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Estimation of Demand Elasticities for Transportation Modes in Grain Transportation

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FOREWORD

Modal demand elasticities are estimated in this study in the case of grain shipments from North Dakota. This research has benefited from discussions and suggestions from T. Oum of Queen's University, and Won Koo and Gene Griffin from North Dakota State University. This research was conducted under Regional Project NC-160, Performance of the U.S. Grain Marketing System in a Changing Policy and Economic Environment.

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Highlights

One of the more important institutional changes affecting agricultural transportation in recent years is the recent trend toward deregulation. The extent to which rail rates will change under deregulation depends on the nature of competing in particular movements, as reflected by the railroads' own-rate elasticity of demand. Three types of competitive forces are normally distinguished in the transportation industry. These are intermarket, intermodal, and intramodal competition. The purpose of this study is to evaluate intermodal competition in the case of grain shipments from North Dakota.

Transportation demand functions can be specified using several logical approaches. In this study transportation was treated as a factor input. The parameters of the derived demand function are estimated jointly from a translog cost and revenue share function. The estimated parameters were then used to derive estimates of own-rate and cross-rate elasticities for rail and truck shipments. The effect of output on revenue shares and technological change was also evaluated.

The results of the translog demand function can be used to explain the characteristics of modal demands for grain transportation. They indicate that any implicit technological or institutional change has not favored one mode over the other. The results also indicate that transportation output affects revenue shares in a few cases. Generally changes in output were rail intensive with the exception of barley shipments to Duluth which were truck intensive. Price elasticities were calculated for both modes and all were in the inelastic range of the demand function. Consequently, the railroads could increase their revenue by increasing rates since little traffic diversion between modes would occur. The study did not analyze the effects of intra-modal and inter-market competition.

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By

William W. Wilson*

One of the more important institutional changes affecting agricultural transportation has been the recent trend toward deregulation. Traditionally, regulation of railroad rates by the Interstate Commerce Commission has been an important public policy affecting the grain transportation industry. However, recent legislation has encouraged a trend toward less regulation over railroad rates. Although regulation of railroad pricing has only been partially relaxed, the thrust of both the Railroad Revitalization and Regulatory Reform Act of 1976 (4R Act) (U.S. Congress, 1976) and the Staggers Rail Act of 1980 (U.S. Congress, 1980) has encouraged more flexibility in railroad pricing.

One of the purposes of the 4R Act was to promote long-term viability of the entire railroad industry by reforming the railroad regulatory system. Specifically, the 4R Act mandated that the Interstate Commerce Commission look with favor on seasonal and regional peak period rate-making. This was the first piece of legislation to suggest that railroad pricing should be more demand-oriented. The 4R Act set a precedence for further legislation, but its provisions were never fully implemented--most likely because of uncertainty in legal interpretation of the provisions and shipper dissatisfaction.

The Staggers Rail Act followed the 4R Act and is the most recent legislation affecting railroad pricing. The general thrust of the clauses affecting railroad pricing was for price flexibility. Limits were established for minimum and maximum rates as well as a zone of rate flexibility. The concept of "market dominance" which was introduced in the 4R Act is used as a measure of competitive force affecting railroad rates. If a particular movement does not have market dominance, it is precluded from the jurisdiction of the Interstate Commerce Commission (ICC). If market dominance exists, then the rate is subject to the jurisdiction of the ICC with the exception of cost recovery increases plus an additional 6 percent annually. Market dominance is currently in the process of being interpreted. The Staggers Act

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indicated that the revenue to variable cost ratio should be used as a measure of market dominance. If the ratio is below 1.65, market dominance does not exist.[1] However, if the ratio exceeds 1.65 it still has to be shown that market dominance does exist. Other "qualitative evidence" will be evaluated to determine if a railroad has market dominance. A "zone of rate flexibility" was established which allows quarterly rate increases, without shipper protest, in proportion to the inflationary increase in a rail cost index as well as a maximum of 6 percent annually not to exceed 18 percent in four years. General rate increases, which were traditionally used for railroad revenue needs, are more limited to joint rates.

While many clauses of the Staggers Act are in the process of being interpreted and implemented, the precedence has been established to allow more flexibility in railroad rate making. The extent to which rates will change depends on the nature of competition in the particular movement, as reflected in the railroads' own-rate elasticity of demand. This change in transportation policy could have very important implications for both the agricultural industry, and railroad management. For agriculture, adjustments in rates and relationships between rates may be introduced as reliance on general rate increases for revenue needs is curtailed. The potential also exists for more frequent rate changes depending on temporal changes in demand, resulting in greater uncertainty for shippers. The pricing department in railroad firms will take on a higher posture as pricing strategies are developed. Of primary importance will be the relationship between price and shipments, which requires knowledge of demand elasticities and relationships.

Deregulation is desirable from a public policy perspective if the competitive forces can serve as a regulator of railroad prices. Three types of competitive forces are normally distinguished in the transportation industry. First, intermarket competition is the effect of spatially separated demands competing for spatially separated and limited supplies of commodities, and transportation price serves as the allocative function. The effectiveness of intermarket competition is normally assessed using spatial equilibrium models. Second, intermodal competition results from different modes competing for the same traffic. Third, intramodal competition results from firms in the same mode of transportation competing for the same traffic.

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[1] The critical ratio for market dominance will be increased each year until it reaches 1.80.

The presumption in reducing regulation over railroad rates is that the combination of these three types of competition are sufficient regulators of modal rates. The demand for transportation is traditionally assumed to be price inelastic because transportation costs account for such a small proportion of the delivered price of the commodity. Modal demands, however, are less price inelastic because of the possibility of intermodal substitution (Wilson, 1978). In the case of grain, most rail movements either have immediate or potential substitutes from trucks and/or barges. Because the parameters affecting competition vary spatially, it is expected that the elasticity of demand also varies spatially.[2]

Intermodal or intramodal competition can be assessed by evaluating the modal demand function for transportation. The purpose of this study is to analyze intermodal competition in the case of grain transportation from North Dakota. Specific objectives are to develop a method for estimating modal demand elasticities for grain transportation and to estimate the model and assess the competition between modes in the movement of wheat and barley from North Dakota origins to major destinations.

I. Studies on Estimation of the Demand for Transportation

Many studies have estimated the demand for transportation in general and by mode. The methodologies can be broken down into four general categories. These are: 1) optimization models; 2) models of modal choice; 3) *ad hoc* specified and estimated demand functions; and 4) derived demand models. Examples of each are discussed below.

The general purpose of optimization models is to incorporate the interaction of commodity supply and demand conditions with transportation rates as well as constraints inherent in the system. The underlying objective in these analyses is to minimize costs. Commodity flows, modal market shares, and other information can be traced from the results. Changes in the transportation rate matrix can be imposed and the effects analyzed. Of particular interest in demand function analysis is the effect on modal market shares. Koo and Bredvolt (1982a) recently constructed a national model of grain transportation to analyze the effects of constraints, expanded output

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[2] Koo and Bredvolt (1982b) found that rail rates vary cross-sectionally depending on the type of grain, and a competitive variable.

and different rate structures. Intermodal competition was evaluated by calculating normative price elasticities of demand. Barge shipments were found to be elastic with respect to their own rates and inelastic with respect to rail rates. Rail own-rate elasticities were smaller.[3] Recently, Fuller and Shanmugham analyzed intramodal competition (rail/rail) in the Southern Plains states using an optimizing transshipment model. They concluded that intramodal competition would be effective in restricting railroad price increases. However, they expressed reservations with respect to the effect of mergers.

The second type of demand analysis is estimation of a modal choice behavioral function. Endogenous variables in the two-mode case are binary and indicate which of the two modes was utilized. Exogenous variables typically include both rate and service characteristics. Examples of the latter include frequency of service and transit time. By nature of the specification, these models are oriented to use of cross-section data, and procedures involve estimating a probability function for a firm choosing a particular mode. McFadden provides a thorough review of the theory and estimation procedures. Levin used a multimodal logit model to estimate the division of traffic between truck, rail boxcar, and piggyback in the manufactured goods industry. One of his findings was that market shares were more responsive to transit time than to modal prices. Miklius, et al., used similar procedures in the case of rail and truck shipment of cherries from the Pacific Northwest Region and apples from Washington State. Somewhat similar logic was used to analyze truck-barge demand in the case of wheat at the Pacific Northwest (Logsdon). Johnson used logit procedures to analyze branchline shipper response to quality variables in Michigan. The theory of modal choice as applied to grain elevator decision processes was also developed in Daughety and Inaba. More recently, Oum developed the theoretical assumptions underlying the use of linear logit models for transport demand studies (Spring 1979). The linear logit model imposes several rigid a priori restrictions on the estimated parameters. Second, the model imposes a structure of technology which is irregular and inconsistent. Consequently, Oum concluded that the linear logit model is not appropriate to use in the case of transport demand studies. He demonstrated in an example

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[3] These statements are subject to many assumptions, all of which are elaborated in the study. Different elasticities were derived depending if a cost-based rate structure or the current rate structure was used.

that parameter estimates of the elasticity of substitution were very sensitive to the empirical specification.

