, the corresponding elasticities were -1.46 and 2.54. Own-price elasticities for truck were -0.73 in the pre-Staggers period and the cross price elasticity was 0.70. In the post-Staggers period, the corresponding figures were -13.4 and 8.29.

Yu and Fuller (2005) estimated the structural demand for grain barge transportation on the upper Mississippi River. They specified a model in which the dependent variable is the quantity of barge grain service. The independent variables included grain barge rate, grain exports, the domestic grain demand and supply, a rate proxy for the price of other modes, weather and seasonal dummy variables, and the quantity of barge grain service, lagged one period.

The authors estimated the equation in OLS and 2SLS. In the OLS estimates, the barge rate had the expected negative sign and was statistically significant. Grain exports had the expected positive sign and were significant. Neither the domestic grain demand nor supply was significant. The same was true for rail rates to the PNW from Minnesota and ocean freight rates. However, the rail rate from Minnesota to upper Mississippi River elevators had the expected negative sign and was statistically significant. The weather and seasonal dummies had the expected sign and were significant.

The 2SLS estimates of the coefficients were worse than OLS. The barge rate elasticity increased but was more non-significant. Grain exports continued to be significant, but the regional grain stock variable as well as total domestic corn consumption were not significant. The rates for other transport modes were also non-significant. Thus grain exports, winter season, and the flood dummy are the only unlagged statistically significant variables influencing barge demand.

The authors concluded that the short-run own-price elasticity is -0.479 while the long-run elasticity is -1.015. In summary, the authors found that barge demand on the upper Mississippi is influenced by barge rates, grain exports, the rail rate for Minnesota-originated grain shipped on the Mississippi River, winter season, and floods.

Train and Wilson (2007) focus on the access that shippers have to transportation markets. They estimate a discrete choice model framed around the access shippers have to transport markets, and they use the model to aggregate shipment decisions to provide spatially generated transport demands. The choice model results are combined with models of access cost (truck rates) over distance and aggregated to form demand functions.

In applying the model, two alternatives (barge or rail) for each shipper are used. The connection to barge and/or rail facilities is treated as an access cost. The shipper selects the alternative that maximizes profits, which are a function of barge and rail rates, access costs (measured by truck costs), and railcar loading capacity (number of railcars that can be placed on the shippers' siding). The model is estimated with a logit specification and the method of maximum likelihood.

The estimated model has a good fit, and the variables have the theoretically expected sign and are statistically significant. The results are that as the rate for barge or rail rises, profits of using the higher cost mode decline. Also, as the cost of trucking to a barge or rail terminal rise, profits fall, and the probability of using barge or rail falls. Profits for shippers that have greater car loading capacities have higher profits from rail relative to barge.

For an excellent discussion of the types of freight demand models as well as empirical findings and public policy applications see Small and Winston (1999).

THEORETICAL MODEL

As indicated by Train and Wilson (2007), the demand for freight transportation has historically taken two alternative approaches. Early studies modeled aggregate demands using aggregate data across locations and commodities. More recently, emphasis has shifted to modeling transport demands at a disaggregate level where transport demands are modeled at a shipment level using choice methods. We use an alternative approach developed by Yu and Fuller (2005).

