

ESTIMATION OF THE DEMAND FOR GRAIN TRANSPORTATION  
IN NORTH DAKOTA

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## ABSTRACT

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The primary study objective was to estimate the demand elasticities for rail and truck transportation for grain from North Dakota to Minneapolis and Duluth. Grain movement data, as well as modal rate and characteristic data, were used to estimate the demand for grain transportation. Demand for transportation is treated as a derived demand and is estimated from a cost approach. This study utilized the translog cost model for estimation. From this model, the elasticities were estimated.

The elasticity estimates indicate that rail is the dominant mode for grain shipments from North Dakota to Minneapolis and Duluth. The elasticities for rail and truck show that the demand for rail transportation is inelastic while the demand for truck transportation is elastic. These results indicate that trucking firms could increase revenue by decreasing prices. However, they do not, which indicates that the trucking industry is pricing near marginal cost. The rail industry is facing an inelastic demand, and by increasing rates, revenue could be increased. As with the trucking example, rail firms do not. This practice indicates that indirect regulation and other factors may be maintaining current rail rates.

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## TABLE OF CONTENTS

ABSTRACT .....	iii
ACKNOWLEDGMENTS.....	iv
LIST OF TABLES.....	vii
LIST OF FIGURES.....	viii
CHAPTER I. INTRODUCTION.....	1
Need for Study.....	1
Problem and Objective of Study.....	4
Hypothesis.....	5
Thesis Organization.....	6
CHAPTER II. LITERATURE REVIEW.....	7
Mathematical Programming Models.....	9
<i>Ad Hoc</i> Models.....	10
Models of Modal Choice.....	13
Derived Demand Models.....	19
CHAPTER III. METHODOLOGY AND DATA.....	23
Background Information.....	23
Derived Demand Theory.....	25
Examined Factors Affecting Demand.....	25
Theoretical Background.....	26
Model Specification.....	31

**TABLE OF CONTENTS (Continued)**

Estimation Procedures.....	32
Data Sources.....	33
<b>CHAPTER IV. RESULTS.....</b>	<b>35</b>
Descriptive Results.....	35
Results of Regression Analysis.....	39
Elasticity Estimates.....	48
<b>CHAPTER V. SUMMARY AND CONCLUSIONS.....</b>	<b>55</b>
Reasons for Study.....	55
Objectives.....	56
Data Sources.....	56
Methodology.....	57
Conclusions and Implications.....	57
Service Characteristic Elasticities.....	60
Limitations and Suggestions for Further Study.....	62
<b>BIBLIOGRAPHY.....</b>	<b>63</b>

## LIST OF TABLES

<u>Table</u>	<u>Page</u>
2.1 Comparison of Elasticity Estimates by Study.....	11
4.1 Share of Specific Commodities from North Dakota to Minneapolis and Duluth, 1996-2001.....	38
4.2 Modal Shares from North Dakota by Commodity and Destination, 1996-2001.....	39
4.3 Shares of Transportation Costs from North Dakota by Commodity and Destination, 1996-2001.....	40
4.4 Parameter Estimates for Wheat to Minneapolis Model Using 3SLS Estimation.....	42
4.5 Parameter Estimates for Wheat to Duluth Model Using 3SLS Estimation.....	43
4.6 Parameter Estimates for Durum to Minneapolis Model Using 3SLS Estimation.....	44
4.7 Parameter Estimates for Durum to Duluth Model Using 3SLS Estimation.....	45
4.8 Parameter Estimates for Barley to Minneapolis Model Using 3SLS Estimation.....	46
4.9 Parameter Estimates for Barley to Duluth Model Using SUR Estimation.....	47
4.10 Elasticity Estimates by Commodity and Destination.....	48
4.11 Estimates of Modal Elasticities for Grain Shipments by CRD (at Mean Levels).....	54

**LIST OF FIGURES**

<u>Figure</u>	<u>Page</u>
3.1 Map of North Dakota Crop Reporting Districts.....	24
4.1 Average Elevator Classification by CRD.....	36
4.2 Shipments to Minneapolis and Duluth by CRD and Commodity.....	37
5.1 Demonstration of the Effects of Increased Fuel Prices.....	59
5.2 Demonstration of the Impact of Linehaul vs. Terminal Costs.....	61

# CHAPTER I

## INTRODUCTION

North Dakota is the leading state in the United States in production of spring wheat, durum wheat, and barley. According to the North Dakota Agricultural Statistics Service, North Dakota's production of spring wheat, durum wheat, and barley in 2000 accounts for 42%, 71%, and 31% of the United States' total production for these commodities respectively. Of the total production for these commodities in 2000-2001, 84-95% is shipped outside the state of North Dakota to processors or terminal markets (Vachal 2001). This volume of grain shipments demonstrates the importance of grain transportation to the marketing of North Dakota's commodities.

Most elevators face two options for grain transportation: truck and rail service. The decision on which mode to choose is dependent on many factors, most importantly of which is the rate associated with each mode. Cost minimization is key when making mode choice decisions for shipping grain. Shipment and elevator characteristics play a role in the selection of modal choice as well. They determine whether an elevator can take advantage of discounted rates, whether additional shipments are needed, geographic location of terminals, and the nature of services available.

### **Need for Study**

The study of the demand for grain transportation in North Dakota is not a new subject. However, the most recent study dates back to 1982. It is likely that the competitive environment for modal shares has changed in 20 years, which this study intends to ascertain.

Estimation of the elasticity of demand for each shipment mode will be a useful tool for understanding the nature of rail-truck competition. As mentioned previously, most North Dakota elevators face two transportation choices: truck and rail. If one mode dominates the other, such as truck dominating rail service, it is likely to be indicated in the elasticity of demand for that mode. If the mode is dominated by its competitor, it will have a high elasticity. A high elasticity shows that a small increase in price causes a shift to the competing mode. Moreover, demand elasticities at different shipment distances will provide insight into the distances where rail and truck compete.

A current and accurate estimation of the elasticity of demand for transportation services is also useful for regulatory purposes. When deciding appropriate prices for transportation services for regulation, the elasticity of demand is useful for determining the amount of dead weight loss (DWL) to society from various pricing alternatives and the effect of any proposed regulated prices on social welfare. In cases where the firm experiences increasing returns to scale, the regulator cannot force marginal cost pricing since it would result in losses to the firm. However, a second best solution is possible by setting price inversely to the elasticity of demand. This practice is referred to as Ramsey Pricing, and when firms have increasing returns to scale ( $MC < AC$ ), Ramsey Pricing can be used to minimize DWL without excessive injury to provider firms.

The market structure due to recent railroad mergers is another issue which regulators are studying. Firms in the railroad industry are characterized as having increasing returns to scale. If a firm does have increasing returns to scale, it means that

the firm may be able to provide service at a lower cost than other firms. Increasing returns to scale implies that there are excess resource costs used to produce a given quantity of service. If further mergers are allowed to take place, the excess resource costs can be minimized, providing further economic efficiency to the industry. The minimization of these costs can improve social welfare, which may offset large price effects from increases in market power. The degree to which these effects may happen is dependent on the demand for transportation.

Knowledge of the elasticity of demand is needed for a transportation firm to maximize profits. The elasticity of demand for transportation would indicate what the effects of pricing changes would have on the firm's revenues. For example, if demand for transportation is inelastic, an increase in price would increase total revenue. Conversely, if demand is elastic, an increase in price would bring about a decrease in revenue. A transportation firm can take advantage of marginal price increases or decreases to add to its revenue by knowing the current elasticity of demand for its particular mode.

Recently, the transportation environment was confronted with fluctuations in the price for fuel inputs. In the summer and fall of 2001, fuel prices were at exceptionally high levels with a consequent impact on the prices for transportation services. Several observers commented on the likely effect of such fuel price increases on freight transport costs. However, knowing the effects depends heavily on knowledge of supply and demand conditions. The effect of increased fuel prices depends on the shape of demand. The relative elasticities of supply and demand will determine the price effect. The increase in fuel prices causes a decrease in supply. If the elasticity of demand is low

relative to the supply, the effect on price would be high. On the other hand, a relatively high elasticity of demand would result in a smaller effect on price change as a result of increase in fuel prices.

Depending on the relative elasticities of supply and demand, the trucking firm would have to, on one hand, increase rates to offset its increased fuel prices. On the other hand, the railroad service provider would also need to increase rates to accommodate the rising variable costs. It can be argued that the degree to which the change in fuel prices would affect each mode should be different, however. The truck shipper is faced with a limited quantity of capacity per load and, therefore, has fewer bushels over which to spread the increased variable cost across. The rail provider, however, has the opportunity to increase train capacity to limit the increased cost compared to the trucking firm.

### **Problem and Objective of Study**

It is not known how the effect of rate changes and transportation characteristics will affect modal choices among North Dakota's elevators. As mentioned previously, the last study on this subject was done in 1982, and the environment may have changed over 20 years due to regulatory issues; increased fuel prices, elevator size and concentration; changes in transportation services, such as shuttle trains; and countless other issues.

The objective of this study is to estimate the demand for transportation services for grain in North Dakota. Also, this study will estimate the price and cross-price elasticities for each transportation mode in the state. The elasticities will provide an estimation of the shift in modal shares based on changes in rates.

The demand for grain transportation is studied as an input or derived demand.

Treating transportation demand in this manner means that transportation services are used as an input to the production process of grain marketing. Essentially, the finished product for grain elevators in North Dakota is grain delivered at the destination. Transportation is an input used to produce the finished product. Therefore, the demand for transportation is derived from its use as an input to the production process. Through duality theory, the demand can be estimated from a cost function approach. A translog transportation cost function will be used to estimate total transportation costs. From this cost function, the modal shares can be derived through Shephard's lemma. The price and cross-price elasticities are derived from these input shares.

The data for this study are obtained from the Grain Movement Database from the Upper Great Plains Transportation Institute, which provides the shipment data for specific commodities from North Dakota elevators to multiple destinations. Rail and truck rates are obtained from BNSF rate books and an estimation of truck rates across the state of North Dakota.

### **Hypothesis**

The hypothesis of this study is that the price and cross-price elasticities of modal demand in grain transportation have changed since 1982, when the previous study was performed. The differences may be due to the changing transportation environment as a result of deregulation, changes in transportation options, mergers, size of elevators, shuttle programs in the state of North Dakota, and the nature of the geographic distribution of elevators across the state.

### **Thesis Organization**

This thesis is organized in five chapters. Chapter I is the Introduction, Need for Study, problem statement and objective, and Hypothesis. Chapter II is a review of past studies which have addressed the issue of transportation demand from different approaches. The models in the past studies examined include ad hoc, mathematical programming studies, Models of Modal Choice, and derived demand approaches. Chapter III provides a description of the theory and methodology behind this study as well as Estimation Procedures. Chapter IV reports the Results of the estimation procedures. Chapter V provides a summary, conclusions and implications of the results, limitations of the study, and suggestions for future studies.

## CHAPTER II

### LITERATURE REVIEW

The literature reviewed in this chapter contains models that endeavor to develop a demand function for transportation modes. The demand model allows researchers to quantify attributes that a shipper will consider when making modal choices for freight shipments. In general, there are four ways in which transportation demand models have been estimated. They are mathematical programming models, models of modal choice, ad hoc demand functions, and derived demand models (Wilson 1982). This study will utilize a derived demand function.