A third type of demand analysis is specification of behavioral equations using ad hoc conceptual reasoning. Examples in agriculture include recent studies by Fitzsimmons and Wilson. Fitzsimmons analyzed rail demand for grain shipments in the United States using quarterly and annual data. Quantity shipped by rail was the endogenous variable. The exogenous variables included the quantity of grain used for domestic consumption and export and rail and barge rates. The results indicated that rail demand was inelastic with respect to both its own rates and barge rates. Wilson analyzed modal demands for wheat shipment from North Dakota to Duluth/Superior (Wilson, 1980). A recursive model which incorporated a behavioral function of producers' deliveries into the marketing system was specified. Exogenous variables in the rail demand function included total movements estimated from within the model, rail rates, and truck costs. The latter was used as a proxy for truck rates, which are not published because of their exempt carrier status. The results indicate that rail movements were elastic both with respect to their own rates and truck rates. Ad hoc models are typically useful for forecasting but suffer in several respects in the analysis of price responsiveness of demand. The proper set of exogenous variables, and the functional form of the model, are somewhat arbitrary. A compounding factor is that coefficients estimated from these models are typically sensitive to the functional form and included exogenous variables (Oum 1978).

The fourth general methodology for analyzing modal demands for transportation is estimation of derived demand models. Assuming dual relationships between production and cost functions of shippers' distribution activities, and flexible forms of the cost function, modal factor shares can be derived. The procedures involve estimating the parameters from either the factor share equations and/or the cost function. The estimated parameters can be used to derive elasticities of modal substitution, own and cross price elasticities, and ordinary (Marshallian) demand elasticities. Friedlander and Spady applied these procedures to a cross-section of shipments from U.S. manufacturers. The results indicated that rail demand was elastic with respect to its own rate, and the own-rate elasticities for trucks were close to unity. The cross-rate elasticities were inelastic and in many cases indicated that trucks and rails were complements. There was a great deal of variation, however, across regions and commodities. Oum applied similar procedures in Canada and found that rail demand was own-rate elastic (Autumn, 1979). In a similar study, Oum used time series data for three modes in Canada (1978). The results were similar to his cross-section study but also indicated the use of these models with time series data. Specifically, dynamic behavior of lagged responses were incorporated in the estimated model.

The research reported here uses the derived demand approach in specifying and estimating factor share equations and deriving elasticities. The model is developed and estimated in the case of grain shipments from North Dakota using trucks and rails.

II. Model Specification

A. Theoretical Development

Transporation demand functions can be specified using one of several logical approaches as developed above. In this case, we treat transportation activities as factor inputs to the firm. The parameters of the derived demand function for each mode are developed from the theory of the firm with a particular technology and an objective of cost minimization. In particular, the firm is a country elevator which engages in the distribution of grain commodities. In our case, the choice between modes is essentially truck and rail, and the least cost decision is based on relative prices. However, by nature of dynamic economic phenomena affecting demands through time, other variables are introduced into the analysis.

Grain transport services are assumed separable from other inputs in the production function. In other words, modal decisions are assumed to be independent from other factor decisions such as the optimal combinations of labor and capital. Oum (1978) and Blackorby et al. have demonstrated that a sectoral cost function for transport which is independent of prices of inputs other than transportation services can be derived. The assumption is also made that a dual, or duality, relationship exists between the shipping firm's production and cost function. The duality relationship means that information about a technology can be recovered by evaluating a cost function or a production function. The cost function of a firm is simply a summary of all the economically relevant aspects of the firm's technology. Since data typically lend themselves more readily to the estimation of cost functions rather than production functions, the former are normally the base for empirical analysis. Assuming a flexible functional form and dual relationships, the demand functions for factors can be derived from the cost function. The concept of duality with respect to cost functions has been developed previously. See, for example, Shepherd, Uzawa, McFadden, Diewert, and Varian.

A dual cost function exists and corresponds to every cost minimization problem. For example, assume that costs are minimized subject to a production function as follows:

$$\text{Min } C = \sum_{i=1}^{n} X_i P_i \qquad i = 1, 2, \ldots n$$

$$\text{Subject to } Q = F(X_1, X_2, \ldots X_n)$$

Where: C = cost of distribution activities
X_i = input levels for each of n modes
P_i = price of mode i
Q = transportation output

Corresponding to this problem, there exists the following dual minimized cost function:

$$C^* = g(Q, P_1, P_2, \ldots P_n) \qquad (1)$$

Where C^* is the cost of distribution activities when cost minimizing input (modal) combinations are used. Derived demand functions for each mode can be developed from the cost functions in equation (1).

A specific functional form for g must be assumed for estimation. A highly general functional form is desired which places no *a priori* restrictions on the Allen partial elasticities of substitution. Several possibilities exist which are in the general category of flexible functional forms. Examples include the generalized Leontief cost function (Diewert), translog cost function (Christensen *et al*.) and the square root quadratic cost function.

The translog cost function was arbitrarily chosen for analysis in this study. The translog cost function is homogenous of degree one in prices which does not impose homogenous of degree one on the production function. It is a continuous function of prices and can serve as a local second-order approximation to an arbitrary cost function. The translog cost function has been used frequently in empirical studies because of its attractive properties. It was developed by Christensen et al. and has since been used in energy-related studies by Berndt and Wood, Christensen and Greene (1976, 1978) and Stevenson. It has been used in analyses of the agricultural sector by Binswager. Oum (1978, 1979, Autumn 1979) and Friedlander and Spady have used it in the analysis of transportation demand.

The translog cost function is a complex relationship between the logarithm of total cost and the logarithm of output and modal prices. For our purpose, we assume the production process is subject to constant returns to scale. In the two mode case, the translog cost function has the following specification:

$$\begin{aligned} \ln C = {} & \ln a_0 + a_Q \ln Q + a_1 \ln P_1 + a_2 \ln P_2 + \\ & 1/2\ \gamma_{11}(\ln P_1)^2 + 1/2\ \gamma_{22}(\ln P_2)^2 + \\ & 1/2\ \gamma_{12}\ln P_1 \ln P_2 + 1/2\ \gamma_{21}\ln P_2 \ln P_1 + \\ & \gamma_{1Q}\ln P_1 \ln Q + \gamma_{2Q}\ln P_2 \ln Q \end{aligned} \qquad (2)$$

Where: 1 = rail
2 = truck

The variables are as previously defined and a_0, a_Q, a_1, a_2 and γ_{11}, γ_{22}, γ_{12}, γ_{21}, γ_{1Q}, and γ_{2Q} are parameters to be estimated.

Inclusion of trend in the cost function allows for nonneutral technological and institutional change through time. Trend is often included in time series analysis of production or cost functions and serves as a proxy for technological change. In the cases of transportation, technological change is possible, as well as institutional change. The latter is somewhat unique to grain transportation in that public or private policy may have changed through time which affects factor shares. Examples include changes in marketing practices at the originating point or the terminal market. Trend has been included in the model in the form of a null hypothesis that technical or institutional change has been non-neutral and is tested against the alternative hypothesis that change has been neutral. In the latter case, the model is constrained to be neutral by not including the trend variables or parameters associated with trend.