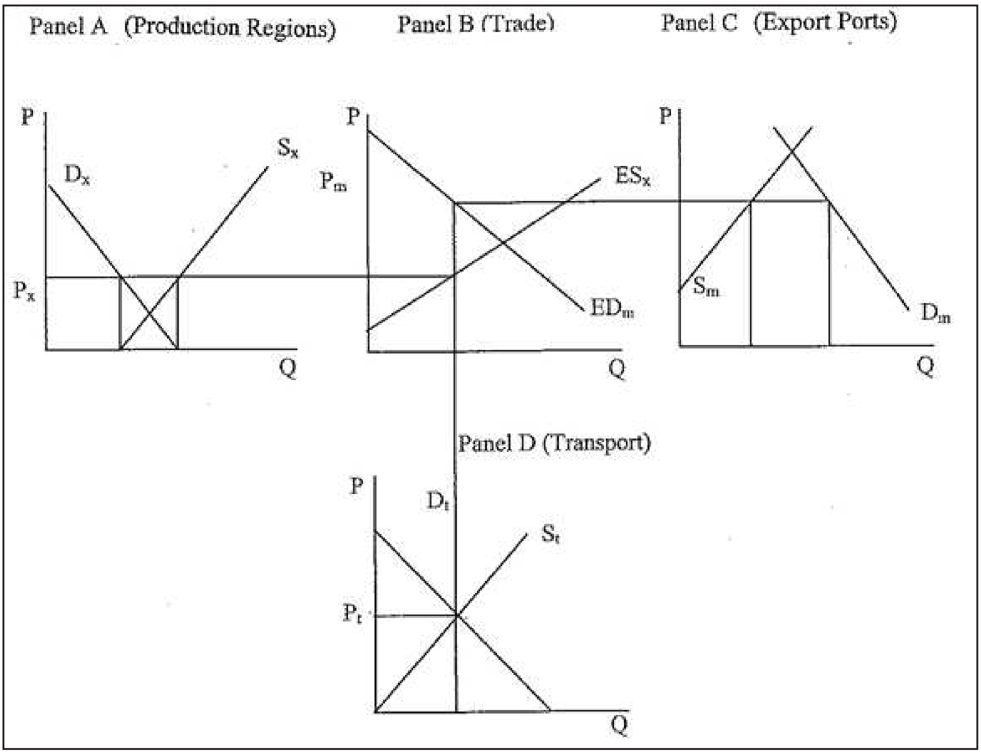
Theory of Transport Demand

The demand for agricultural grain rail service is a derived demand. Therefore, factors that shift grain supply and demand in production regions and export demand will shift the demand for rail transportation (Boyer 1997). A two-region spatial equilibrium model is used to illustrate the theoretical foundation of grain railroad demand.

Panel A depicts the supply (S_x) and demand (D_x) of grain in production regions, while Panel C represents the rest of the world's (ROW) demand (D_m) and supply (S_m) for grain as reflected at U.S. export ports. Panel B is the trade panel, which includes the excess grain supply of grain production regions ($ES_x = S_x - D_x$) and the excess demand of the ROW that buy grain at U.S. export ports ($ED_m = D_m - S_m$). The intersection of excess supply (ES_x) and excess demand (ED_m) determines the equilibrium price and quantity of grain traded between production regions and export ports if no transportation costs were required to link the production regions to the ports.

Of course, transportation costs are very important in the marketing of grain. The derived demand for grain transportation and the supply of grain transportation service are depicted in Panel D. The derived transportation demand is equal to the vertical distance between the excess supply (ES_x) and the excess demand (ED_m) in Panel B. Also in Panel D is the supply of transportation service linking grain production regions with export ports. In 2010, railroads transported 68% of the combined railroad and barge tonnage of corn, wheat, and soybeans (AAR 2010). Thus, it is reasonable to assume that the supply is an approximation of the railcar fleet operating on the U.S. railroad system and the barge fleet operating on the inland waterways. The intersection of derived transport demand and supply determines the transportation rate (P_t) linking grain production regions to export ports. The corresponding grain prices are P_x in Panel A for the grain production regions, and P_m in Panel B for ports, where grain prices in the two regions (P_x and P_m) differ by the transport rate (P_t) that links the two areas.

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



Any variable that shifts the regional supply (S_x) and demand (D_x) of grain in the production regions will also shift the excess supply (ES_x) and the derived transport demand. Similarly, any variable that shifts the ROW excess grain demand and supply will alter the derived demand for rail transport. We use actual grain production, which embodies the demand (both domestic and foreign) and supply shifting factors in grain markets as a regressor in the grain rail demand specification to capture the derived demand nature of rail transport.

In addition to the economic factors identified in the partial equilibrium case in Figure 1, other transport modes may compete with, as well as complement, grain railroad transportation. For example, much of the grain is delivered by truck to rail transloading locations, resulting in a complementary relationship. Railroads compete with barge transport in the coal, grain, ores and chemical markets.

Model Specification

Grain Tonnage Transported by Rail$_{ijt}$ = *f* (*Rail Price*$_{ijt}$, *Grain Production*$_{ijt}$, *Barge Rates*$_t$, η_i, λ_j, τ_t)

i – commodity which includes wheat, corn, sorghum, and soybeans

j – region which includes East and West

t – year

η_i – commodity fixed effect

λ_j – region fixed effect

τ_t – time trend

Railroad prices (rates) should be included as an explanatory variable. According to the law of demand, an inverse relationship exists between rail demand and rate. That is, an increase in grain rail rate will reduce grain rail demand.