This chapter serves to review literature pertaining to estimating transportation demand. Because of the large amount of studies that have estimated transportation demand, this review does not cover all transportation demand studies. In this section, a number of studies that are representative of this broad array of literature are reviewed. The review is separated into four sections, one for each common type of model. Each section includes an explanation of the type of demand model given, followed by explanations of specific studies using the model. The general findings of the studies are also discussed shortly following the description of the studies, and summarized in Table 2.1 at the conclusion of the review.

Before discussing each type of model, it is useful to keep in mind several cautions in estimating demand models. Oum (1979a and b) voices caution regarding several factors when constructing transportation demand models. Oum (1979a) lists four weaknesses that

transportation demand models may suffer from

1. "The functional form of the model imposes a priori restrictions on the parameters of price responsiveness of demand and intermodal substitution."  
According to Oum, the Cobb-Douglas and Logit demand models impose "unacceptable" restrictions on elasticities of substitution (pg. 374)
2. "Since most models are crudely specified in ad hoc fashion without reference to the underlying technology, the properties of shippers' preference structures cannot be identified from the estimated demand model." (pg. 374)
3. Quality-of-service attributes are often not included in demand models due to lack of data sources.
4. "Many demand models are estimated from data which are too highly aggregated over heterogeneous commodities and regions to achieve reasonable accuracy." (pg. 374)

It is also useful to examine the different types of elasticities that are calculated in the studies. The time frame of the elasticity calculated may have a large effect on the results obtained. In the short run, many agricultural firms are not able to make use of a substitute mode, or the use of a substitute is cost prohibitive. Examples of these barriers are geographic location, technology constraints, or mechanical constraints. In the long run, much of the firm's shipment options are open. The firm can be more responsive to changes in price and or service characteristics when the ability to change its infrastructure is an option. Therefore, the long-run elasticity estimates are likely to be more elastic than the short-run estimates (Oum 1992).

### **Mathematical Programming Models**

Mathematical programming models are based on the concept of minimizing or maximizing an objective function subject to constraints. For transportation demand, this procedure involves minimizing transportation cost for a firm based on commodity supply, demand, and transportation mode characteristic constraints. By optimizing a firm's transportation cost subject to these constraints, a researcher can see the effects of a change in rates or characteristics on a firm's modal choice as well as production choices.

Koo and Thompson (1982) offer a mathematical programming model for studying the transportation demand in the United States. A linear programming model was calculated using truck, rail, and barge modes of transportation to transport from geographic regions of production to geographic regions of consumption and export. The goal was to minimize transport costs, subject to constraints on production, storage, consumption, and transportation capacity. When the transportation objective function is minimized, it represents the minimized transportation and distribution cost for grain transportation in the United States.

One aspect of Koo and Thompson's (1982) study that may be particularly valuable is their estimation of transportation costs. Trucking costs were estimated for both tandem and semi tractor-trailers. The average cost per hundred-weight (cwt.) for a semi tractor-trailer was based on 260 working days per year, 10 working hours in a workday, average truck speed of 50 mph, on the assumption that 84.28 percent of return trip movements were driven empty. From this, Koo and Thompson estimated the average cost per cwt. for semi tractor-trailers based upon costs in 1979 with  $d$  representing distance as

$$AC = 2.224 + 0.24d$$

A similar method was used to estimate tandem trucking costs. While these costs are based upon 1979 cost data, it provides a framework for estimation of truck costs in 2001 terms. Due to the nature of competition in the transportation industry, the truck cost could be used to approximate truck rates. It can be argued that due to the degree of competition in the truck industry, rates are near to marginal cost; therefore, the approximation is valid. Rail and barge costs are also estimated but, for the purposes of this study, are not necessary to examine.

Koo and Thompson (1982) estimated elasticities by variation of the rail and barge rates in the mathematical programming problem. Exact elasticity estimates for rail and barge with respect to own price and cross price, including truck rates, are shown in Table 2.1. It should be noted that, with respect to barge traffic, the own-price elasticity is negative, as should be expected, but the cross elasticity with respect to truck rates is also negative. This suggests that, in the case of this study, truck transportation is a complement to barge transportation.

### **Ad Hoc Models**

Ad hoc models are essentially statistical models that are estimated from a statistical perspective without formal economic theory underlying the model formulation. Fitzsimmons (1981) uses an ad hoc model to calculate elasticity estimates for rail and barge transportation of grain. Time-series data for rail volumes, rail and barge rates, and domestic grain usage are used to estimate the model. The model is a log-linear function that places rail volume as a function of quantity of grain used for domestic consumption,

Table 2.1. Comparison of Elasticity Estimates by Study

Author	Model	Commodity	Variable	Truck	Rail
Koo & Thompson (1982)	Mathematical Programming	Grain	Rail Rate		-1.010
			Barge Rate		8.000
			Truck Rate		2.430
Fitzsimmons (1981)	ad hoc	Grain & Soybeans	Income		0.740
			Rail Rate		-1.121
			Truck Rate		2.430
Miklius et al. (1976)	Logit	Cherries	Rail Rate	4.147	-2.870
			Truck Rate	-1.659	1.140
		Apples	Rail Rate	3.546	-12.57
			Truck Rate	-6.440	10.04
Friedlaender & Spady (1980)	Derived Demand	Food Products	Rail Rate	0.004	-2.583
			Truck Rate	-1.001	-0.023
Wilson (1982)	Derived Demand	Wheat	Rail Rate	0.170	-0.150
			Truck Rate	-0.170	0.150
Oum (1979b)	Derived Demand	Edible Foods	Rail Rate	0.452	-1.006
			Truck Rate	-0.452	1.006

rail rates, and barge rates. Due to possible collinearity problems, the model is transformed to include a ratio of barge rates to rail rates in place of barge rates. The model is estimated using the ordinary least-squares method.

The elasticity estimates are represented by the parameter estimates from Fitzsimmons's (1981) model. The results are shown in Table 2.1 where the parameter

estimates for domestic consumption represents elasticity of rail demand with respect to output. The remaining parameters represent the own price and cross price elasticities for rail transportation. Rail transportation demand is inelastic with respect to output, and the cross-price elasticity with respect to barge rate is elastic. The own-price elasticity for rail grain volume is -1.21.

Although *ad hoc* models have been used to forecast transportation demand and have been indicated to perform reasonably well (Oum 1979b), models have two major shortcomings for investigating price responsiveness and possibilities of cross modal competition. First, the set of variables to include and the functional form to use for the estimation of demand model are arbitrary, yet the parameter estimates are likely to be sensitive to them, and second, in general, neither the structures of shippers' preferences that the ad hoc demand models assume to be approximate nor the properties of approximation are known.

Shippers' choices in modal usage depend on shipment and modal characteristics as well as prices. These characteristics are reflected in the shippers' preferences for modal choice. A simple example of this comes from Miklius et al. (1976). The study quantified the differences in elasticities on the modal preference for the transportation of cherries and apples, two commodities that are very different in their shipment characteristics. A longer-term shipping mode may work with apples that have a longer useful life but would not work with cherries, which are highly perishable. These preferences, as Oum (1979a) states, are not adequately accounted for in the *ad hoc* models.

### **Models of Modal Choice**

Models of modal choice are divided into two main types: aggregate mode-choice studies and disaggregate mode-mode choice studies. Aggregate mode-choice studies are studies which examine shares of a fixed (constant) volume of traffic among modes. These studies focus on the mode choice behavior of a particular geographic region or group of shippers with the same shipment and destination. The aggregate group makes modal share decisions based on transportation and shipment characteristics.

Disaggregate discrete choice models concentrate on the probability that a shipper will make a particular mode choice. “These models investigate users’ travel-choice behavior based on attributes of various modes of transport and individuals’ socio-economic characteristics.” (Oum 1992, pg. 152) These models assume that transportation usage is an “all or nothing” decision. In the case of this study, a disaggregate discrete choice model would limit the shipper to either a rail shipment or a truck shipment. The decision in this model is an either/or decision for the individual shipper.

A mode-choice model is a model in which the dependent variable involves one or more qualitative choices. Quantitative variables measure how much or how many while qualitative variables represent types or categories. For instance, suppose it is of interest to predict voting behavior during an election. Whether the person votes or not is a qualitative variable, however, and must be assigned numerical values if it is to be used in a regression study. Other examples include being a part of the labor force or not or, for the purposes of this paper, a shipper’s preference to use rail or truck transportation. Pindyck and Rubinfeld (1991) states that qualitative models provide a valuable tool to analyze survey

data that involves qualitative responses from the survey participants.

In the past, for both aggregate and disaggregate mode choice studies, logit and probit models have been used to estimate demand for transportation services. These two types of models are qualitative models, and some background on these choice models is given below.

Qualitative models have been used for estimation of demand for transportation services. The two most common types are the probit and logit models. Both of these models are based upon a qualitative choice model that provides the probabilities that an individual will take a certain action. The logit and probit are two examples of generalized linear models. The logit and probit regression models regress a function of the probability that a case falls in a certain category of  $Y$  on a linear combination of  $X$  variables.  $Y$  represents a particular action, such as voting yes or no in an election. For example, if the voter casts his or her ballot for yes,  $Y=1$ ; if the vote is cast for no,  $Y=0$ . The independent variables perform the same use as in the classical normal linear regression model. The slope coefficients tell us the effect of a unit change in  $X$  on a function of the probability of  $Y$ . The probability of  $Y$  is the dependent variable, not  $Y$  itself which is an independent variable. The difference between the logit and probit models is on the left-hand side of the equation. The logit model is the logit of  $Y$ , or the log of the odds that a case falls in one category of  $Y$  versus another.

The logit model has been used extensively for estimation of transportation demand. It is based on the cumulative logistic probability function and is specified as the following for estimation:

$$P_i = F(Z_i) = F(\alpha + \beta X_i) = \frac{1}{1 + e^{-Z_i}} = \frac{1}{1 + e^{-(\alpha + \beta X_i)}}$$

As mentioned above, "the dependent variable in this regression equation is the logarithm of the odds that a particular choice will be made" (Pindyck & Rubinfeld 1991, pg. 251).

Miklius et al. (1976) used a logit model to estimate demand for transportation services. The logit model was also applied to estimate the elasticities and cross elasticities of demand. Two data sets were used: apples and cherries. Cherries were selected because of their high perishability that brings about the necessity for fast, reliable transportation. Apples are storable, so other modal characteristics affect the usage of each mode. The two commodities are expected to bring different elasticities due to the nature of their shipment characteristics. In addition to two commodities, geographic characteristics are used to determine elasticities across different regions. Due to the perishability of cherries, this factor has some importance.

The decision process of a purchaser would be broken down into discrete segments as follows: 1) whether or not to purchase the commodity, 2) what quantity to purchase, 3) from what production area, and 4) what transportation mode to employ. If the decision process of the purchaser is assumed to follow these guidelines, it can also be assumed that the transportation mode decision is separable and can be estimated separately.

The results for Miklius et al. (1976) were elasticities for cherries and apples and are shown in Table 2.1. It should be noted that, for cherries and apples, demand for transportation is very elastic with respect to own-price and cross-prices. Moreover,

elasticities are much higher for apples than for cherries. This large difference is apparently due to a perishability consideration. It is mentioned in the article that, for apples, which are less perishable than cherries, the transport price becomes a more important variable, and rail seems to be the dominant mode of shipment.