Several theoretical conditions can be imposed on the parameters of the translog cost function. The Hicks-Samuelson symmetry condition is:

$$\gamma_{ij} = \gamma_{ji} \qquad (3)$$

and is imposed on the parameters. This condition states that the elasticities of substitution between modes are symmetric. The second set of conditions are the linear homogenity conditions. In the two mode case, these are:

$$\begin{aligned} a_1 + a_2 &= 1 \\ \gamma_{11} + \gamma_{12} &= 0 \\ \gamma_{21} + \gamma_{22} &= 0 \\ \gamma_{1Q} + \gamma_{2Q} &= 0 \end{aligned} \qquad (4)$$

and imply homogenity of degree one in prices but do not impose homogenity on the production function. Imposing the above conditions on the translog cost function in equation (2) results in:

$$\begin{aligned} \ln C = {} & \ln a_0 + a_Q \ln_Q + a_1 \ln P_1 + (1 - a_1) \ln P_2 + \\ & 1/2\ \gamma_{11}\ (\ln P_1)^2 - 1/2\ \gamma_{11}\ (\ln P_2)^2 - \gamma_{11} \ln P_1 \ln P_2 + \\ & \gamma_{1Q} \ln P_1 \ln Q - \gamma_{1Q} \ln P_2 \ln Q \end{aligned} \qquad (5)$$

With the theoretical conditions imposed on the model, the number of parameters to be estimated is reduced to include a_0, a_Q, and a_1, γ_{11} and γ_{1Q}.

Constant output modal demand functions can be derived from the cost function, but in the translog case, the resulting equations are nonlinear in parameters. Alternatively, factor share, or cost share, equations can be derived which are linear in parameters and are more easily estimable. Elasticities of the modal demand function can be derived from the estimated parameters for the factor share equation. Differentiation of equation (3) with respect to each of the input prices and application of the Hotelling-Shepherd Lemma gives:

$$\frac{\partial \ln C}{\partial \ln P_1} = \frac{\partial C}{\partial P_1} \cdot \frac{P_1}{C} = [a_1 + \gamma_{11} \ln P_1 - \gamma_{11} \ln P_2 + \gamma_{1Q} \ln Q] \qquad (6)$$

$$\frac{\partial \ln C}{\partial \ln P_2} = \frac{\partial C}{\partial P_2} \cdot \frac{P_2}{C} = [(1 - a_1) + \gamma_{11} \ln P_2 - \gamma_{11} \ln P_1 - \gamma_{1Q} \ln Q]$$

The cost minimization expenditure share functions then become:

$$\begin{aligned} S_1 &= a_1 + \gamma_{11} \ln P_1 - \gamma_{11} \ln P_2 + \gamma_{1Q} \ln_Q \\ S_2 &= (1 - a_1) + \gamma_{11} \ln P_2 - \gamma_{11} \ln P_1 - \gamma_{1Q} \ln_Q \end{aligned} \qquad (7)$$

where $S_i = \frac{Q_i P_i}{C}$ or the proportion of total transportation cost spent on mode i.

From the mode's perspective, S_i is its share of the total transportation revenue. The revenue share, or factor share, equation is similar to the concept of market share, but the two differ to the extent that $P_1 \neq P_2$. If $P_1 = P_2$, then S_i would be the same as the market share.

The parameters in the factor share equations are the same as those in the cost functions. These parameters can be interpreted directly or can be used to calculate elasticities. γ_{iQ} shows the effect of changes in Q on the factor shares. If γ_{iQ} equals zero, then the output level does not affect factor shares, given constant prices. If γ_{iQ} differs from zero, then the revenue share of mode i would change at a logrithmic rate equal to the parameter, given modal prices. For example, if γ_{iQ} were greater than zero, the share of transportation revenue for the railroads would increase with increases in output. In this case, changes in output would be railroad intensive. Similar interpretation could be made of γ_{iT}, the parameter associated with trend. If γ_{iT} were negative, any implicit technological or institutional change would be truck intensive. If γ_{iT} were not significantly different from zero, any implicit technological or institutional change would be neutral with respect to modes.

The other parameters have little economic meaning by themselves. However, they can be used to derive elasticities. Uzawa has shown that in the 2 mode case, the elasticity of substitution is:

$$\sigma_{12} = (-\gamma_{11}/S_1S_2) + 1 \qquad (8)$$

Berndt and Wood have shown that Hicksian own-price and cross-price elasticities of demand can be derived as follows:

$$E_{ii} = (\gamma_{ii}/S_i) + S_i - 1 \qquad (9)$$

$$E_{ij} = (\gamma_{ij}/S_i) + S_j$$

Hicksian elasticities describe price responsiveness assuming constant output (i.e., on the same isoquant). In the two factor case, $E_{11} = - E_{12}$ and $E_{22} = -E_{21}$ because the compensated modal elasticities sum to zero. It is also possible to calculate the elasticity of Marshallian ordinary demand from:

$$F_{ij} = (\sigma_{ij} + \eta)S_j \qquad (10)$$

Where η is the own price of the elasticity of the commodity being transported (Oum, Autumn 1979). The Marshallian elasticity allows for the effect of changes in modal rates on commodity prices. For example, if P_1 decreased, prices to grain producers would increase, and/or, prices to buyers would decrease. In either case, the total quantity transported would increase, so there would be a movement to a higher isoquant, and F_{ij} reflects this effect.

B. Empirical Specification and Estimation

Empirical Specification

The translog cost function (5) and the factor share equation (7) form a system of three equations with common parameters. Several possible procedures exist for estimating these parameters. The simplest would be single equation estimation of either of the three equations. However, single equation estimation of any one of the factor share equations would neglect additional information contained in the cost equation. Similarly, single equation estimation of the cost equation would neglect additional information in the modal share equation. An alternative estimation procedure would be to estimate the cost equation jointly with the factor share equations. The effect of this would be to add additional degrees of freedom without adding any unrestricted parameters. As a result, the parameter estimates would be more efficient than applying ordinary least squares to any one of the equations (Christensen and Greene, 1976:662).

Adding a vector of additive error terms to each of the theoretical equations in (5) and (7) gives an empirical specification. At each observation, summation of the factor shares equals one, and summation of the error terms equals zero. Consequently, the disturbance covariance matrix of the full three equation system is singular and nondiagonal and cannot be used for estimation. The parameter estimates can be derived, however, by dropping one of the factor share equations and applying Zellner's technique for efficient estimation. Kmenta and Gilbert have shown that iterating the Zellner estimation procedure yields maximum-likelihood results, and Barten has shown that maximum-likelihood estimates are indifferent to the choice of deleted equation. The truck factor share equation, S_2, was arbitrarily dropped, and the translog cost function was jointly estimated with S_1, subject to the parameter restrictions in equations (3) and (4).

Time-series data are used in this study. Consequently, adjustments need to be introduced into the equation system to allow for potential dynamic behavior of the shippers and the error terms. In particular, a potential exists for lagged responses in modal shares to price changes and serial correlation. The dynamic behavior of decision makers may include a partial adjustment process similar to Nerlove's adjustment model. If the dynamic adjustment process is built into the model, the error term becomes:

$$U_t = \rho U_{t-1} + e_t$$

where ρ is the autocorrelation coefficient assuming a first order autoregressive scheme, U_t is a vector of auto regressive disturbances, and e_t is an error term which is normally, independently distributed with mean zero and constant variance. Including the first order autoregressive scheme in the partial adjustment model gives an error term:

$$e_t = \beta \, (U_t - \rho \, U_{t-1})$$

where β is the partial adjustment coefficient. The dynamic adjustment process is a behavioral hypothesis which is included in the model and empirically tested.