As mentioned previously, *Grain Production*, which embodies the demand (both domestic and foreign) and supply shifting factors in grain markets, is used as a regressor in the grain rail demand specification to capture the derived demand nature of rail transport. Grain production is expected to affect the derived rail transport demand in a positive manner.

The prices of alternative modes would also impact rail grain demand. The principal substitute mode for railroads in the grain markets is barge transport. An increase in barge rates would increase rail grain demand as shippers switch to relatively lower priced rail service.

Last, η_i controls for determinants of rail demand that are commodity-specific and unobserved to the researchers; λ_j controls for determinants of rail demand that are region-specific and unobserved to the researchers; and τ_t controls for determinants of rail demand that are time-specific and unobserved to the researchers.

DATA

Data for railroad tonnage of corn, wheat, sorghum, and soybeans for east and west regions, as well as data to compute rail price (revenue per originated ton), were obtained from various issues of *Freight Commodity Statistics* published by the Association of American Railroads. Data for grain production of corn, wheat, sorghum, and soybeans were obtained from various issues of *Agricultural Statistics* published by the U.S. Department of Agriculture. Barge rates were obtained from personnel at the Agriculture Marketing Service (AMS) of the U.S. Department of Agriculture. Data for the variables in the equation were collected for the 1965-2011 period. The AMS surveys barge companies on a weekly basis to obtain grain barge rates.

The barge industry uses percent of tariff as rate units for buying and selling barge services. These rate units are from the Bulk Grain and Grain Products Freight Tariff No. 7, which was used by the Waterways Freight Bureau of the Interstate Commerce Commission (ICC). In 1976, the U.S. Department of Justice entered into an agreement with the ICC that made Tariff No. 7 no longer applicable, but the barge industry continues to use it as a benchmark. For example, Tariff No. 7 (1976) has a grain barge rate of $4.04 per ton for the lower Ohio River. If the current rate is 200% of tariff, then the rate is $8.08 per ton (2.0 x $4.04 = $8.08).

Figure 2 plots the volumes (measured in thousands of tons) of agriculture grains transported by rail over the time span of the data set. The figure shows that for much of the time period, corn is transported by rail in greater volumes compared with the other three commodities. In contrast, for almost all the time period, sorghum is transported by rail in smaller volumes compared with the other three commodities. In addition, 28,446.20 thousand tons of corn, 9,782.20 thousand tons of soybeans, and 39,686 thousand tons of wheat were transported by rail in 1965, compared with 73,322.70 thousand tons of corn, 22,243.10 thousand tons of soybeans, and 44,460.50 thousand tons of wheat in 2011, respectively. Therefore, over the sample period, the volumes of corn, soybeans, and wheat that are transported by rail grew by 157.75%, 127.38%, and 12.03%, respectively. In contrast, 9,498.80 thousand tons of sorghum was transported by rail in 1965, compared with only 1,918.70 thousand tons in 2011, resulting in a 79.80% decline. In summary, over the sample period, corn was transported by rail in greater volumes and showed the largest growth compared with the other three commodities, while sorghum was transported by rail in the smallest volumes and these volumes actually declined.