The logit model is employed as follows. "For each shipment, the buyer is assumed to be faced with a set of mutually exclusive choices, which may include truck, rail, piggyback, and air. Examination of variables influencing these choices allows an estimation of probability that for a given shipment the buyer will make a particular choice" (Miklius et al. 1976, pg. 218) The elasticities are limited to truck and rail due to geographic and cost considerations. The function itself consists of freight charges, transit times, and variance in transit times for each mode. Since air and piggyback shipments are a very small proportion of shipments, again the function is reduced to truck and rail only.

Some interesting inferences were made from the commodity characteristics in the expected results. First, "for a highly perishable commodity, the probability that a particular mode is chosen is expected to be negatively correlated with its own transit time and positively correlated with the transit time of competing modes" (Miklius et al. 1976, pg. 218) This inference suggests that mode choice depends on service characteristics as well as rates. Second, the value of the product is expected to be correlated with the willingness of a shipper to pay higher freight rates. If the commodity has a high value, there are interest costs associated with the delay in shipment.

Oum (1979a) argues that aggregate logit models are not appropriate to use for studying freight demand functions, especially calculating the price responsiveness of

shippers for three reasons. The first argument is that aggregate logit models impose many a priori restrictions on the parameters of price responsiveness of demand. Second, some aggregate logit models include a ratio of prices as a dependent variable. Third, the structure of preference underlying the aggregate logit model is "severely irregular and inconsistent" (Oum 1979a, pg. 375).

In the estimation of the logit model, the purpose is to estimate the parameters that correspond to the probability of a particular modal choice. Oum (1979a) states that the logarithm of the market share ratio should not be treated as a dependent variable in order to estimate the shippers' responsiveness to price changes in those two modes. This implies that the ratio of market shares should be one of the objectives in estimation of a model, rather than the probability of utilization of a mode.

Oum (1992, pg. 154) states that "mode choice studies are studies which examine shares of a fixed volume of traffic among modes." By applying a logit or similar model to aggregated transportation markets, valuable information may be lost. When aggregated demand is considered, the objective of the study is to find the shifts in modal shares of a fixed quantity of freight transportation. The decision that the firms will make is which mode to use rather than to use a mode at all. Oum states that an aggregate model does not take into account "the effect of a price change on the aggregate volume of traffic" (pg. 154). Theoretically, if the price of transportation increased, firms may choose not to ship at all versus paying higher rates.

Disaggregate discrete choice models assume that "consumption is an all or nothing decision" (Oum 1992, pg. 153). This means that a firm will either ship or not. If the firm

ships freight, it will either choose rail or truck. In disaggregate discrete choice models, the firm is given the opportunity (in the framework of the model) to choose to not ship based on price and service characteristics. In order to estimate consumers' transportation choices for a population or a region, a certain degree of aggregation is required, however. As the degree of aggregation increases, the results become more applicable to a region or population, but the inclusion of non-traveling (or shipping) consumers decreases from the models.

Walid Abdelwahab and Michel Sargious (1992) proposed a system of simultaneous equations to develop a demand model for analyzing transportation demand.

The model is based on the three following equations:

$$I_i^* = X_i\gamma + Y_{1i}\eta_1 + Y_{2i}\eta_2 - \varepsilon_i \quad (1)$$

$$\text{Truck: } Y_{1i} = X_{1i}\beta_1 + \varepsilon_{1i} \quad \text{iff } I_i^* > 0 \quad (2)$$

$$\text{Rail: } Y_{2i} = X_{2i}\beta_2 + \varepsilon_{2i} \quad \text{iff } I_i^* \leq 0 \quad (3)$$

Equation (1) is specified as a binary probit model and represents an unobserved index which determines the modal choice where  $Y_{1i}$  and  $Y_{2i}$  represent endogenous variables that represent the shipment size by mode.  $X$  represents exogenous variables that represent market and modal attributes that total 18 separate variables in all. "The residuals ... are assumed to be serially independent and have a trivariate normal distribution."

(Abdelwahab and Sargious 1992, pg. 54) Due to this covariance structure, the three equations must be estimated as a system of simultaneous equations and estimated by the maximum likelihood method.

From the estimation of the probit model, the elasticities can be calculated.

Abdelwahab and Sargious (1992) make the distinction between disaggregate and aggregate elasticities. Disaggregate elasticity represents "the responsiveness of a shipper's probability of choosing mode i." (Abdelwahab and Sargious 1992, pg. 51) Aggregate elasticity refers to the "responsiveness of shippers' actions for choosing mode i." Since the aggregate elasticity is derived in this case from disaggregate elasticities, the elasticities tend to be more accurate. Aggregate studies make use of average values, a procedure that generally leads to underestimating the population response to the proposed changes. (Oum 1979, Abdelwahab and Sargious 1992) Also, due to the fact that simultaneous equations are used, the total market size does not need to be fixed in order to be estimated. The unique interrelationship between the simultaneous equations demonstrates the effects of prices on the elasticity estimates.

### **Derived Demand Models**

Derived demand models make use of the theory of the firm to obtain transportation demand functions that are consistent with economic theory. Freight transportation has no real value to a firm if the firm has no need for transportation. Therefore, the demand for freight transportation is derived from the demand for a certain good or commodity. When transportation is treated as an input to production, the demand for transportation can be gleaned from a firm's cost function when the function is minimized.

Derived demand models begin with the firm's cost function. "Duality theory implies that if producers minimize input costs of producing given outputs, and if factor prices are exogenous, then the cost function satisfying the usual regularity conditions contains sufficient information to describe completely the corresponding production

technology, and vice versa (Oum 1979b, pg. 151)." The cost function is often expressed in the translog functional form. The following is a representative function:

$$\ln C_s = \alpha_0 + \sum \alpha_i \ln P_i + \sum B_h \ln X_h + \frac{1}{2} \sum_i \sum_j A_{ij} \ln P_i \ln X_h + \frac{1}{2} \sum_h \sum_s C_{hs} \ln X_h \ln X_s,$$

where  $P_i$  = Prices of Inputs

$X_i$  = Characteristics of Inputs

From this optimized cost function, the input demand functions are obtained through the Shephard's Lemma. Differentiation with respect to the price of transportation inputs yields the input share equations for transportation services.

$$\frac{F_i}{C_s} = \frac{\partial \ln C_s}{\partial \ln P_i} = \alpha_i + \sum A_{ij} \ln P_j + \sum B_{ih} \ln X_h$$

$i = T, R$  (Truck and Rail),

where  $F_i$  = Firm expenditures on each mode

Restrictions to ensure homogeneity are imposed. Friedlaender and Spady (1980, pg. 435) state that "since the input share equations are not direct demand equations, we cannot obtain estimates of the elasticity of demand for rail and truck," so the following equations from Berndt and Wood (1975) are used to derive the elasticities.

$$E_{ii} = A_{ii} / S_i + S_i - 1$$

$$E_{ij} = A_{ij} / S_i + S_j$$

$i = L, T, R$  (Labor, Truck, Rail)

In many cases, it is assumed that the firm's transportation costs are separable from its other production costs. This assumption allows the researcher to estimate a

transportation cost function rather than a total cost function. Often, this assumption is necessary due to a lack of information regarding firm production costs and input prices.

Friedlaender and Spady (1980) attempt to provide a model for deriving an explicit freight demand equation from a general cost function. Shephard's Lemma allows the researchers to derive a transportation share equation from the firm's total cost function. Since firms are typically not in long-run equilibrium, the share equation is derived from the firm's short-run cost function. Friedlaender and Spady constructed a short-run cost function, which considered labor, capital, materials and energy, rail transportation, and truck transportation to produce an aggregate output. The firm's cost is a function of output; capital; materials and energy; and price of labor, truck transportation, and rail transportation. The authors treat the price of rail and truck transportation as more than simply the transportation rate for the services. They develop a composite price that considers the effects of modal characteristics on inventory costs.

Wilson (1982) uses a method similar to Friedlaender and Spady. The translog cost function is again used. The cost function in this study is not the total cost function, but rather the total transportation cost function that is called the cost of distribution activities. Wilson assumes that transportation inputs are separable from other inputs; therefore, transportation cost can be examined separately from total cost. Wilson adds a trend variable to the translog function to account for technological changes in transportation and institutional change. Again, symmetry and homogeneity conditions are imposed on the translog cost function. Through the Shephard's Lemma, the modal shares are calculated. The shares represent the proportion of total transportation cost spent on each mode. From

these transportation share equations, elasticities were calculated using the same formulas from Berndt and Wood (1975).

Wilson (1982) studied the demand for grain transportation from North Dakota to selected destinations in Minnesota. This study endeavors to estimate the same demand. The elasticity estimates for the state as a whole are shown in Table 2.1. As mentioned in the Introduction, the hypothesis of this study is to see whether the nature of the grain transportation industry in North Dakota has changed since the last study was performed.

Oum (1979b) assumes that the transportation cost function is separable from the total cost function. In this case, demands for highway, rail, and water transportation are obtained. The price elasticities are calculated by taking the partial derivative of the input demand with respect to price multiplied by the price divided by the input demand.

Oum (1979b) notes that there are "errors in the adjustment to the cost minimizing modal shares." (pg. 154) To his share model, Oum adds a disturbance term to the original transportation share function and imposes linear homogeneity conditions to obtain a new modal share model. The issues of serial correlation and a potential lag in shipper's response to price changes are addressed. There is a possibility of serial correlation in the time series data because of potential cyclical variations in modal shares. The issue of lags in shipper's response to price changes could arise due to contractual obligations of the shippers, imperfect information, capital investment, and nature of shipments. To avoid these potential problems, Oum (1979b) designed three share models: autoregressive, partial adjustment, and a combination of the two.

## **CHAPTER III**

### **METHODOLOGY AND DATA**

This chapter describes the Methodology and Data used to estimate grain transportation modal demand in North Dakota. In summary, pooled cross-sectional and time series grain transportation data from 1996-2001 were gathered, estimated, and organized. Regression analysis was used to analyze these data to obtain modal demand. The following sections describe the background, analysis, and data sources and modifications employed.

#### **Background Information**

This study attempts to quantify responsiveness in grain transportation modal choice based on several characteristics using an econometric model. The representative firm in this case is a typical grain elevator within the state of North Dakota. The commodities shipped from these elevators to be examined are hard red spring wheat (HRS), durum wheat, and barley. It is assumed that these elevators have acted rationally and minimized their production costs by using optimal inputs to produce a given value of output. Two important inputs in producing the final product of grain elevators which is grain at terminal markets are rail and truck transportation. Since railroad service may vary based on the number of cars shipped, a track capacity variable will be included to obtain the effect of rail shipment sizes on demand.

The large number of elevators, and the lack of uniformity in size or capacity in North Dakota present a problem in the area of data collection. This study aggregates the transportation volumes by mode by the nine crop reporting districts (CRDs) in the state.

North Dakota is divided for statistical and research purposes into nine CRDs. Each district is believed to have similar crop and producer characteristics as well as similar geographic locations. A map outlining the different crop reporting districts is shown in Figure 3.1.