Transformation of the translog cost function and the factor share equation to include a different partial adjustment and autocorrelation coefficient in each, results in two complex equations. The dynamic partial adjustment model with a first order autoregressive process is:

$$\begin{aligned} \ln C = \; & \beta_c[a_0(1 - \rho_c) + a_Q(\ln Q_t - \rho_c \ln Q_{t-1}) + \qquad (10) \\ & a_1(\ln P_{1t} - \rho_c \ln P_{1t-1}) + (1 - a_1)\,(\ln P_{2t} - \rho_c \ln P_{2t-1}) + \\ & \sum_{i=1}^{2} \gamma_{11}(1/2 \ln P^2_{it} - \rho_c \ln P^2_{it-1}) - \\ & \gamma_{11}(\ln P_{1t} \ln P_{2t} - \rho_c \ln P_{1t-1} \ln P_{2t-1}) + \\ & \gamma_{1Q}(\ln P_{1t} \ln Q_t - \rho_c \ln P_{1t-1} \ln Q_{t-1}) - \\ & \gamma_{1Q}(\ln P_{2t} \ln Q_t - \rho_c \ln P_{2t-1} \ln Q_{t-1}) + \\ & (1 - \beta_c - \rho_c)\ln C_{t-1} + \rho_c\,(\beta_c - 1)\ln C_{t-2} + e_{ct} \end{aligned}$$

$$\begin{aligned} S_1 = \; & \beta_s[a_1(1-\rho_s) + \gamma_{11}(\ln \frac{P_1}{P_2}1 - \rho_s \ln \frac{P1}{P_2}\,t-1) + \qquad (11) \\ & \gamma_{1Q}(\ln Q_t - \rho_s \ln Q_{t-1}) + (1 - \beta_s - \rho_s)S_{1t-1} + \\ & \rho_s(\beta_s - 1)S_{1t-2} + e_{1t} \end{aligned}$$

where β_c and β_s are the partial adjustment parameters and ρ_c and ρ_s are the first order autoregressive parameters. If $\beta_c = \beta_s = 1$, then the adjustment process is instantaneous. In this case, the model reduces to an autocorrelated model with no time lag between a change in an exogenous variable and costs or factor shares. If $\rho_c = \rho_s = 0$, the model would be a partial adjustment model without a first order autoregression scheme. In this case β_c and $\beta_s < 1.0$.

The potential for dynamic lags in shippers' responses and autocorrelated error terms are hypotheses which should be tested empirically. Imposing _a priori_ restrictions on any of these parameters, i.e., $\beta_c = 1$ or $\rho_c = 0$, would restrict the model without proper testing. There are four potential time series specifications of the models. These are listed in Table 1 with the

TABLE 1. POTENTIAL DYNAMIC ADJUSTMENT MODELS

Model	Restriction on Parameters[a]
a) Basic	$\beta_c = \beta_s = 1,\ \rho_c = \rho_s = 0$
b) Partial adjustment with autocorrelation	$\beta_c \neq 1,\ \beta_s \neq 1,\ \rho_c \neq 0,\ \rho_s \neq 0$
c) Autocorrelation	$\beta_c = \beta_s = 1,\ \rho_c \neq 0,\ \rho_s \neq 0$
d) Partial adjustment	$\beta_c \neq 1,\ \beta_s \neq 1,\ \rho_c = \rho_s = 0$

[a] β_c and β_s are the partial adjustment coefficients for the cost and factor share equations respectively. ρ_c and ρ_s are the respective first-order autocorrelation coefficients.

corresponding restrictions imposed on the partial adjustment and autocorrelation coefficients. A priori it is not known which of the models in Table 1 is appropriate. Consequently, hypotheses in the form of restrictions placed on each model are tested.

Estimation

The two empirical equations with common parameters form a system of equations, and as discussed above, iterative three stage least squares (IT3SLS) is the appropriate estimation technique. The basic model (a) in Table 1 is linear in parameters and the iterative Zellner technique is used. The other three models are all nonlinear in parameters. The procedure used to estimate the parameters in these models is a combination of the Zellner technique and the Gauss-Newton method of nonlinear least squares. Each model is iterated until the estimates converge. The estimated parameters are equivalent to maximum likelihood estimates. The method is asymptotically efficient, and the tests reported are based on large sample approximations. However, the estimates may not have good small sample properties.

The model specified above implies that P_1 and P_2 are exogenous variables and that the regressors are uncorrelated with the disturbances. However, it is likely that in the case of transportation pricing, P_1 and P_2 should be treated as endogenous variables. Railroad rates, though regulated, have responded to competitive conditions in the past. Truck rates are exempt and do respond to railroad prices and rail car availability. To account for this simultaneity, the method of instrumental variables is used. Estimates using this method are consistent but they are not unbiased. The variables used as instruments were included exogenous variables, market shares, an index of rail car availability, and the wholesale price index.[4] Similar procedures were used in Friedlander and Spady, and Berndt and Wood.

Hypothesis Testing

In the system of equations specified above, two sets of hypotheses were introduced. The first is whether technological or institutional change is neutral with respect to modes. The logic behind this hypothesis was discussed above. From the equations specified, the hypothesis tests whether the trend variable should be included. If it is not included, the model is said to be restricted in that we are imposing Hicks neutral technological and institutional change. If it is included, the model is unrestricted and we allow for non-neutral change associated with time. The second set of hypotheses to be tested is to determine the appropriate form of the time series adjustment. As discussed above, we do not know a priori if a dynamic partial adjustment model is the correct specification. In order to be general, we allow for a partial adjustment process and an associated first order autoregressive scheme, and empirically test to determine the appropriate model. The empirical tests are between the four models listed in Table 1 and the associated restrictions on the partial adjustment and autocorrelated parameters.

These hypotheses are tested in two stages, following Oum (1978). First, we test the hypothesis of neutral technological change in each of the four time series specifications in Table 1. Each model accepted in the first stage is retained and used in the second stage tests. In the second stage, we test to determine which of the time series adjustment models in Table 1 is appropriate. The restricted model in this case is the basic model (a) which is tested against (b), (c), and (d), respectively, and then (c) and (d) are each tested against (b). In the latter case, model (b) is the unrestricted model.

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[4] A rail car availability index was developed from unpublished mid-month shortage and surplus statistics made available by Burlington Northern Railroad.

The technique for testing these hypotheses is that developed by Gallant and Jorgensen. Normally, the likelihood ratio test would be used to test these hypotheses if maximum likelihood estimation procedures were used (Thiel: pp. 396-97). The 3SLS analog of the likelihood ratio test is that developed by Gallant and Jorgensen and allows making statistical inference on the appropriateness of restrictions. The test involves estimating the model first without the restrictions, and then with the restrictions, and comparisons are made across the estimates. It is necessary, however, to use the S matrix (covariance of errors across models) from the unrestricted model in estimation of the restricted model. The null hypothesis is the restriction imposed on the model (i.e., Hicks neutral technological change) versus an unrestricted model. The test statistic is:

$$T^o = n\ (S_r - S_u)$$

where S is the value of the criterion function and the subscripts r and u indicate the restricted and unrestricted model respectively. T^o has an asymptotic chi-square distribution with the number of degrees of freedom equal to the difference between the number of parameters in the unrestricted and restricted models.

III. Data

The system of two equations including the translog cost function and the rail factor share equation were estimated for grain shipments from North Dakota to major terminal markets. The time period of study was from July 1973, to May 1981, and monthly observations were used. The analyses were conducted and the results are presented in two phases. In the first case, the state was used as the origin. In the second case, individual Crop Reporting Districts (CRD) were used as origins (Figure 1). Wheat (hard red spring and durum) and barley were the commodities used in the analysis and separate equations were estimated for each. These grains are traditionally the two most important crops produced in North Dakota. Consequently, they are the two most important grains shipped from the state and normally comprise about 75-80 percent of the grain shipments.

Data necessary for the analysis include shipment and price (or rate) data for each mode. The shipment data were those collected by the North Dakota Public Service Commission. These data represent grain shipments from