Figure 2: Grain Tonnage Transported by Rail from 1965 to 2011

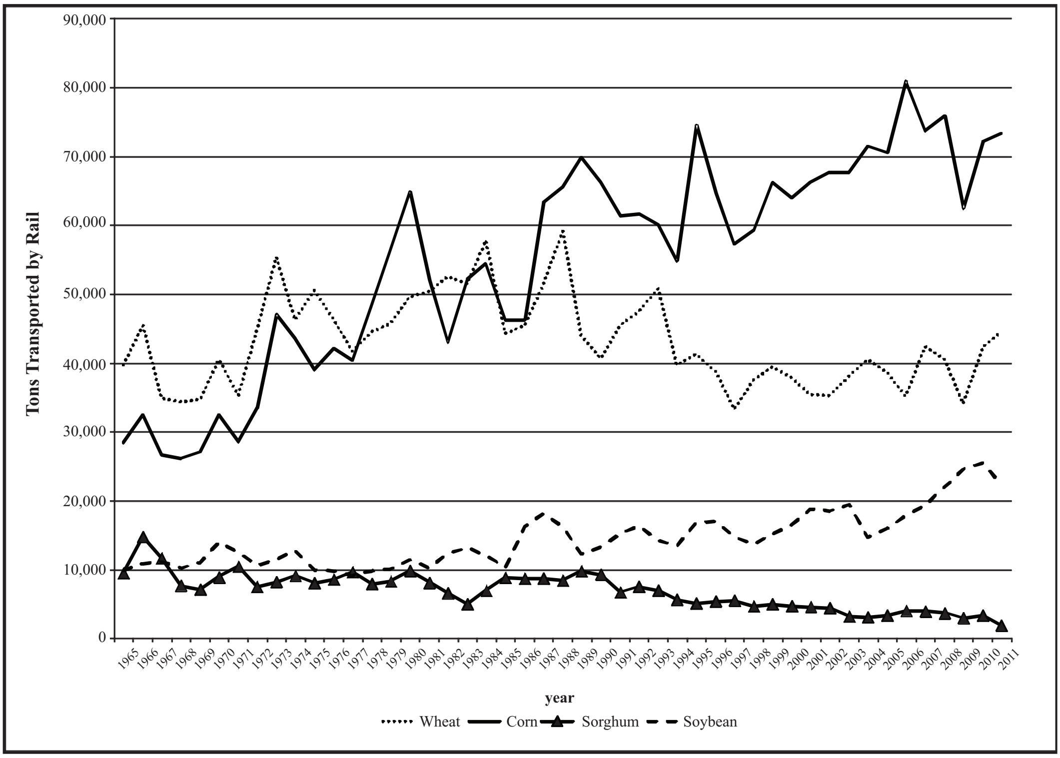


Table 1 reports descriptive statistics for the dependent, independent, and instrument variables used in estimating the agricultural grain railroad demand model. The table reports each variable's mean, standard error, number of observations, minimum value, and maximum value. The sample means for all variables are statistically different from zero at the 1% level of statistical significance. In terms of mean tons of each commodity transported by rail over the sample period, we see that corn has the largest mean tonnage of rail transport followed by wheat, soybeans, and sorghum, respectively.

Rail revenue per ton is the measure we use for rail price. The mean rail price to transport wheat is highest ($17.14 per ton) followed by the mean rail price for corn ($14.87 per ton), sorghum ($14.66 per ton), and soybeans ($13.29 per ton), respectively. As previously discussed, the demand for rail transport coming from producers of grain is derived from the volume of grain produced that needs to be transported. Mean grain production is largest for corn (7,970,880 thousand bushels) followed by mean production of soybeans (2,079,755 thousand bushels), wheat (2,076,975 thousand bushels), and sorghum (636,632.40 thousand bushels), respectively.

Grain is also transported by barge. As such, changes in the relative price to transport by barge, measured by the Barge Rates variable, should influence the demand for rail transport. Barge rates are measured by the grain spot barge price as a percent of tariff. Mean barge rate is 214.38%, and it ranges from a low of 117% to a high of 494%.

Three variables that were used as instruments for rail price when estimating demand: Railroad Labor Cost, Railroad Diesel Fuel Price, and Number of Covered Hopper Railcars. These variables are all expected to influence the unit cost of providing rail transport and therefore capture rail supply-shifting shocks to rail price. Railroad labor cost is measured by earnings per employee per year in dollars. Mean annual earnings per employee is $37,734.20. Railroad diesel fuel price has a mean 73.79 cents per gallon, and the mean number of covered hopper railcars is 293,824.2.

Table 1: Descriptive Statistics for Variables Used in the Agricultural Grain Railroad Demand Model