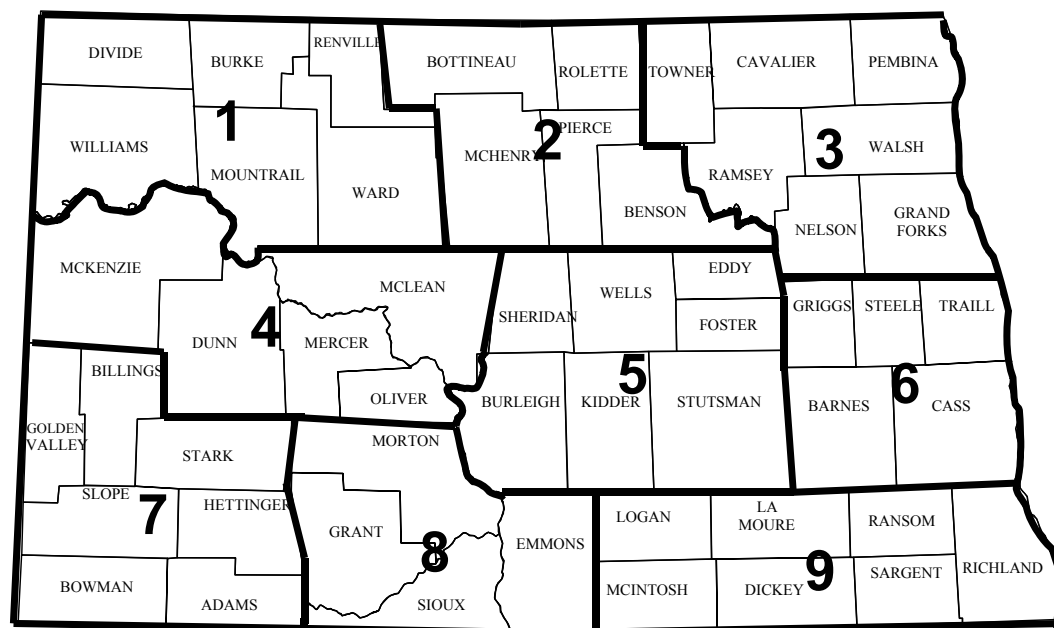


Figure 3.1. Map of North Dakota Crop Reporting Districts.

It is assumed that the elevators in each CRD make decisions in a similar manner as the others in their district. Because rail rates differ by geographic location and elevator size, this study calculated a weighted average rail rate for each CRD, weighted by elevator storage capacity. In calculating this average, each elevator is assumed to use the largest rail shipment size possible. (i.e., use the 52-car rate for 52-car elevators) Thus, rail rates by CRD represent the weighted average available to the elevators. For truck rates, a

representative elevator which is located near the center of the CRD is chosen from each district. The rationale for this approach is that not all modes are available to each elevator in the CRD. By using a representative elevator which represents the combination of the characteristics of all the elevators in the CRD, a cross-section of the elevators' behavior can be obtained.

### **Derived Demand Theory**

Based on the Literature Review, the demand for grain transportation is treated as an input demand or derived demand. The finished product for North Dakota elevators is grain at the destination. Transportation is an input used to achieve the production process. By treating transportation in such a manner, the demand for the services can be obtained through the firm's cost function using Shephard's Lemma. Since the cost function shows the minimum cost of producing a given amount of output, it can be used to describe the firm's production technology (Bitzan 2000). This allows the researcher to estimate input demand through the firm's cost function.

### **Examined Factors Affecting Demand**

When estimating demand for transportation services, it is necessary to establish factors that affect the demand for transportation. The obvious first choice is the rates of the respective modes because rates affect the quantity of transportation service demanded. For grain transportation in North Dakota, these modes are rail and truck transportation. The underlying factor in modal choice is whether it is cost effective.

Other characteristics that may affect elevator modal choice selection also play a part. Average elevator track capacity is included as representative of railroad service.

This variable is included to proxy the quality of service. If an elevator has better service due to an ability to ship in larger volumes, it may be more likely to use rail. Conversely, if an elevator does not have the track capacity to take advantage of unit-train service, for example, the elevator may be less likely to use rail.

Distance to the destination is another factor that affects modal demand. As distance to destination increases, so does the cost of transportation, both for the shipper and the shipping provider. It is assumed that the degree to which each mode will be affected is different.

### **Theoretical Background**

Each elevator is assumed to have a link-specific minimized cost function. This function describes the minimum cost of transporting a given quantity of output to a given destination using optimal combinations of railroad and truck services.

Past studies have assumed that grain transport services are 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" (Wilson 1982, pg. 6). Some studies have gone a step further to assume that transport costs to each destination are separable from total transportation costs. "This implies that each link-specific transportation technology is unaffected by the transportation activity levels of all other links (destinations) and the amounts of non-transport inputs used in the production" (Oum 1979b, pg. 464). The same assumption is made in this study. Therefore, the firms' link-specific transportation cost is estimated separately using a transportation cost function.

Another rationale for the separability of transportation services is the nature of the commodity being shipped. Grain is a low value commodity, and the costs associated with time and storage are low. For higher value commodities, service characteristics and shipment times may attribute more to the total logistics cost for the firm. For this study, however, it is assumed that grain shippers ignore the total logistics cost of shipping grain and minimize the grain shipment costs themselves.

Another restriction on the cost function also applies. Homogeneity of degree one is imposed, suggesting that a one-percent increase in the price of inputs results in a one-percent increase in total cost.

The firm's link-specific transportation cost function can be specified as follows:

$$C = C(w_i, q, t_j)$$

"which [represents] the minimum cost of producing output  $q$ , given prices of  $w$  (factor prices), and technological characteristics of inputs (e.g. length of haul)" (Bitzan 2000, pg. 40).

The given output, in this case, is the total amount of a commodity shipped from an elevator to Duluth or Minneapolis. Factor prices include rail and truck rates. Technological characteristics include elevator track capacity, length of haul, and a time variable to measure changes over time.

In this study, the factors that affect elevator transportation cost have been established. If the elevator's transportation cost function, or even the functional form was known, estimation would be a simple process. However, neither is known. It is necessary to choose a functional form that does not impose many restrictions on what the function

should look like. According to Bitzan (2000, pg. 43), "One way to approximate an unknown function,..., is to perform a Taylor series expansion with a remainder."

Friedlander and Spady (1980) show that the translog cost function can be thought of as a second order Taylor series expansion of an arbitrary function." Following the derivation in Bitzan (1999), an application of the function to this study is below:

$$\ln C(w_i, q, t_i) = \alpha_o + \sum_i \alpha_i \ln w_i + \beta \ln q + \sum_j \gamma_j \ln t_j + \frac{1}{2} \sum_i \phi_i (\ln w_i)^2 + \sum_i \theta_i \ln w_i q + \sum_i \sum_j \omega_{ij} \ln w_i t_i + \frac{1}{2} \rho (\ln q)^2 + \sum_j \zeta_j \ln t_j q + \frac{1}{2} \sum_j \phi_j (\ln t_j)^2 + \varepsilon$$

By applying Shephard's Lemma to this transportation cost function, the factor share equations for each transportation input are obtained. This is the conditional input factor demand. From this, the input price and cross-price elasticities can be estimated.

$$S_i = \frac{\partial \ln C}{\partial \ln w_i} = \frac{\partial \ln C}{\partial C} \frac{\partial C}{\partial w_i} \frac{\partial w_i}{\partial \ln w_i} = \frac{1}{C} x_i w_i = \frac{x_i w_i}{C}$$

The elasticities are obtained from this factor share equation in the following manner:

The general form for own-price elasticity is

$$\varepsilon_{ii} = \frac{\partial x_i}{\partial w_i} \frac{w_i}{x_i}$$

From Shephard's Lemma, we know that

$$\frac{\partial C}{\partial w_i} = x_i$$

This derivation implies that

$$\varepsilon_{ii} = \frac{\partial^2 C}{\partial w_i^2} \frac{w_i}{x_i}$$

It is also known that

$$\frac{\partial \ln C}{\partial \ln w_i} = \frac{\frac{\partial C}{\partial w_i} w_i}{C}$$

By taking the second derivative with respect to  $w_i$ ,

$$\begin{aligned} \Rightarrow \frac{\partial^2 \ln C}{\partial \ln w_i^2} &= \frac{\partial \left( \frac{\frac{\partial \ln C}{\partial \ln w_i} w_i}{C} \right)}{\partial w_i} \frac{\partial w_i}{\partial \ln w_i} \\ &= \left( \frac{\frac{\partial^2 C}{\partial w_i^2} w_i C + \frac{\partial C}{\partial w_i} C - \frac{\partial C}{\partial w_i} \frac{\partial C}{\partial w_i} w_i}{C^2} \right) w_i = \frac{\partial^2 C}{\partial w_i^2} \frac{w_i^2}{C} + \frac{\partial \ln C}{\partial \ln w_i} - \frac{\partial \ln C}{\partial \ln w_i} \frac{\partial \ln C}{\partial \ln w_i} \\ &\Rightarrow \frac{\partial^2 C}{\partial w_i^2} = \frac{C}{w_i^2} \left[ \frac{\partial^2 \ln C}{\partial \ln w_i^2} - \frac{\partial \ln C}{\partial \ln w_i} + \frac{\partial \ln C}{\partial \ln w_i} \frac{\partial \ln C}{\partial \ln w_i} \right] \\ &\Rightarrow \frac{\partial^2 C}{\partial w_i^2} \frac{w_i}{x} = \frac{1}{S_i} \left[ \frac{\partial^2 \ln C}{\partial \ln w_i^2} - \frac{\partial \ln C}{\partial \ln w_i} + \frac{\partial \ln C}{\partial \ln w_i} \frac{\partial \ln C}{\partial \ln w_i} \right] = \varepsilon_{ii} \end{aligned}$$

From the translog

$$\varepsilon_{ii} = \frac{\phi_{ii}}{S_i} - \frac{\alpha_i}{S_i} + \frac{\alpha_i \alpha_i}{S_i} = \frac{\phi_{ii}}{S_i} - 1 + S_i$$

Using a similar procedure, the cross-price elasticities can be determined.

$$\varepsilon_{ij} = \frac{\phi_{ij}}{S_i} + S_j$$

This equation provides the Hicksian or compensated demand for transportation, which describes price responsiveness assuming constant output. It is also of interest to calculate the Marshallian or ordinary demand for grain transportation.

Oum (1979b) and Wilson (1982) estimate the Marshallian elasticities using a similar formula:

$$F_{ij} = (\sigma_{ij} + \lambda_i \eta) S_j ,$$

where  $\sigma = (\alpha_{ij} / S_i S_j) + 1$  which is the elasticity of modal substitution

h = Own-price elasticity of consumer demand for the commodity being transported  
assumed by Oum to equal -1 or unitary elasticity of commodity

l = Proportionate change in price of the commodity with respect to a change in the  
price of the j<sup>th</sup> mode, which is assumed by Oum to equal 0.1

The Marshallian elasticity of demand allows for the effect of changes in modal rates on commodity prices. “For example if  $[w_i]$  decreased, prices to grain producers would increase, and/or prices to buyers would decrease. In either case, the total quantity transported would increase” (Wilson 1982, pg. 9). The elasticity of the Marshallian demand reflects this effect. By varying the level of the own-price elasticity for consumer demand for the commodity being transported, the effect on the Marshallian elasticity may be useful in determining the impact of modal rate changes.