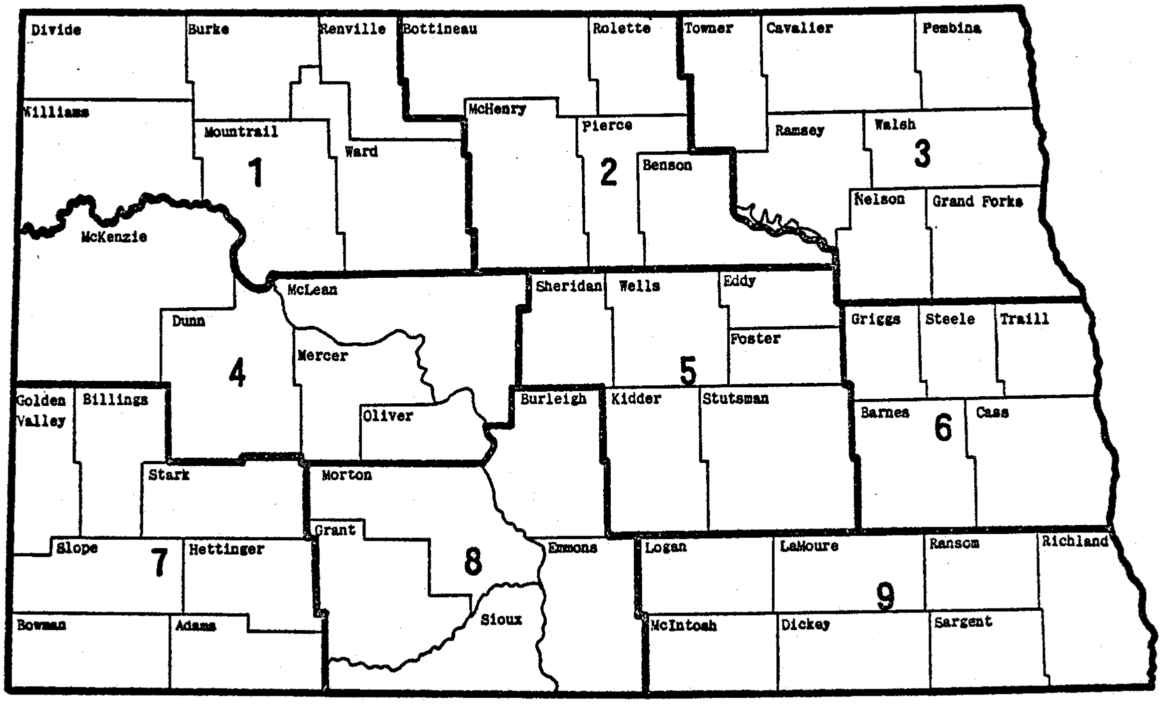

Figure 1. North Dakota Crop Reporting Districts

all licensed warehouses and are reported in bushels by month, origin, mode, type of grain, and destination.

The destinations used in the analysis were Minneapolis and Duluth, and separate equations were estimated for each. These are the principal destinations for North Dakota wheat and barley shipments. The relative importance of these destinations for wheat and barley is shown in Table 2. Minneapolis and Duluth account for about 80 percent of the wheat shipments from North Dakota and about 57 percent of the barley shipments. The third most important destination for North Dakota is the Pacific Northwest. This market could not be used in the analysis because of the inapplicability of truck rate data, which are influenced greatly by back hauls. In fact, truck shipments of grain to the west are normally treated as a back haul to a more predominant front haul movement such as lumber. Further, the rail market share to this destination is relatively large indicating little intermodal competition.[5]

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[5] Intermarket competition is perhaps the more relevant competitive influence affecting railroad pricing and grain shipments to the Pacific Northwest.

TABLE 2. SHIPMENTS OF ALL WHEAT AND BARLEY TO MINNEAPOLIS AND DULUTH AS A PERCENT OF ALL WHEAT AND BARLEY SHIPMENTS, 1978/79

Destination	Wheat	Barley
	percent	percent
Minneapolis	17.4	39.0
Duluth	62.0	18.4

Rail rates were taken from the Minneapolis Grain Exchange Book. A central point was chosen for each of the nine crop reporting districts, and monthly rates were collected for each of the grains to each of the destinations. In the analysis of state shipments, a weighted average rail rate was calculated. The rate from each origin was weighted by the proportion of total movements shipped from that origin relative to the state. The rates from each origin were the same to both destinations during the sample period. However, rates on barley were greater than those on wheat. All rail rates were deflated by the Wholesale Price Index (WPI) with 1967 = 100.

The truck industry is exempt from rate regulation on shipments of agricultural commodities and, consequently, these rates are not published. The unavailability of published truck rates poses problems for empirical analysis. One option is to use an index of truck costs as a proxy for their rates. The implicit assumption here is that truck rates equal their costs and are perhaps more appropriate in longer term (i.e., annual) analyses. Other studies have used truck costs as a proxy for truck rates. See, for example, Koo and Bredvolt (1982a) and Wilson (1980). However, in the shorter term, this may be inappropriate since truck rates respond to demand conditions, especially in light of the fixed rail rates. Truck rates respond to seasonal demands, availability of rail cars, intramodal competition, and intermarket price differentials. But, over the long run, their total revenues must equal total costs.

In this study, we use a proxy for truck rates which is developed from the theory of intermarket price differentials. The following identity shows the relationship between intermarket price differentials and handling and transportation costs:

$$P_D - P_0 \equiv H + P_T \qquad (10)$$

where P_D and P_0 are the price of the commodity at the destination (terminal market) and origin respectively; H and P_T are handling and transportation rates, respectively. All are measured in cents/bushel. In the two mode case, equation (10) becomes:

$$P_D - P_0 \equiv H + P_1\ \delta_1 + P_2\ (1 - \delta_1) \qquad (11)$$

where P_1 and P_2 are the rates for rail and truck respectively and δ_1 is the proportion of grain shipped by rail. Transformation of equation (11) yields an identity for truck rates:

$$P_2 \equiv \frac{P_D - P_0 - H - P_1\delta_1}{(1 - \delta_1)}$$

Given values for each of the variables on the right side of the identity, a value for truck rates (P_2) can be calculated.

In this study, monthly truck rates were calculated for wheat shipments to Duluth and Minneapolis from North Dakota. The rates so calculated are used as a proxy for both wheat and barley to both destinations. H is the country elevator handling margin, and unpublished averages were provided by a local cooperative lending agency. δ_1 is the rail market share and was taken from the grain shipment statistics discussed above. P_D is the price of grain at the terminal market. In this case, we used hard red spring wheat prices at Duluth. Many prices for hard red spring wheat are reported for different levels of protein. The chosen price varied depending on the protein level of the spring wheat crop in that year. P_0 was the state average price received by farmers in North Dakota for hard red spring wheat. The truck rate so derived was deflated by the Wholesale Price Index with 1967 = 100.

The annual average rail rates and truck rates used in this analysis are reported in Table 3. Rail rates for both wheat and barley have increased in real terms since 1973. Rail rates have increased 73 percent for wheat and 74 percent for barley. However, the rates in Table 3 are in constant dollars. Consequently, the increases discussed above are increases greater than the deflator. Truck rates were quite high in 1973 and 1974 relative to rail rates and have since decreased. Those years were characterized by relatively large grain movements and rail car shortages. Rail rates were fixed and unable to readily respond to the increased demand; consequently, trucks were able to charge quite high rates. Since then demand has fallen off, rail cars have become more readily available, and truck rates have decreased.

TABLE 3. ANNUAL STATE AVERAGE RAIL AND TRUCK RATES FROM NORTH DAKOTA TO MINNEAPOLIS AND DULUTH IN 1967 REAL DOLLARS[a]

Year	Rail		Truck[b]
	Wheat	Barley	
	$/bushel in 1967 Dollars		
1973	.22	.27	1.08
1974	.20	.26	.90
1975	.28	.35	.40
1976	.32	.39	.85
1977	.32	.40	.53
1978	.32	.40	.35
1979	.30	.37	.43
1980	.32	.41	.62
1981	.38	.47	.53

[a] Rates to Minneapolis and Duluth are the same.
[b] Truck rates were the same for wheat and barley.

Rail rate data were available for estimation of the models for each crop reporting district. However, calculated truck rate data were not available or could not be calculated for each originating crop reporting district. In lieu of the lack of this data, we used state average rates for each mode, in the demand analysis by origin. The underlying assumption here is that the relative variability of truck rates and rail rates are the same across origins.

IV. Results

Presentation of the results is as follows. First the results of the model estimation for the state are presented. The analysis by individual origins (crop reporting districts) follows. In each case the results of the hypotheses testing are presented first, followed by the parameter estimates of the chosen model and their interpretation. In the final part of this section, implications of the results are discussed.

A. Analysis of Modal Demands in Wheat and Barley Shipments from North Dakota

Hypothesis Testing. The empirical hypotheses were tested in two stages. The first part determined if the hypothesis of Hicks' neutral technological change could be accepted. The second determined the appropriate time series transformation. In the first step, each of the four time series models in Table 1 were estimated with and without imposing the assumption of Hicks neutral technological change. The results of these tests are in Table 4. The results indicate that regardless of which model was chosen for wheat shipments to Duluth, the hypotheses could not be rejected at the 5 percent level. In other words, any implicit technical or institutional change through time has been neutral with respect to modes. In the case of wheat to Minneapolis and barley to Duluth and Minneapolis, the hypothesis depends on which of the time series adjustment processes is accepted.