	Wheat	Corn	Sorghum	Soybean
Variables	Mean (Std. error; N) [Min] {Max}	Mean (Std. error; N) [Min] {Max}	Mean (Std. error; N) [Min] {Max}	Mean (Std. error; N) [Min] {Max}
Grain Tonnage Transported by Rail (measured in thousands of tons)	43,062.16*** (952.84; 47) [33,200.30] {59,048.10}	54,914.40*** (2,257.38; 47) [26,199.70] {80,974.30}	6,897.84*** (387.77; 47) [1,918.70] {14,784.80}	14,480.03*** (593.79; 47) [9,189.60] {25,543.70}
Rail Price (measured by Rail Revenue Per Ton in dollars)	17.14*** (1.18; 47) [5.88] {37.15}	14.87*** (1.09; 47) [4.27] {32.08}	14.66*** (0.84; 47) [5.35] {27.31}	13.29*** (1.25; 47) [3.50] {34.00}
Grain Production (measured in thousands of bushels)	2,076,975*** (56,965.03; 47) [1,304,889] {2,785,357}	7,970,880*** (378,999.30; 47) [4,102,867] {13,091,862}	636,632.40*** (28,103.79; 47) [214,443] {1,120,271}	2,079,755*** (102,983.40; 47) [845,608] {3,359,011}
Barge Rates [a] (measured as grain spot barge price as a percent of tariff)	214.38*** (19.20; 32) [117] {494}			
Railroad Labor Cost (measured by earnings per employee per year in dollars)	37,734.2*** (3,129.28; 46) [7,490] {73,843}			
Railroad Diesel Fuel Prices (measured by average cost per gallon in cents)	73.79*** (9.38; 46) [9.16] {312.05}			
Number of Covered Hopper Railcars	293,824.30*** (12,760.86; 46) [100,608] {414,418}			
Years (total of 47)	1965 to 2011			

Notes: *** indicates statistical significance at the 1% level. [a] We only have data on Barge Rates from 1980 to 2011. Whenever the number of observations for a variable, denoted by N in the table, is 46 or 45, it means that observations for the variable were missing in year 2011 or years 2010 and 2011 respectively.

RESULTS

The demand model estimates are reported in Table 2. We begin by estimating the demand model without using instruments for railroad price, i.e., we first use ordinary least squares (OLS) to estimate the demand equation parameters.[3] These model estimates are reported in the columns labeled OLS. We then re-estimate the demand equation parameters using instruments for price via Generalized Methods of Moments (GMM) estimation. The substantial difference in the size of the OLS and GMM coefficient estimates on rail price suggests that rail price is endogenous. The endogeneity of rail price is confirmed using a formal statistical test of endogeneity, which is reported in the third-to-last row of Table 2. The statistical test is distributed Chi-square under the null hypothesis (*Ho*) that rail price is exogenous. Given that the probability value for the Chi-square statistic is 0.0035, which is less than 0.05, then we reject that rail price is exogenous at the 5% level of statistical significance.

An overidentification test, reported in the second-to-last row of Table 2, is used to help evaluate the validity of instruments used in the GMM estimation. A criterion for validity of instruments is that they are uncorrelated with the residuals of the model. The overidentification test is distributed Chi-square under the null hypothesis that instruments are uncorrelated with residuals of the model. Given that the probability value of the Chi-square statistic is 0.837, which is greater than 0.05, then we cannot reject the null hypothesis that the instruments are uncorrelated with the residuals at the 5% level of statistical significance. In other words, the instruments are orthogonal to the residuals of the demand model.

Another criterion for validity of instruments is that they are correlated with the endogenous regressor, i.e., valid instruments should be correlated with rail price. The weak instruments test, reported in the last column of Table 2, is used to evaluate the validity of instruments based on this criterion. The weak instrument test is distributed *F* under the null hypothesis that instruments jointly cannot explain variations in rail price. Given that the probability value for the *F*-statistic is 0.000, which is less than 0.05, we then reject this null hypothesis at the 5% level of statistical significance. Therefore, the instruments pass the weak instruments test, revealing that the instruments have a joint statistically significant effect on rail price.

In summary, both standard demand-supply equilibrium theory and diagnostic statistical tests suggest that rail price is endogenous in the regression model. Furthermore, the diagnostic statistical tests discussed above suggest that the instruments we use to deal with the endogeneity problem are valid and effective. Therefore, the remainder of the discussion focuses on the GMM estimates.

Since both dependent and independent variables are in their logarithm form when estimating the model, coefficient estimates are interpreted as elasticities. The own-price elasticity estimate of grain demand for rail transport has the theoretically correct sign and is estimated to be -1.228. This own-price elasticity estimate is statistically significant at the 1% level of statistical significance.

The coefficient on Grain Production is 0.956, suggesting that a 1% increase in grain production increases rail demand by 0.956%. This rail derived demand effect is statistically significant at the 1% level of statistical significance. The positive relationship between grain production and rail demand agrees with theoretical expectations.

The coefficient estimate on Barge Rates is positive and statistically significant, suggesting that barge transport of grain is predominantly a substitute for rail transport. The 0.484 coefficient estimate suggests that a 1% increase in barge rates will increase railroad grain demand by 0.484%.