These procedures will provide the short-run elasticity of demand for transportation modal demand. Since the amount shipped by mode is only dependent on the current rate, the rate effect on the current month's shipments is examined. It is possible to get a long-run elasticity of demand for transportation by adding time-lagged rate variables to explain shipments. To account for changes in demand due to different commodities and destinations, six link-specific models are estimated. One model is estimated for each commodity to each destination. As mentioned previously, this provides a link-specific cost and share function model for each commodity and destination. Below is the model specification, which is identical for each of the six models estimated.

### **Model Specification**

The model which this study utilizes for each commodity and destination is

$$\begin{aligned} \ln C(w_i, q, t_i) = & \ln a_0 + a_1 \ln w_1 + a_2 \ln w_2 + b_Q \ln Q + g_1 \ln t_1 + g_2 \\ & \ln t_2 + g_3 \ln t_3 + \frac{1}{2} f_{11} (\ln w_1)^2 + \frac{1}{2} f_{22} (\ln w_2)^2 + f_{12} (\ln w_1 \ln w_2) + q_{1Q} (\ln w_1 \ln Q) + \\ & q_{2Q} (\ln w_2 \ln Q) + w_{11} (\ln w_1 \ln t_1) + w_{12} (\ln w_1 \ln t_2) + w_{13} (\ln w_1 \ln t_3) + w_{21} (\ln w_2 \ln t_1) + \\ & w_{22} (\ln w_2 \ln t_2) + w_{23} (\ln w_2 \ln t_3) + \frac{1}{2} r_{11} (\ln t_1)^2 + \frac{1}{2} r_{22} (\ln t_2)^2 + j_{12} (\ln t_1 \ln t_2) + j_{13} (\ln t_1 \\ & \ln t_3) + j_{23} (\ln t_2 \ln t_3) + z_{1Q} (\ln t_1 \ln Q) + z_{2Q} (\ln t_2 \ln Q) + z_{3Q} (\ln t_3 \ln Q), \end{aligned}$$

where  $w_i$  = Rate for mode  $i$  ( $i$  = rail, truck)

$t_i$  = Service characteristic ( $i$  = capacity, time, distance to destination)

The input share equations obtained through Shephard's Lemma are as follows:

$$S_1 = a_1 + f_{11}\ln w_1 + f_{12}\ln w_2 + q_1\ln Q + w_{11}\ln t_1 + w_{12}\ln t_2 + w_{13}\ln t_3$$

$$S_2 = a_1 + f_{22}\ln w_2 + f_{21}\ln w_1 + q_2\ln Q + w_{21}\ln t_1 + w_{22}\ln t_2 + w_{23}\ln t_3,$$

where  $w_i$  = Rate for mode  $i$  ( $i$  = rail, truck)

$t_i$  = Service characteristic ( $i$  = capacity, time, distance to destination)

### **Estimation Procedures**

The translog transportation cost function and the input share function form a group of three equations with common parameters. Several procedures for estimating these parameters exist. Pindyck and Rubinfeld (1981) indicates, "Each equation could be estimated independently using ordinary least-squares, and consistent and unbiased parameter estimates could be obtained" (Pindyck and Rubinfeld 1981, pg. 308).

However, this estimation procedure may result in lost information. Single equation estimation of any of the share equations may overlook information in the cost equation, and single equation of the cost equation may result in lost information from the share equations.

By simultaneously estimating the cost and share equations, the possibility of lost information from single equation estimation can be avoided. It may be realistic to expect that the equation errors will be correlated. A set of equations that has contemporaneous cross-equation error correlation is called a seemingly unrelated regression (SUR) system. At first look, the equations seem unrelated. However, the model consists of a set of equations that are linked because the error terms across equations are correlated. SAS is

used to estimate the modal share and cost functions simultaneously using the syslin procedure.

The regression model is based upon the assumption that the explanatory variables are independent. Due to the nature of the data used in this model, the initial SUR results will be tested for simultaneity using the Hausman F-Test. “We have seen that when simultaneity is present, one or more of the explanatory variables will be endogenous, and therefore correlated with the disturbance term” (Pindyck & Rubinfeld 1991).

The Hausman F-Test tests for simultaneity using a two-step procedure. The first step involves estimation of the variable being tested for endogeneity as a function of instruments or related exogenous variables. The estimated parameter for the endogenous function replaces the variable in the function, and results are compared.

### **Data Sources**

Much of the data for this study was obtained from the Grain Movement Database at the Upper Great Plains Transportation Institute. The database provides the monthly commodity shipment by mode from elevators in the state of North Dakota. It also provides the track capacity and storage capacity by elevator.

Truck rate data were estimated from a rate estimation approach. A survey of elevators from across the state resulted in an average per-mile rate of \$1.05. Seasonality in truck rates is implied by the nature of the fertilizer backhaul from Minneapolis and Duluth during the spring of the year. As the backhaul will have a large impact on the rate charged to the shipper, seasonality must be included in the estimation of truck rates. This was done by obtaining the average monthly Minneapolis HRS wheat basis index and

applied to the truck cost. Since historical truck rate data are not available, it was necessary to adjust the current rates to accurately represent past rate data. Past data are obtained by adjusting current rates by a trucking producer price index obtained through the Bureau of Labor Statistics.

Railroad rate data was obtained from BNSF. Since rates vary across CRD due to variation in the geographic location of the elevators, an average rate for each CRD must be established. Elevators in any given CRD face different effective rail rates based on their track capacity. To add accuracy to the rail rate by volume, the rail rate is estimated using a weighted average of the rail rates in the CRD by elevator capacity. In estimating this weighted average rate, each elevator's rate is assumed to be the lowest achievable rate based on track capacity.

## CHAPTER IV

### RESULTS

This chapter presents the results of the statistical data analysis. The Descriptive Results section is divided into three parts: elevator characteristics, shipment characteristics, and modal characteristics. The descriptive results are followed by the presentation and discussion of the regression analyses.

#### **Descriptive Results**

To first understand the nature of elevators in North Dakota, the placement of these elevators should be examined. Figure 4.1 shows the number and type of elevator by CRD. If an elevator has no rail service, it is classified as a no rail elevator. If the track capacity is between 1 and 25, it is a single car elevator. If between 26 and 52, it is a multi-car elevator. Finally, if track capacity is 53 or higher, it is classified a unit train elevator.

Figure 4.1 shows that the largest number of elevators in descending order are concentrated in CRD numbers 3, 6, 9, and 5. These CRDs correspond to the three eastern and central crop reporting districts in North Dakota where the majority of wheat and barley are produced. The higher concentration of elevators in this part of the state is indicative of the higher production of HRSW and barley. Large numbers of elevators are unit train elevators in CRDs 1, 3, 6, and 9.

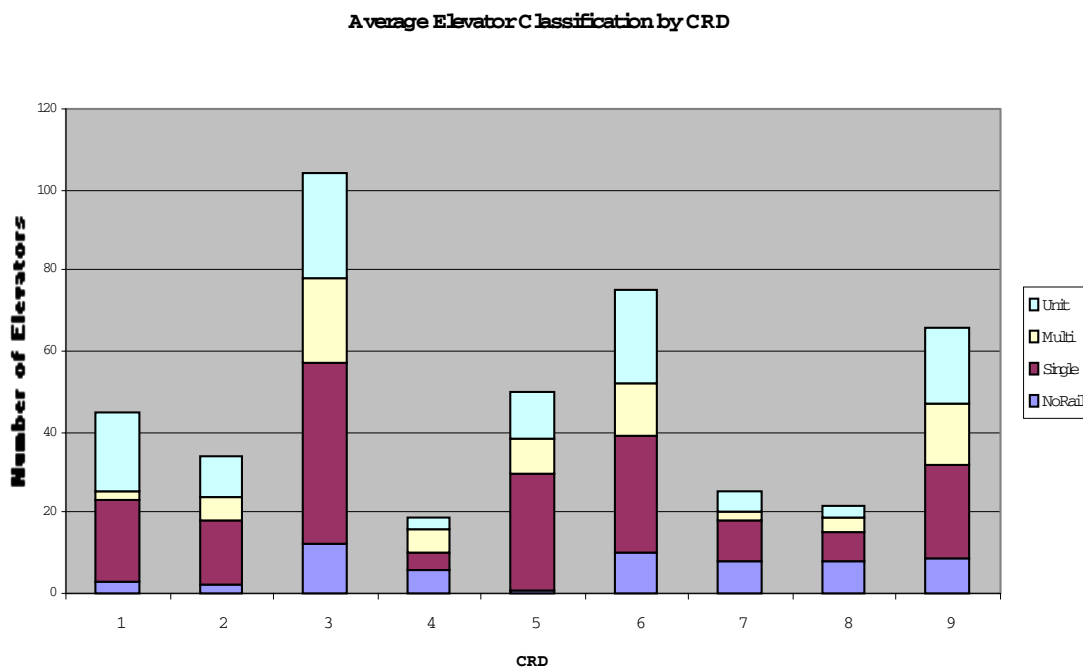


Figure 4.1. Average Elevator Classification by CRD.

Figure 4.1 showed that the highest concentration of elevators is in the eastern portion of the state. Figure 4.2 reinforces the statement that the largest overall production of HRS, durum, and barley is in the eastern portion of the state. Once again, crop reporting districts 3, 6, and 9 have the largest overall quantity of bushels shipped to Minneapolis and Duluth. Crop reporting district 1 is the largest producer of durum wheat in the state, but the smallest in HRS production.

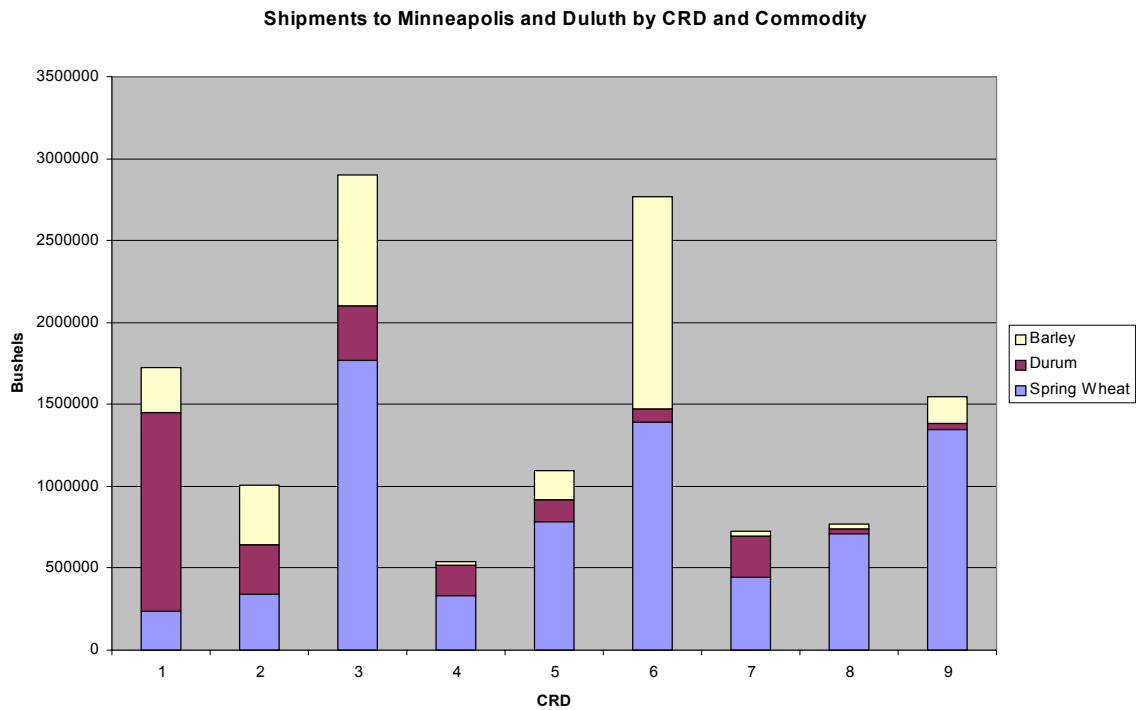


Figure 4.2. Shipments to Minneapolis and Duluth by CRD and Commodity.