TABLE 4. TESTS OF THE HYPOTHESES OF NEUTRAL TECHNOLOGICAL CHANGE FOR EACH TIME SERIES MODEL

Commodity and Destination	Basic	Partial Adjustment with Autocorrelation	Autoregression	Partial Adjustment
Wheat				
Duluth	5.57	0.58	1.50	4.15
Minneapolis	11.73*	2.08	0.84	6.77*
Barley				
Duluth	11.19*	1.88	1.02	13.50*
Minneapolis	13.19*	2.10	3.01	0.02

$\chi^2_{.05}$ = 5.99 with 2 degrees of freedom.

*Reject H_0: at 5 percent level of significance.

The second stage of the hypothesis testing determined the appropriate time series transformation. In this case, we empirically tested for the existence of a dynamic partial adjustment process, as well as a first-order autoregressive error structure. In each case, a series of five tests was made. The first three were between the basic model and the models with partial adjustment with autocorrelation, autoregression, and partial adjustment. Trend was included in each of these models depending on the results of the tests in the first stage. The other two tests were between the autoregressive model against the partial adjustment model with autoregression, and the partial adjustment model against the partial adjustment model with autoregression. All tests were based on the 5 percent level of significance. The conclusions of these tests are reported in Table 5.

TABLE 5. SELECTED MODELS FOR WHEAT AND BARLEY SHIPMENTS FROM NORTH DAKOTA

	Duluth	Minneapolis
Wheat	Partial adjustment with autocorrelation	Autoregressive
Barley	NA[1]	Autoregressive

[1] The partial adjustment model with neutral technological change did not converge.

The degrees of freedom were insufficient to test among the models in the case of wheat to Minneapolis. In this case, the selected model was chosen *a posteriori* based on the value of the criterion function. In all cases, neutrality of factor augmentation was accepted. In the case of barley to Duluth, the partial adjustment model with autocorrelation and neutral technological change did not converge. Consequently, it was not possible to test this unrestricted model against the others. The partial adjustment process was accepted in Duluth shipments for wheat, but it was rejected for both grains to Minneapolis.

Parameter Estimates

The parameter estimates for the selected models are reported in Table 6. All the models converged with the exception of that for barley to Duluth.

TABLE 6. IT3SLS PARAMETER ESTIMATES OF EQUATION SYSTEM FOR WHEAT AND BARLEY SHIPMENTS FROM NORTH DAKOTA (ASYMPTOTIC t RATIOS IN PARENTHESES)

Parameter	Wheat Duluth	 Minneapolis	Barley Minneapolis
a_0	-0.03 (0.04)	0.23 (0.08)	0.08 (0.70)
a_Q	1.00 (12.51)	1.00 (29.02)	0.99 (68.15)
a_1	0.32 (0.44)	0.30 (0.79)	0.57 (4.39)
γ_{11}	0.22 (3.83)	0.17 (11.40)	0.06 (6.22)
γ_{1Q}	0.05 (0.71)	0.05 (1.18)	0.05 (3.02)
β_c	0.92 (11.35)		
β_s	0.69 (4.26)		
ρ_c	1.06 (3.70)	0.91 (5.03)	1.04 (3.43)
ρ_s	1.06 (9.48)	1.04 (16.16)	0.93 (7.19)
MSE	0.106	0.127	0.123

Consequently, the results are not reported, but OLS estimates are presented below. Conventional R^2 values for the cost equations all exceeded .90, and those for the factor share equations all exceeded .70. However, these cannot be interpreted directly as in the case of OLS.

The parameters of interest are γ_{11} and γ_{1Q}. In all cases, the asymptotic t ratios for γ_{11} exceeded 2.00. These values are used to derive elasticities. However, γ_{1Q} can be interpreted directly. It indicates the effect of changes in output on factor shares assuming constant modal prices. In all cases, γ_{1Q} exceeded zero and it was asymptotically significant in the case of barley shipments to Minneapolis. That value indicates that for every

1 percent increase in transportation output, the rail factor share would increase by 0.05 percent. Because of the homogeneity condition, $\gamma_{1Q} = -\gamma_{2Q}$, factor shares for trucks would decrease by 0.05 percent. Increases in output would be "rail-intensive" in this case. In the other three cases, γ_{1Q} is not significantly different than zero and increases in output would be neutral with respect to modes.

For comparison purposes, ordinary least squares (OLS) estimates of the factor share equations are presented in Table 7. The partial adjustment and autoregressive coefficients were included to correspond with the models estimated using IT3SLS. The coefficients estimated using OLS are similar to those estimated using IT3SLS. However, the OLS estimates ignore information contained in the system of equations and are embedded with potential simultaneity between P_1 and P_2.[6]

TABLE 7. OLS PARAMETER ESTIMATE OF THE RAIL FACTOR SHARE EQUATION FOR WHEAT AND BARLEY SHIPMENTS FROM NORTH DAKOTA (t RATIOS IN PARENTHESES)

	Wheat		Barley	
Parameter	Duluth	Minneapolis	Duluth	Minneapolis
a_1	-0.01 (0.05)	0.014 (0.08)	1.25 (7.00)	0.64 (8.39)
γ_{11}	0.20 (7.52)	0.18 (15.54)	0.18 (6.40)	0.61 (8.67)
γ_{1Q}	0.80 (3.51)	0.07 (3.49)	-0.10 (4.30)	0.04 (4.26)
β_s	0.90 (12.04)		1.12 (13.00)	
ρ_s	0.73 (8.86)	0.71 (9.60)	(0.80) (11.94)	0.53 (5.71)
R^2	.75	.79	.75	.58

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[6] See the discussion on p. 17.

Elasticities of Demand

The estimated coefficient, γ_{11}, can be used to calculate Hicksian elasticities of demand--or constant output elasticities. These were calculated using mean levels of the factor shares and are presented in Table 8. The results indicate that rail and trucks are substitutes in transportation of grain from North Dakota to the eastern markets. In all cases, both modes are operating in the inelastic portion of their demand function. The own-rate elasticity for trucks is slightly greater than that for rail. Cross-rate elasticities for each mode are also quite low. Throughout the time series, the factor shares were relatively constant, indicating the modes have been pricing in the same range of their demand function. In the most recent year, 1981, rail factor shares were .64 and .56 for wheat to Duluth and Minneapolis, respectively, and .49 and .96 for barley to the two markets, respectively. These are close to the averages over the time series.

TABLE 8. ESTIMATES OF MODAL RATE ELASTICITIES FOR GRAIN SHIPMENTS FROM NORTH DAKOTA AT MEAN LEVELS

	Wheat		Barley	
	Duluth	Minneapolis	Duluth	Minneapolis
Rail Factor Share (S_1)	.61	.54	.45	.93
Truck Factor Share (S_2)	.39	.46	.55	.07
σ_{12}	.08	.32	.27	.08
E_{11} (= $-E_{12}$)	-.03	-.15	-.15	-.0055
E_{22} (= $-E_{21}$)	-.04	-.17	-.12	-.07

B. Analysis of Wheat and Barley Shipments from Individual Origins (CRDs) in North Dakota

Parameters for the translog cost function and rail factor share equation were also estimated from each of nine origin regions (CRD) in North Dakota to Duluth and Minneapolis. The intent of this origin-specific analysis was to examine differences in elasticities across the state. OLS and IT3SLS estimates were derived for each and were similar. Consequently, only the latter are presented.

Hypothesis Testing

Similar procedures to those discussed above were applied to each of the grain shipments. The selected models are presented in Table 9. In several cases it was impossible to test the hypotheses because of zero degrees of freedom. In those cases, the chosen model was that with the lowest value of the criterion function. In seven cases, the quantity of barley shipped was nil which made transformations necessary for the translog function impossible. Those movements were excluded from the remainder of the analysis.

TABLE 9. SELECTED MODELS FROM TESTS OF HYPOTHESES OF NEUTRAL TECHNICAL CHANGE AND DYNAMIC ADJUSTMENT[a]

	Wheat		Barley	
Origin[b]	Duluth	Minneapolis	Duluth	Minneapolis
1	auto[c]	auto	NA	auto
2	partial and auto	auto	auto	auto
3	partial and auto	auto	partial and auto	auto
4	auto	partial and auto	NA	NA
5	partial and auto	partial and auto	auto	auto
6	auto	auto	partial and auto	auto
7	auto	auto	NA	NA
8	auto	auto	NA	NA
9	auto	auto	auto	auto

[a] Five percent level of significance was used in all tests.
[b] See Figure 1 for delineation of origins.
[c] For abbreviation purposes auto indicates the autoregressive model, and partial and auto indicates the partial adjustment model with autocorrelation.