Table 2: Agricultural Grain Railroad Demand Model Estimates

	Dependent Variable: Grain Tonnage Transported by Rail			
	Ordinary Least Squares (OLS)		**Generalizes Methods of Moments (GMM)**	
Variables	Coefficients	Standard Errors	Coefficients	Robust Standard Errors
Rail Price	-0.333***	0.118	-1.228***	0.282
Grain Production	1.022***	0.035	0.956***	0.055
Barge Rates	0.197**	0.095	0.484***	0.111
Sorghum	0.030	0.141	-0.254	0.208
Soybean	-0.098	0.083	-0.319***	0.112
Wheat	0.944***	0.082	1.039***	0.100
Western Region	0.420***	0.072	0.676***	0.104
Time Trend (year)	0.005	0.004	0.019***	0.007
Constant	-15.293*	7.984	-41.945***	13.454
R-squared	0.964		0.955	
Sample Size	248		248	
Test of Endogeneity *Ho*: Rail Price is exogenous	$\chi^2(1) = 8.523$ Probability Value = 0.0035			
Test of overidentifying restrictions	*Hansen's* $J\ \chi^2(8)=4.216$ Probability Value = 0.837			
Weak instruments test	$F(9, 231) = 7.27$ Probability Value for $F = 0.000$ First Stage Regression R-squared = 0.809			

Notes: *** indicates statistical significance at the 1% level, ** indicates statistical significance at the 5% level, while * indicates statistical significance at the 10% level. Regressions are estimated using the logarithm of dependent and all continuous right-hand-side variables. Therefore, reported coefficient estimates are interpreted as elasticities.

We include commodity fixed effects (captured by commodity zero-one dummy variables) to control for unobserved differences in the level of rail demand across different commodities. The excluded commodity dummy variable is corn. Therefore, the coefficients on dummy variables sorghum, soybeans, and wheat measure these commodities' rail demand relative to corn rail demand. The coefficient on the sorghum dummy is not statistically significant at conventional levels of statistical significance; suggesting that level of rail demand from sorghum producers that is not captured by the other control variables in the demand model is not statistically different from the level of rail demand from corn producers, *ceteris paribus*. At first glance this result might seem surprising given the line plots of grain volumes transported by rail in Figure 2. Figure 2 revealed that substantially smaller tonnage of sorghum is transported by rail compared with tonnage of corn transported by rail. However, the regression results in Table 2 are simply suggesting that much of the rail transport volume difference across these two commodities displayed in Figure 2 can be explained by the control variables included in the demand model.

The coefficient estimate on the soybean dummy is -0.319 and statistically significant, suggesting that soybeans have a lower rail demand compared with corn, *ceteris paribus*. In contrast, the coefficient estimate on the wheat dummy is 1.039 and statistically significant, suggesting that wheat has a higher rail demand compared with corn, *ceteris paribus*. So the coefficient estimates on the commodity dummies suggest that wheat has the highest rail demand that is not explained by regressors included in the demand model followed by corn, sorghum and soybeans, respectively.

The 0.676 coefficient estimate on the western region dummy variable suggests that grain rail demand is higher in the western region of the United States compared with the eastern region. This regional rail demand difference is statistically significant at conventional levels of statistical significance.

Last, the coefficient estimate of 0.019 on the time trend variable suggests that grain rail demand, on average, grew annually by 1.9%, *ceteris paribus*. This annual growth in grain rail demand is statistically significant at 1% level of statistical significance.

CONCLUSION

The Staggers Rail Act of 1980 promoted a major restructuring of the U.S. Class I railroad industry. The number of Class I railroads fell from 40 in 1980 to seven today due to numerous mergers and consolidations. The Class I railroads reduced their costs as they abandoned branch lines or sold these lines to regional or local railroads. The Class I industry achieved tremendous increases in labor productivity, which contributed to improved financial condition. Despite the enormous changes in the Class I railroad industry, recent studies of railroad demand have been relatively few. This paper partially addressed this research gap by estimating the railroad demand for wheat, corn, sorghum, and soybeans for the United States as well as the east and west region. Railroads, grain exporters, grain marketing companies, and barge operators need estimates of railroad demand as an aid to strategic planning.