This study examines the shipment of these commodities to two different markets: Minneapolis and Duluth. Table 4.1 shows the ratios of shipments to these two destinations. One-third of the HRS wheat is shipped to Duluth and two-thirds to Minneapolis. Durum wheat shipments are similar to HRS wheat shipments while only 14 percent of the barley shipments are shipped to Duluth.

Table 4.1. Share of Specific Commodities from North Dakota to Minneapolis and Duluth, 1996-2001 (Source: Grain Movement Database)

Commodity	Destination	Percentage
Spring Wheat	Minneapolis	67%
	Duluth	33%
Durum Wheat	Minneapolis	71%
	Duluth	29%
Barley	Minneapolis	86%
	Duluth	14%

For each destination, each elevator must make a choice by which mode the commodity will be shipped. Table 4.2 shows the modal shares by commodity and destination for the years 1996-2001. When the destination is Minneapolis, the largest modal share is multi-car rail shipments for HRSW and barley. For durum wheat, the unit-train shipment to Minneapolis is largest. Single-car rail transportation has the smallest modal share for all three commodities being shipped to Minneapolis. When the destination is Duluth, the largest modal share for HRSW and durum wheat is unit-train rail transportation, and for barley, the largest share is multi-car rail transportation. The smallest modal share for Durum wheat and barley is truck transportation, and single-car for spring wheat transportation.

Table 4.2. Modal Shares from North Dakota by Commodity and Destination, 1996-2001  
(Source: Grain Movement Database)

Commodity	Destination	Single	Multi	Unit	Truck
Spring Wheat	Minneapolis	16.48%	30.02%	29.22%	24.26%
	Duluth	9.20%	26.24%	38.93%	25.61%
Durum Wheat	Minneapolis	10.16%	30.87%	48.18%	10.77%
	Duluth	15.02%	29.09%	42.16%	13.72%
Barley	Minneapolis	21.47%	35.07%	21.42%	22.02%
	Duluth	14.62%	40.61%	36.32%	8.43%

### **Results of Regression Analysis**

Six models were estimated to provide results unique to each commodity and destination. The models that were estimated were wheat to Minneapolis, wheat to Duluth, durum to Minneapolis, durum to Duluth, barley to Minneapolis, and barley to Duluth. All six models were initially estimated using Seemingly Unrelated Regression (SUR) analysis.

Once the initial results were obtained, a Hausman F-Test was performed to determine whether the truck and rail rates were endogenous to the system. In all the models except Barley to Duluth, the Hausman F-Test indicated that the truck and rail rates were endogenous to the systems, and a new method of analysis was necessary to estimate the remaining five models. The models that demonstrated endogeneity were estimated using a three-stage least-squares analysis.

For three-stage least-squares analysis, several instrumental variables were chosen to explain the variation in input rates. The instruments included total spring wheat, barley, and durum production in North Dakota; a fertilizer price index; and a fuel price index. The production data were obtained from the North Dakota Agricultural Statistics Service and

reflected annual production for the state of North Dakota in the years in question for this study. The fertilizer and fuel price indexes were obtained from the Bureau of Labor Statistics 2002 website at [http://data.bls.gov/servlet/SurveyOutputServlet?data\\_tool=latest\\_numbers&series\\_id=WPS0571&output\\_view=pct\\_1mth](http://data.bls.gov/servlet/SurveyOutputServlet?data_tool=latest_numbers&series_id=WPS0571&output_view=pct_1mth).

In the parameter estimates, the share of transportation costs attributed to each mode are represented by  $a_r$  for rail transportation and  $a_t$  for truck transportation. In all cases, rail transportation accounts for the highest portion of transportation cost. Table 4.3 shows the transportation cost shares by mode, commodity, and destination.

Table 4.3. Shares of Transportation Costs from North Dakota by Commodity and Destination, 1996-2001

Commodity	Destination	Rail	Truck
Spring Wheat	Minneapolis	71.26%	28.74%
	Duluth	65.07%	34.93%
Durum Wheat	Minneapolis	64.17%	35.83%
	Duluth	53.79%	46.21%
Barley	Minneapolis	72.06%	27.94%
	Duluth	62.76%	37.24%

Table 4.3 shows that the highest cost shares for rail transportation were observed in shipments of spring wheat to Minneapolis and barley to Minneapolis. The largest cost shares for truck transportation occurred in durum shipments to Duluth.

Tables 4.4-4.9 are the parameter estimates for each model. The first order parameters which include the rates for each mode, and the service characteristics have expected signs. It is expected that the parameter estimate for the modal cost shares will be positive. Since increasing track capacity will allow an elevator to reduce the average shipping rate, the sign is expected to be negative. Conversely, the parameter estimate for distance is expected to be positive because increasing distance from the destination is expected to increase cost of transportation. The parameter estimate for quantity is generally 1, which shows that a one-percent increase in quantity shipped leads to a one percent increase in transportation costs.

Table 4.4. Parameter Estimates for Wheat to Minneapolis Model Using 3SLS Estimation.

Parameter	Name	Parameter Estimate	t-Value
$a_0$	Intercept	12.3078*	179.58
$a_R$	$\log(\text{Rail Rate})^a$	0.7126*	28.29
$a_T$	$\log(\text{Truck Rate})^b$	0.2873*	11.41
$b_0$	$\log(\text{Quantity})$	0.9345*	18.24
$g_T$	Time	0.0033	0.75
$g_R$	$\log(\text{Track Capacity})$	-0.3912**	-1.92
$g_D$	$\log(\text{Distance to Minneapolis})$	0.1822	0.91
$f_{TT}$	$1/2 \log(\text{Truck Rate})^{2b}$	-0.1260	-0.96
$f_{RR}$	$1/2 \log(\text{Rail Rate})^{2a}$	-0.1260	-0.96
$f_{TR}$	$\log(\text{Truck Rate}) * \log(\text{Rail Rate})$	0.1260	0.96
$q_{RQ}$	$\log(\text{Rail Rate}) * \log(\text{Quantity})$	0.1957*	10.50
$q_{TQ}$	$\log(\text{Truck Rate}) * \log(\text{Quantity})$	-0.1957*	-10.50
$t_{QQ}$	$1/2 \log(\text{Quantity})^2$	0.0116	0.31
$w_{RT}$	$\log(\text{Rail Rate}) * \text{Time}$	-0.0014**	-2.06
$w_{RC}$	$\log(\text{Rail Rate}) * \log(\text{Track Capacity})^a$	0.3882*	9.67
$w_{RD}$	$\log(\text{Rail Rate}) * \log(\text{Distance})^a$	0.2876*	3.69
$w_{TT}$	$\log(\text{Truck Rate}) * \text{Time}^b$	0.0014**	2.06
$w_{TC}$	$\log(\text{Truck Rate}) * \log(\text{Track Capacity})^b$	-0.3881*	-9.67
$w_{TD}$	$\log(\text{Truck Rate}) * \log(\text{Distance})^b$	-0.2875*	-3.69
$r_{TT}$	$1/2 \text{Time}^2$	-0.0010	-0.90
$r_{RR}$	$1/2 \log(\text{Track Capacity})^2$	-0.1131	-0.40
$r_{DD}$	$1/2 \log(\text{Distance})^2$	5.1518*	5.52
$r_{TR}$	$\text{Time} * \log(\text{Track Capacity})$	-0.0007	0.17
$r_{TD}$	$\text{Time} * \log(\text{Distance})$	-0.0051	-0.89
$r_{RD}$	$\log(\text{Track Capacity}) * \log(\text{Distance})$	1.1241	1.60
$j_{TQ}$	$\text{Time} * \log(\text{Quantity})$	-0.0012	-0.89
$j_{CQ}$	$\log(\text{Track Capacity}) * \log(\text{Quantity})$	0.1338	1.43
$j_{DQ}$	$\log(\text{Distance}) * \log(\text{Quantity})$	0.2706	1.68

<sup>a</sup> Predicted Value of  $\log(\text{Rail Rate})$ .

<sup>b</sup> Predicted Value of  $\log(\text{Truck Rate})$ .

\* Significant at the 1% Level.

\*\* Significant at the 5% Level.

\*\*\* Significant at the 10% Level.

# of Observations = 486.

DW = 1.57.

$R^2 = 0.834$ .

Table 4.5. Parameter Estimates for Wheat to Duluth Model Using 3SLS Estimation.

Parameter	Name	Parameter Estimate	t-Value
$a_0$	Intercept	11.7719*	109.34
$a_R$	$\log(\text{Rail Rate})^a$	0.6570*	22.11
$a_T$	$\log(\text{Truck Rate})^b$	0.3492*	11.87
$b_0$	$\log(\text{Quantity})$	0.8922*	18.85
$g_T$	Time	0.0114	1.52
$g_R$	$\log(\text{Track Capacity})$	-0.3705	-1.09
$g_D$	$\log(\text{Distance to Duluth})$	-2.5842*	-6.14
$f_{TT}$	$1/2 \log(\text{Truck Rate})^{2b}$	0.0657	0.44
$f_{RR}$	$1/2 \log(\text{Rail Rate})^{2a}$	0.6570	0.44
$f_{TR}$	$\log(\text{Truck Rate}) * \log(\text{Rail Rate})$	-0.1657	-0.44
$q_{RQ}$	$\log(\text{Rail Rate}) * \log(\text{Quantity})$	0.1891*	16.28
$q_{TQ}$	$\log(\text{Truck Rate}) * \log(\text{Quantity})$	-0.1891*	-16.28
$t_{QQ}$	$1/2 \log(\text{Quantity})^2$	-0.0167	-0.68
$w_{RT}$	$\log(\text{Rail Rate}) * \text{Time}$	0.0013	1.52
$w_{RC}$	$\log(\text{Rail Rate}) * \log(\text{Track Capacity})^a$	-0.9929***	-1.64
$w_{RD}$	$\log(\text{Rail Rate}) * \log(\text{Distance})^a$	0.8372 *	6.69
$w_{TT}$	$\log(\text{Truck Rate}) * \text{Time}^b$	-0.0013	-1.52
$w_{TC}$	$\log(\text{Truck Rate}) * \log(\text{Track Capacity})^b$	0.9929***	1.64
$w_{TD}$	$\log(\text{Truck Rate}) * \log(\text{Distance})^b$	-0.8372*	-6.69
$r_{TT}$	$1/2 \text{Time}^2$	-0.0002	-1.03
$r_{RR}$	$1/2 \log(\text{Track Capacity})^2$	-0.2454	-0.45
$r_{DD}$	$1/2 \log(\text{Distance})^2$	2.8197	1.37
$r_{TR}$	$\text{Time} * \log(\text{Track Capacity})$	0.0188**	2.27
$r_{TD}$	$\text{Time} * \log(\text{Distance})$	0.0517*	4.19
$r_{RD}$	$\log(\text{Track Capacity}) * \log(\text{Distance})$	-2.9664**	-2.46
$j_{TQ}$	$\text{Time} * \log(\text{Quantity})$	0.0009	0.78
$j_{CQ}$	$\log(\text{Track Capacity}) * \log(\text{Quantity})$	-0.0504	-0.62
$j_{DQ}$	$\log(\text{Distance}) * \log(\text{Quantity})$	-0.0995	-0.58

<sup>a</sup> Predicted Value of  $\log(\text{Rail Rate})$ .