In all cases, the hypotheses of neutral technological change could not be rejected, indicating any implicit trends had a neutral effect on modal shares. The first-order autoregressive model predominated for both barley and wheat shipments. Only in some shipments to Duluth could the partial adjustment be accepted.

Parameter Estimates and Elasticities

The IT3SLS parameter estimates for wheat shipments are reported in Table 10 and those for barley shipments in Table 11. The parameters of particular interest are γ_{11} and γ_{1Q}. The latter indicates the effect of output on factor shares assuming constant factor prices. In the case of wheat, γ_{1Q} was not significantly (asymptotically) different from zero in most cases. Only in wheat shipments from CRD 1, 2, 4, and 7 to Duluth and from CRD 7 to Minneapolis was it different from zero. In all of the cases, the value of the parameter was positive indicating increases in output were rail-intensive. In other words, expansion in transportation output resulted in an increase in rail revenue shares in these cases. Transportation output expansion did not affect factor shares in barley shipments except from CRD 2, 5, and 9 to Minneapolis and CRD 3 and 6 to Duluth. In the case of barley shipments to Duluth, changes in output were truck-intensive (i.e., $\gamma_{1Q} < 0$) and those to Minneapolis were rail-intensive (i.e., $\gamma_{1Q} > 0$).

Own and cross-price elasticities for the constant output demand function were calculated using γ_{11} and S_1 from each origin/destination combination. The revenue share, S_1, used to calculate the elasticities was the average over the time series. These were quite similar to the annual average for each year and are consequently representative. The results are presented in Table 12. The rail revenue share of wheat shipments to Duluth increases moving from the east to the west (CRD 3 to 1, and CRD 6 to 4) away from the terminal market. However, this is not the case in southern North Dakota. There is no apparent systematic behavior of factor shares in the case of wheat to Minneapolis. Both the own-rate and cross-rate elasticities indicate the modes are pricing in the inelastic portion of their demand functions. Consequently, a relatively small diversion of traffic would result from a given change in prices. E_{11} are smallest in northeastern and southeastern North Dakota to both Minneapolis and Duluth.

The rails' revenue share in barley shipments to Duluth is smaller relative to the wheat movements. S_1 ranges around .50 and is somewhat less in extreme eastern North Dakota than the central crop reporting districts. Own and cross-rate elasticities for barley shipments to Duluth were somewhat greater than in the wheat shipments. However, both the rails and trucks are pricing in the inelastic portion of their demand functions. Rail revenue shares are about 90 percent or greater for barley shipments to Duluth. This large rail share is because of an institutional arrangement discouraging truck shipments of barley

TABLE 10. IT3SLS PARAMETER ESTIMATES OF THE EQUATION SYSTEM FOR WHEAT SHIPMENTS BY ORIGIN (ASYMPTOTIC t RATIOS IN PARENTHESIS)

	Origin								
Wheat to Duluth	CRD1	CRD2	CRD3	CRD4	CRD5	CRD6	CRD7	CRD8	CRD9
a_0	-0.07	-0.04	0.33	-0.03	0.002	-0.03	0.007	-0.08	0.18
	(0.10)	(0.04)	(0.23)	(0.31)	(0.00)	(0.04)	(0.03)	(0.65)	(0.71)
a_Q	0.99	1.01	0.96	1.00	1.04	1.00	1.00	1.02	0.97
	(38.33)	(11.22)	(5.29)	(57.86)	(33.27)	(20.55)	(19.84)	(44.61)	(26.17)
a_1	0.19	-0.32	0.10	0.53	0.36	0.59	-0.53	0.52	0.75
	(0.48)	(0.47)	(0.47)	(2.59)	(1.09)	(1.61)	(1.33)	(2.16)	(2.39)
γ_{11}	0.07	0.20	0.22	0.13	0.10	0.16	0.14	0.11	0.14
	(3.23)	(2.46)	(3.13)	(5.13)	(3.85)	(5.80)	(2.84)	(3.30)	(4.62)
γ_{1Q}	0.09	0.17	0.07	0.06	0.07	0.007	0.23	0.06	0.02
	(1.81)	(1.74)	(0.52)	(1.92)	(1.43)	(0.14)	(3.40)	(1.28)	(0.44)
β_c		0.91	0.86						
		(8.44)	(2.95)						
β_s		0.64	0.61						
		(3.13)	(8.58)						
ρ_c	1.02	0.98	1.12	0.80	0.98	1.02	1.13	0.70	1.18
	(6.88)	(4.28)	(2.95)	(3.19)	(5.07)	(5.66)	(5.02)	(3.73)	(4.77)
ρ_s	1.10	1.06	1.07	1.08	1.04	1.05	1.14	0.93	1.02
	(9.67)	(7.42)	(8.58)	(6.07)	(12.37)	(11.26)	(7.69)	(9.28)	(9.79)
MSE	0.119	0.076	0.077	0.040	0.162	0.115	0.019	0.107	0.104
Wheat to Minneapolis									
a_0	0.31	0.14	-0.11	-0.17	-0.28	-0.10	0.08	0.17	0.08
	(0.24)	(0.78)	(0.73)	(0.14)	(0.45)	(0.23)	(0.37)	(0.12)	(0.29)
a_Q	0.94	0.97	1.01	1.04	1.05	1.01	0.99	0.96	0.99
	(25.77)	(29.96)	(43.40)	(14.16)	(9.78)	(25.72)	(25.69)	(16.79)	(30.35)
a_1	0.71	0.64	0.90	0.07	0.57	0.67	-0.25	0.40	0.91
	(1.91)	(1.78)	(3.98)	(0.19)	(1.33)	(2.30)	(0.82)	(1.60)	(2.60)
γ_{11}	0.11	0.16	0.15	0.16	0.18	0.17	0.14	0.11	0.16
	(4.09)	(6.83)	(7.11)	(3.24)	(2.35)	(6.09)	(5.53)	(3.94)	(6.40)
γ_{1Q}	0.02	0.067	-0.003	0.11	0.032	-0.015	0.12	0.03	-0.01
	(0.30)	(0.69)	(0.11)	(1.54)	(0.47)	(0.32)	(2.41)	(0.56)	(0.27)
β_c				0.89	0.85				
				(12.12)	(7.07)				
β_s				0.95	0.76				
				(3.99)	(2.40)				
ρ_c	1.02	0.83	0.90	0.97	1.08	0.96	0.90	1.01	1.04
	(5.79)	(3.33)	(5.51)	(4.16)	(1.98)	(4.52)	(4.35)	(5.59)	(4.42)
ρ_s	1.05	0.94	0.94	1.08	0.97	0.97	1.03	1.01	1.01
	11.75	(3.66)	(6.79)	(6.96)	(5.42)	(14.16)	(11.68)	(21.56)	(7.34)
MSE	0.064	0.103	0.095	0.051	0.047	0.102	0.096	0.085	0.095

TABLE 11. IT3SLS PARAMETER ESTIMATES OF THE EQUATION SYSTEM FOR BARLEY SHIPMENTS BY ORIGIN (ASYMPTOTIC t RATIOS IN PARENTHESES)