As opposed to utilizing an aggregate or disaggregate approach, this study used a two region spatial equilibrium model developed by Yu and Fuller (2005). The empirical model made grain tonnage transported by rail a function of rail price, grain production, barge rates, commodity and region fixed effects, and a time trend. The model was initially estimated with OLS. However, rail price was found to be endogenous. The demand equation was re-estimated using instrumental variables for price via the Generalized Method of Moments (GMM) estimation.

All the variables had the theoretically expected signs and were statistically significant at the 1% level (except sorghum). The equation had a good fit with an R^2 of 0.96. The own-price elasticity of grain demand for rail transport was -1.23. The barge rate elasticity was 0.48, confirming that barge transport of grain is a substitute for rail transport.

The coefficient of the soybean dummy was negative, suggesting that soybeans have a lower rail demand compared with corn. In contrast, the coefficient of the wheat dummy was positive, suggesting that wheat had a higher rail demand compared with corn. In summary, the coefficients of the commodity dummies suggest that wheat has the highest rail demand not explained by other variables in the model, followed by corn, sorghum, and soybeans, respectively. Another contribution of the paper was the result that region has a differential effect on railroad grain demand, which is higher in the west region compared with the east.

Endnotes

1. For a comprehensive discussion of Class I railroad productivity trends between 1980 and 2010 see Martland (2012).

2. In 2010, field crops accounted for 98% of total railroad originated tonnage of farm products.

3. Recall that rail price instruments include: (1) Railroad Labor Cost, (2) Railroad Diesel Fuel Price, and (3) Number of Covered Hopper Railcars. We also include as instruments, interactions and the square of these three instrumental variables.

References

American Short Line and Regional Railroad Association (ASLRRA). *Short Line and Regional Railroad Facts and Figures*, 2012 edition. Washington, D.C., 2012.

Association of American Railroads. *Railroad Facts*, 2011 edition. Washington, D.C., 2011.

Association of American Railroads. *Freight Commodity Statistics 2010*. Washington, D.C., 2010.

Babcock, Michael W. and H. Wade German. "Forecast of Agricultural Rail Demand to 1985." *Proceedings of the 23rd Annual Meeting of the Transportation Research Forum* 23 (1), (1982): 589-598.

Babcock, Michael W. and H. Wade German. "1985 Forecast: Rail Share of Intercity Manufactures Freight Markets." *Transportation Research Forum* 24 (1), (1983): 614-620.

Boyer, K.D. *Principles of Transportation Economics*. Addison-Wesley, Reading, MA, 1997.

Friedlaender, Ann F. and Richard H. Spady. "A Derived Demand Function for Freight Transportation." *Review of Economics and Statistics* 62 (3), (1980): 432-441.

Martland, Carl D. "Productivity Improvements in the U.S. Rail Freight Industry, 1980-2010." *Journal of the Transportation Research Forum* 51 (3), (2012): 83-107.

Miklius, Walter, K.L. Casavant, and P.V. Garrod. "Estimation of Demand for Transportation of Agricultural Commodities." *American Journal of Agricultural Economics* (1976): 217-223.

Oum, T.H. "A Cross Sectional Study of Freight Transport Demand and Rail-Truck Competition in Canada." *Bell Journal of Economics* 10, (1979): 463-482.

Small, Kenneth A. and Clifford Winston. "Demand for Transportation: Models and Applications." Jose-Gomez Ibanez, William B. Tye, and Clifford Winston eds. *Essays in Transportation Economics and Policy*. Washington, D.C.: The Brookings Institution (1999): 11-56.

Train, Kenneth and Wesley W. Wilson. "Spatially Generated Transportation Demands." Scott M. Dennis and Wayne K. Talley eds. *Railroad Economics*. London: Elsevier (2007): 97-118.

U.S. Department of Agriculture. *Agricultural Statistics*. Washington, D.C., various issues.

Wilson, W.W., Wesley W. Wilson, and W.W. Koo. "Modal Competition and Pricing in Grain Transport." *Journal of Transport Economics and Policy* 22 (3), (1988): 319-337.

Winston, Clifford. "A Disaggregate Model of the Demand for Intercity Freight Transportation." *Econometrica* 49 (4), (1981): 981-1006.

Yu, Tun-Hsiang (Edward) and Stephen W. Fuller. "The Measurement of Grain Barge Demand on Inland Waterways: A Study of the Upper Mississippi River." *Journal of the Transportation Research Forum* 44 (1), (2005): 27-40.

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