<sup>b</sup> Predicted Value of  $\log(\text{Truck Rate})$ .

\* Significant at the 1% Level.

\*\* Significant at the 5% Level.

\*\*\* Significant at the 10% Level.

# of Observations = 405.

DW = 1.59.

$R^2 = 0.921$ .

Table 4.6. Parameter Estimates for Durum to Minneapolis Model Using 3SLS Estimation.

Parameter	Name	Parameter Estimate	t-Value
$a_0$	Intercept	11.6424*	94.10
$a_R$	$\log(\text{Rail Rate})^a$	0.6417*	17.73
$a_T$	$\log(\text{Truck Rate})^b$	0.3583*	9.90
$b_0$	$\log(\text{Quantity})$	0.9501*	12.66
$g_T$	Time	0.0041	0.50
$g_R$	$\log(\text{Track Capacity})$	-0.2983	-0.73
$g_D$	$\log(\text{Distance to Minneapolis})$	0.7422	1.43
$f_{TT}$	$1/2 \log(\text{Truck Rate})^{2b}$	-0.3711***	-1.85
$f_{RR}$	$1/2 \log(\text{Rail Rate})^{2a}$	-0.3711***	-1.85
$f_{TR}$	$\log(\text{Truck Rate}) * \log(\text{Rail Rate})$	0.3711***	1.85
$q_{RQ}$	$\log(\text{Rail Rate}) * \log(\text{Quantity})$	0.0667*	3.76
$q_{TQ}$	$\log(\text{Truck Rate}) * \log(\text{Quantity})$	-0.0667*	-3.76
$t_{QQ}$	$1/2 \log(\text{Quantity})^2$	-0.0241	-0.57
$w_{RT}$	$\log(\text{Rail Rate}) * \text{Time}$	-0.0009	-0.96
$w_{RC}$	$\log(\text{Rail Rate}) * \log(\text{Track Capacity})^a$	0.1736**	2.32
$w_{RD}$	$\log(\text{Rail Rate}) * \log(\text{Distance})^a$	0.0161	0.15
$w_{TT}$	$\log(\text{Truck Rate}) * \text{Time}^b$	0.0009	0.96
$w_{TC}$	$\log(\text{Truck Rate}) * \log(\text{Track Capacity})^b$	-0.1736**	-2.32
$w_{TD}$	$\log(\text{Truck Rate}) * \log(\text{Distance})^b$	-0.0161	-0.15
$r_{TT}$	$1/2 \text{Time}^2$	-0.0001	-0.53
$r_{RR}$	$1/2 \log(\text{Track Capacity})^2$	-0.7461	-0.84
$r_{DD}$	$1/2 \log(\text{Distance})^2$	-11.5280*	-4.01
$r_{TR}$	$\text{Time} * \log(\text{Track Capacity})$	0.0832	0.95
$r_{TD}$	$\text{Time} * \log(\text{Distance})$	-0.0093	-0.76
$r_{RD}$	$\log(\text{Track Capacity}) * \log(\text{Distance})$	-0.9732	0.64
$j_{TQ}$	$\text{Time} * \log(\text{Quantity})$	-0.0013	-0.70
$j_{CQ}$	$\log(\text{Track Capacity}) * \log(\text{Quantity})$	0.0237	0.15
$j_{DQ}$	$\log(\text{Distance}) * \log(\text{Quantity})$	0.3726***	1.95

<sup>a</sup> Predicted Value of  $\log(\text{Rail Rate})$ .

<sup>b</sup> Predicted Value of  $\log(\text{Truck Rate})$ .

\* Significant at the 1% Level.

\*\* Significant at the 5% Level.

\*\*\* Significant at the 10% Level.

# of Observations = 397.

DW = 1.73.

$R^2 = 0.886$ .

Table 4.7. Parameter Estimates for Durum to Duluth Model Using 3SLS Estimation.

Parameter	Name	Parameter Estimate	t-Value
$a_0$	Intercept	11.1020*	80.25
$a_R$	$\log(\text{Rail Rate})^a$	0.5379*	12.32
$a_T$	$\log(\text{Truck Rate})^b$	0.4620*	10.58
$b_0$	$\log(\text{Quantity})$	1.0827*	22.26
$g_T$	Time	0.0075	0.81
$g_R$	$\log(\text{Track Capacity})$	-0.8594***	-1.83
$g_D$	$\log(\text{Distance to Duluth})$	-1.1201**	-2.29
$f_{TT}$	$1/2 \log(\text{Truck Rate})^{2b}$	-0.6904*	-3.07
$f_{RR}$	$1/2 \log(\text{Rail Rate})^{2a}$	-0.6904*	-3.07
$f_{TR}$	$\log(\text{Truck Rate}) * \log(\text{Rail Rate})$	0.6904	3.07
$q_{RQ}$	$\log(\text{Rail Rate}) * \log(\text{Quantity})$	0.1069*	7.95
$q_{TQ}$	$\log(\text{Truck Rate}) * \log(\text{Quantity})$	-0.1069*	-7.95
$t_{QQ}$	$1/2 \log(\text{Quantity})^2$	0.0435**	1.97
$w_{RT}$	$\log(\text{Rail Rate}) * \text{Time}$	0.0029**	2.34
$w_{RC}$	$\log(\text{Rail Rate}) * \log(\text{Track Capacity})^a$	-0.2018***	-1.77
$w_{RD}$	$\log(\text{Rail Rate}) * \log(\text{Distance})^a$	0.2063**	1.55
$w_{TT}$	$\log(\text{Truck Rate}) * \text{Time}^b$	-0.0029**	-2.34
$w_{TC}$	$\log(\text{Truck Rate}) * \log(\text{Track Capacity})^b$	0.2018***	1.77
$w_{TD}$	$\log(\text{Truck Rate}) * \log(\text{Distance})^b$	-0.2063	-0.46
$r_{TT}$	$1/2 \text{Time}^2$	-0.0001	-0.53
$r_{RR}$	$1/2 \log(\text{Track Capacity})^2$	-1.9216***	-1.72
$r_{DD}$	$1/2 \log(\text{Distance})^2$	-4.6572**	-2.34
$r_{TR}$	$\text{Time} * \log(\text{Track Capacity})$	0.0259**	2.31
$r_{TD}$	$\text{Time} * \log(\text{Distance})$	0.0033	0.28
$r_{RD}$	$\log(\text{Track Capacity}) * \log(\text{Distance})$	-3.0473**	-2.44
$j_{TQ}$	$\text{Time} * \log(\text{Quantity})$	-0.0006	-0.46
$j_{CQ}$	$\log(\text{Track Capacity}) * \log(\text{Quantity})$	0.0419	0.32
$j_{DQ}$	$\log(\text{Distance}) * \log(\text{Quantity})$	-0.0863	-0.72

<sup>a</sup> Predicted Value of  $\log(\text{Rail Rate})$ .

<sup>b</sup> Predicted Value of  $\log(\text{Truck Rate})$ .

\* Significant at the 1% Level.

\*\* Significant at the 5% Level.

\*\*\* Significant at the 10% Level.

# of Observations = 317.

DW = 1.58.

$R^2 = 0.901$ .

Table 4.8. Parameter Estimates for Barley to Minneapolis Model Using 3SLS Estimation.

Parameter	Name	Parameter Estimate	t-Value
$a_0$	Intercept	11.7691*	109.02
$a_R$	$\log(\text{Rail Rate})^a$	0.7207*	25.28
$a_T$	$\log(\text{Truck Rate})^b$	0.2793*	9.80
$b_0$	$\log(\text{Quantity})$	1.0512*	21.67
$g_T$	Time	0.0109	1.57
$g_R$	$\log(\text{Track Capacity})$	-0.7360**	-2.05
$g_D$	$\log(\text{Distance to Minneapolis})$	-0.2947	-0.89
$f_{TT}$	$1/2 \log(\text{Truck Rate})^{2b}$	-0.3540*	-2.58
$f_{RR}$	$1/2 \log(\text{Rail Rate})^{2a}$	-0.3540*	-2.58
$f_{TR}$	$\log(\text{Truck Rate}) * \log(\text{Rail Rate})$	0.3540*	2.58
$q_{RQ}$	$\log(\text{Rail Rate}) * \log(\text{Quantity})$	0.0478*	3.52
$q_{TQ}$	$\log(\text{Truck Rate}) * \log(\text{Quantity})$	-0.0478*	-3.52
$t_{QQ}$	$1/2 \log(\text{Quantity})^2$	-0.0042	-0.13
$w_{RT}$	$\log(\text{Rail Rate}) * \text{Time}$	-0.0018**	-2.22
$w_{RC}$	$\log(\text{Rail Rate}) * \log(\text{Track Capacity})^a$	-0.0580	-0.83
$w_{RD}$	$\log(\text{Rail Rate}) * \log(\text{Distance})^a$	0.7676*	8.97
$w_{TT}$	$\log(\text{Truck Rate}) * \text{Time}^b$	0.0184**	2.22
$w_{TC}$	$\log(\text{Truck Rate}) * \log(\text{Track Capacity})^b$	0.0580	0.83
$w_{TD}$	$\log(\text{Truck Rate}) * \log(\text{Distance})^b$	-0.7676*	-8.97
$r_{TT}$	$1/2 \text{Time}^2$	-0.0003***	-1.83
$r_{RR}$	$1/2 \log(\text{Track Capacity})^2$	-1.0193	-1.31
$r_{DD}$	$1/2 \log(\text{Distance})^2$	-3.0841	-1.60
$r_{TR}$	$\text{Time} * \log(\text{Track Capacity})$	0.0205*	2.61
$r_{TD}$	$\text{Time} * \log(\text{Distance})$	-0.0309*	-3.47
$r_{RD}$	$\log(\text{Track Capacity}) * \log(\text{Distance})$	2.8574**	2.45
$j_{TQ}$	$\text{Time} * \log(\text{Quantity})$	-0.0036*	-2.74
$j_{CQ}$	$\log(\text{Track Capacity}) * \log(\text{Quantity})$	0.1352	1.17
$j_{DQ}$	$\log(\text{Distance}) * \log(\text{Quantity})$	-0.4695*	-2.70

<sup>a</sup> Predicted Value of  $\log(\text{Rail Rate})$ .

<sup>b</sup> Predicted Value of  $\log(\text{Truck Rate})$ .

\* Significant at the 1% Level.

\*\* Significant at the 5% Level.

\*\*\* Significant at the 10% Level.

# of Observations = 389.

DW = 1.41.

$R^2 = 0.899$ .