	Origin								
Barley to Duluth	CRD1	CRD2	CRD3	CRD4	CRD5	CRD6	CRD7	CRD8	CRD9
a_0	NA	0.004 (0.02)	-0.11 (0.20)	NA	-0.12 (0.86)	0.04 (0.07)	NA	NA	-0.21 (0.65)
a_Q	NA	1.01 (27.39)	1.02 (13.46)	NA	1.03 (37.83)	0.99 (10.02)	NA	NA	1.06 (14.13)
a_1	NA	0.65 (2.23)	0.96 (5.88)	NA	0.56 (2.80)	1.02 (3.75)	NA	NA	0.67 (1.26)
γ_{11}	NA	0.11 (1.62)	0.16 (5.58)	NA	0.16 (2.25)	0.16 (2.68)	NA	NA	0.18 (1.17)
γ_{1Q}	NA	0.006 (0.09)	-0.07 (3.13)	NA	0.025 (0.52)	-0.09 (2.44)	NA	NA	0.007 (0.07)
β_c	NA		0.92 (5.62)	NA		0.89 (8.87)	NA	NA	0.89 (8.71)
β_s	NA		0.31 (0.89)	NA		0.26 (1.42)	NA	NA	0.64 (1.53)
ρ_c	NA	0.86 (2.61)	1.04 (3.89)	NA	0.80 (3.86)	1.32 (2.92)	NA	NA	0.74 (2.67)
ρ_s	NA	1.13 (8.28)	1.11 (2.98)	NA	0.99 (8.21)	0.98 (2.71)	NA	NA	0.98 (4.53)
MSE	NA	0.038	0.053	NA	0.039	0.026	NA	NA	0.035
Barley to Minneapolis									
a_0	0.14 (0.08)	0.008 (0.17)	0.04 (0.80)	NA	-0.002 (0.00)	-0.002 (0.03)	NA	NA	-0.004 (0.13)
a_Q	0.99 (110.79)	0.99 (119.25)	0.99 (167.52)	NA	0.99 (52.33)	1.00 (86.98)	NA	NA	1.00 (181.42)
a_1	0.93 (13.65)	0.83 (5.36)	0.90 (15.47)	NA	0.71 (2.55)	0.78 (3.96)	NA	NA	0.85 (8.67)
γ_{11}	0.01 (0.75)	0.011 (0.16)	0.052 (3.99) 0.01 (1.40)	NA	-0.009 (0.95)	0.07 (4.87)	NA	NA	0.08 (0.62)
γ_{1Q}	0.01 (0.74)	0.023 (2.10)		NA	0.032 (3.99)	0.03 (1.09)	NA	NA	0.02 (2.22)
β_c				NA			NA	NA	
β_s				NA			NA	NA	
ρ_c	1.02 (3.06)	0.82 (1.49)	1.10 (5.29)	NA	0.98 (2.96)	0.70 (2.02)	NA	NA	0.83 (4.18)
ρ_s	0.81 (2.42)	1.06 (4.77)	1.02 (9.58)	NA	0.99 (5.32)	0.90 (3.96)	NA	NA	0.90 (4.60)
MSE	0.033	0.051	0.040	NA	0.067	0.054	NA	NA	0.131

TABLE 12. ESTIMATES OF MODAL RATE ELASTICITIES FOR GRAIN SHIPMENTS BY ORIGINS IN NORTH DAKOTA (AT MEAN LEVELS)

	CRD1	CRD2	CRD3	CRD4	CRD5	CRD6	CRD7	CRD8	CRD9
Wheat to Duluth									
S_1	.79	.64	.51	.79	.67	.47	.58	.65	.77
E_{11} (= $-E_{12}$)	-.12	-.05	-.06	-.04	-.18	-.19	-.18	-.18	-.04
E_{22} (= $-E_{21}$)	-.46	-.08	-.06	-.17	-.37	-.19	-.24	-.33	-.16
Wheat to Minneapolis									
S_1	.64	.74	.76	.56	.58	.34	.30	.26	.65
E_{11} (= $-E_{12}$)	-.18	-.05	-.04	-.15	-.11	-.16	-.23	-.31	-.10
E_{22} = ($-E_{21}$)	-.33	-.12	-.14	-.19	-.15	-.08	-.10	-.11	-.19
Barley to Duluth									
S_1	NA	.54	.41	NA	.53	.45	NA	NA	.55
E_{11} (= $-E_{12}$)	NA	-.26	-.19	NA	-.16	-.28	NA	NA	-.12
E_{22} (= $-E_{21}$)	NA	-.31	-.14	NA	-.19	-.16	NA	NA	-.15
Barley to Minneapolis									
S_1	.97	.95	.93	NA	.89	.92	NA	NA	.94
E_{11} (= $-E_{12}$)	-.02	-.04	-.01	NA	-.12	-.003	NA	NA	.025
E_{22} (= $-E_{21}$)	-.63	-.89	-.19	NA	-.97	-.045	NA	NA	.39

to Minneapolis.[7] The own rate elasticities are extremely small relative to Duluth barley shipments and the wheat shipments. Rail revenue shares of the

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[7] Traditional marketing practices in the malting barley industry have resulted in a preference for barley by rail. A second factor causing the relatively high rail revenue share for barley shipments was the proportional rail rate structure beyond Minneapolis. Inbound rail shipments were required to apply against the proportional outbound rail rate which was less than the flat rate. As a result, inbound shipments by truck were financially penalized and discouraged. These provisions in the inter-market proportional rate structure were changed recently.

barley shipments from CRD 9 do respond to relative prices (γ_{11} = .08). But this value is large relative to the historical value of S_1, and consequently, the calculated elasticity has the incorrect sign--essentially indicating the lack of competition.

V. Conclusion and Implications

The results of the translog demand function can be used to explain the characteristics of the modal demand for grain transportation. They indicate that any implicit technological or institutional change (represented by trend) has not favored one mode over the other. This is not surprising, however, due to the relatively short time span (1973-1981) included in the analysis. A longer time span may indicate changes due to innovations or marketing preferences in the grain industry. The results also indicate that transportation output affects the firm's cost function, as expected, but it also affects revenue shares in a few cases. Generally, output changes are rail intensive in the case of wheat and of barley to Minneapolis. Barley to Duluth, however, exhibited truck intensive changes in output. In other words, if shipments of barley to Duluth increase (decrease), the proportion of revenue spent on trucks would increase (decrease) and that on rail would decrease (increase). The assumption here is that factor prices are constant. However, in all cases, except barley to Duluth, these parameters are relatively small.

The estimated equations also indicate that modal revenue shares are affected by their relative prices. In nearly all cases, the associated parameter was significant. However, the own-rate and cross-rate elasticities calculated from this parameter are all in the inelastic range. Consequently, the railroads, or trucks, have an incentive to increase their rates based on these elasticities. Little diversion of traffic would take place between modes, and revenues and profits would increase. The results indicate that relatively less competition exists in barley shipments to Minneapolis.

This analysis and conclusion, however, does not include the effect of intramodal or intermarket competition. The effect of increased rates on revenues also depends on competition from other firms within the mode and the possibility for implicit or explicit collusive behavior or price leadership arrangements. In past rate-making arrangements, collusive price setting by the rails was permissable and the ICC nearly always approved rate increases. Under the new legislation, this is not possible. The market structure of the railroad industry in North Dakota includes two firms, one of which is predominate, and lends itself to a price leadership arrangement or intense, ruinous competition. By nature of the market structure of the exempt truck industry in North Dakota, it is unlikely that any collusive or price leadership behavior is possible.

The analysis did not examine the effects of changes in modal rates on intermarket competition. The effect of an increase in transportation rates would be to decrease commodity prices at the origin and/or increase those at the destination. Consequently, the total demand for transportation would decrease. The elasticities calculated above were for constant output, derived demand functions. The Marshallian effects of a change in modal rates could also be evaluated. However, this requires knowledge of the price elasticity of demand for the commodity. Given the Hicksian elasticities calculated in this study, the commodity price elasticity would have to be very large before an increase in modal rates would decrease total revenue. The other important aspect in intermarket competition is the effect of relative rates between origins to the same destination. With spatially separated supplies and inelastic demands at the destination, regions compete with each other and transport rates serve the allocation function. The effects of intermarket competitive pressure would have to be evaluated using spatial equilibrium models. The results of this study indicate that the rails have an incentive to increase rates, but the effect of intermarket competition may act as an upper limit. Rate increases beyond that point would result in decreased shipments and revenue.

The thrust of the recent trend toward railroad deregulation was to allow more rate flexibility. As a test of relative competition, the market dominance concept was introduced. The Staggers Act originally defined market dominance by the ratio of revenue to variable cost and by market share. More recently, other qualitative factors such as intermarket competition have been introduced. Problems obviously evolve in quantitative interpretation of market dominance.[8]

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[8] Oum (Autumn 1979) attempted to evaluate relative competition for different shipments by comparing modal rate elasticities.

The purpose of any measure of market dominance is to give an indication as to whether the competitive pressures are sufficient to restrict rail rate increases. At the outset of this study, three types of competitive pressure were discussed. These were intermarket, intermodal, and intramodal competition. This study addressed intermodal competition in the case of grain shipments from North Dakota. The results indicate that the railroads could increase their revenue and profits by increasing rates since little traffic diversion between modes would occur. The study did not analyze the effects of intramodal or intermarket competition. Consequently, any restriction of rail rate increases would have to be from regulation or from intramodal and intermarket competition.

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