Table 4.9. Parameter Estimates for Barley to Duluth Model Using SUR Estimation.

Parameter	Name	Parameter Estimate	t-Value
$a_0$	Intercept	11.3683*	40.34
$a_R$	$\log(\text{Rail Rate})^a$	0.6276*	8.61
$a_T$	$\log(\text{Truck Rate})^b$	0.3723*	5.11
$b_0$	$\log(\text{Quantity})$	1.1276*	12.85
$g_T$	Time	-0.0347***	-1.82
$g_R$	$\log(\text{Track Capacity})$	1.3401	1.24
$g_D$	$\log(\text{Distance to Duluth})$	-0.2436	-0.20
$f_{TT}$	$1/2 \log(\text{Truck Rate})^{2b}$	-0.2823***	-1.79
$f_{RR}$	$1/2 \log(\text{Rail Rate})^{2a}$	-0.2823***	-1.79
$f_{TR}$	$\log(\text{Truck Rate}) * \log(\text{Rail Rate})$	0.2823	1.79
$q_{RQ}$	$\log(\text{Rail Rate}) * \log(\text{Quantity})$	0.1010*	5.11
$q_{TQ}$	$\log(\text{Truck Rate}) * \log(\text{Quantity})$	-0.1010*	-5.11
$t_{QQ}$	$1/2 \log(\text{Quantity})^2$	0.0585***	1.79
$w_{RT}$	$\log(\text{Rail Rate}) * \text{Time}$	0.0031	1.49
$w_{RC}$	$\log(\text{Rail Rate}) * \log(\text{Track Capacity})^a$	-0.1190	-0.50
$w_{RD}$	$\log(\text{Rail Rate}) * \log(\text{Distance})^a$	0.6435**	2.12
$w_{TT}$	$\log(\text{Truck Rate}) * \text{Time}^b$	-0.0031	-1.49
$w_{TC}$	$\log(\text{Truck Rate}) * \log(\text{Track Capacity})^b$	0.1190	0.50
$w_{TD}$	$\log(\text{Truck Rate}) * \log(\text{Distance})^b$	-0.6434**	-2.12
$r_{TT}$	$1/2 \text{Time}^2$	0.0008	1.38
$r_{RR}$	$1/2 \log(\text{Track Capacity})^2$	1.9468	0.90
$r_{DD}$	$1/2 \log(\text{Distance})^2$	-1.6721	-0.24
$r_{TR}$	$\text{Time} * \log(\text{Track Capacity})$	-0.0400	-1.02
$r_{TD}$	$\text{Time} * \log(\text{Distance})$	-0.0138	-0.38
$r_{RD}$	$\log(\text{Track Capacity}) * \log(\text{Distance})$	1.4083	0.34
$j_{TQ}$	$\text{Time} * \log(\text{Quantity})$	-0.0042***	-1.77
$j_{CQ}$	$\log(\text{Track Capacity}) * \log(\text{Quantity})$	0.0445	0.13
$j_{DQ}$	$\log(\text{Distance}) * \log(\text{Quantity})$	-0.2710	-0.76

\* Significant at the 1% Level.

\*\* Significant at the 5% Level.

\*\*\* Significant at the 10% Level.

# of Observations = 164.

DW = 1.71.

 $R^2 = 0.901$ .

## Elasticity Estimates

### Own-Price Elasticities

The elasticity of demand of a product or service with respect to its price is called an own-price elasticity. An own-price elasticity measures the responsiveness of demand for a product or service to changes in its price. All estimates for own-price elasticities are expected to be negative. For each of the six models, the own-price elasticity was estimated, and the results are shown in Table 4.10.

Table 4.10. Elasticity Estimates by Commodity and Destination.

	Spring Wheat		Durum Wheat		Barley	
	Minneapolis	Duluth	Minneapolis	Duluth	Minneapolis	Duluth
<u>Own-Price</u>						
Rail	-0.464	-0.248	-0.937	-1.745	-0.771	-0.822
Truck	-1.151	-0.463	-1.678	-2.032	-1.988	-1.386
<u>Cross-Price</u>						
Rail-Truck	0.464	0.248	0.937	1.745	0.771	0.822
Truck-Rail	1.151	0.463	1.678	2.032	1.988	1.386
<u>Service Characteristics</u>						
Rail-Q	1.209	1.183	1.054	1.281	1.118	1.289
Truck-Q	0.253	0.351	0.764	0.851	0.880	0.856
Rail-Dist	0.586	-1.298	0.993	-0.737	0.773	0.782
Truck-Dist	-0.818	-4.982	0.293	-1.567	-3.043	-1.972
Rail-RCar	0.154	-0.523	-0.028	-1.235	-0.816	1.151
Truck-RCar	-1.168	-2.300	0.258	-0.683	-0.087	0.076

The rail own-price elasticity estimates are predominantly inelastic with the exception of the elastic estimate from the durum to Duluth model and the near unit-elastic estimate for the durum to Minneapolis model. For both destinations in the durum and barley models, the elasticity estimate for destination Duluth was higher than the estimate to Minneapolis. In both cases, the share of the total shipments to Minneapolis and Duluth that is shipped to Duluth is smaller than wheat shipments.

The truck own-price elasticity estimates are predominantly elastic with one exception which is the wheat to Duluth model. The elasticity estimates range from -2.032 for durum to Duluth to -0.463 for wheat to Duluth. The higher elasticity estimates indicate that the demand for truck transportation is almost always twice as responsive to rate changes than rail transportation. For the wheat and barley models, the truck own-price elasticity estimates are higher to Minneapolis than to Duluth.

In most cases, the own-price elasticity for truck transportation was elastic and much higher than the own-price elasticities for rail transportation, which in all but one case were inelastic. An interesting finding from Table 4.10 is that own-price elasticities for rail are still in the inelastic range despite deregulation in 1980. This finding seems to suggest that there are still some regulatory constraints on rail rates, as no firm would voluntarily price in the inelastic portion of demand. This finding also shows that rail is the dominant mode where a one percent increase in truck price will decrease quantity shipped by truck more than one-percent and would decrease revenue. Meanwhile, a one percent reduction in price will increase truck traffic more than one percent and increase revenue. It is conceivable that

truck transportation providers are pricing close to marginal cost and, therefore, unable to take advantage of the higher revenues possible with decreased prices.

#### Cross-Price Elasticities

Cross-price elasticities represent the change in demand for a transportation mode due to changes in the rate of the competing mode. In this case, the rail-truck cross-price elasticity represents the change in the demand for rail transportation due to changes in truck rates. The elasticity estimates are shown in Table 4.9. All estimates of the cross-price elasticities are positive, which indicates that rail and truck transportation for grain shipments are substitutes.

The cross-price elasticities for rail transportation with respect to truck rates vary from 0.248 for wheat to Duluth to 1.745 for durum to Duluth. For barley and durum, the cross-price elasticity is highest to Duluth.

The cross-price elasticities for truck transportation with respect to rail rates range from 0.462 for wheat to Duluth to 2.032 for durum to Duluth. In all cases the cross-price elasticity for truck transportation with respect to rail rate is higher than the cross-price elasticity for rail transportation with respect to truck rate. As mentioned on the previous page, truck providers are likely to not be able to reduce price to acquire a higher market share due to the fact that they are pricing near marginal cost.

#### Service Characteristic Elasticities

Three elevator service characteristics were used in the models to estimate demand for transportation. They are quantity shipped, distance to destination, and track capacity. The service characteristic elasticity shows the responsiveness of demand for a particular

mode to changes in a service characteristic. The elasticity estimates are shown in Table 4.10.

The elasticities for both modes with respect to quantity shipped represent the increase in modal usage to compensate for an increase in quantity. The values are expected to be positive.

The elasticity for rail with respect to quantity shipped ranges from 1.054 for durum to Minneapolis to 1.289 for barley to Duluth. The elasticity for truck transportation with respect to quantity shipped ranges from 0.253 for wheat to Minneapolis to 0.856 for barley to Duluth. By comparing the estimates for the two modes, it can be seen that, as quantity shipped increases, a higher proportion of the grain shipped will be shipped via rail than truck. For the barley models, the service characteristic elasticity for quantity shipped is similar for truck and rail transportation, or of less variation than the wheat and durum models.

The elasticity of both modes with respect to distance represents the responsiveness of demand for each mode with respect to changes in distance. It is expected that demand for truck transportation will decrease as distance increases, which will be shown with a negative elasticity.

The elasticity of rail with respect to distance ranges from -1.298 to 0.782 for wheat to Duluth and barley to Duluth, respectively. Two models indicate that the demand of rail transportation will decrease as distance increases. These models are wheat to Duluth and durum to Duluth.

The elasticity of truck transportation with respect to distance ranges from -4.982 for wheat to Duluth to 0.293 for durum to Minneapolis. As mentioned above, it was expected that the elasticities for truck transportation with respect to distance would be negative. The durum to Minneapolis model estimates the elasticity at 0.293. All models suggest an increase in rail share and a decrease in truck share with distance.

The final service characteristic elasticity is the modes with respect to elevator track capacity. As elevator track capacity increases, the elevator is able to take advantage of the improved rail service as train size increases. It is expected that, as track capacity increases, the demand for rail transportation will increase because it may become a cheaper alternative, and truck transportation will decrease because it is a less attractive option.

The estimates for the elasticity of demand for truck transportation with respect to track capacity are as expected with the exception of durum to Minneapolis. The values are negative, which indicates that a decrease in usage of truck transportation when track capacity and the opportunity to take advantage of better rail service increases.

The estimates for the elasticity of demand for rail transportation with respect to track capacity are not as expected. The wheat to Minneapolis and barley to Duluth models returned estimates that were consistent with expectations by their positive values. For these models, as track capacity increases, the demand for truck transportation decreases. The remaining models that were estimated returned elasticities that were negative which indicate that, as track capacity increases, demand for rail transportation decreases.

### CRD-Specific Elasticities

Table 4.11 shows the own-price elasticities for each of the nine CRDs in North Dakota except CRD 4 and CRD 8 which were dropped from the initial regression due to lack of data. As Table 4.11 shows, the own-price elasticity for truck transportation increases as the distance from the destination increases. For CRDs located in the western part of the state (1 and 7), the truck transportation is more elastic than in the eastern part of the state (3 and 9). Perhaps more notable than the increase in the elasticity of truck transportation with respect to distance is the decrease in the own-price elasticity for rail transportation with an increase in distance. This increase demonstrates that, as distance from the destination increases, the demand for rail transportation becomes less responsive to price while truck transportation increases in responsiveness to price changes. Rail becomes more dominant even though truck transportation is more elastic. Truck transportation is also priced closer to marginal cost, so it cannot reduce price.

Table 4.11. Estimates of Modal Elasticities for Grain Shipments by CRD (at Mean Levels)

	CRD1	CRD2	CRD3	CRD5	CRD6	CRD7	CRD9
<u>Wheat to Minneapolis</u>							
$E_{TT}$	-1.95	-1.52	-1.71	-0.65	-1.13	-1.73	-0.90
$E_{RR}$	-0.26	-0.33	-0.29	-0.85	-0.47	-0.28	-0.62
<u>Wheat to Duluth</u>							
$E_{TT}$	-0.46	-0.48	-0.46	-0.42	-0.48	N/A	-0.39
$E_{RR}$	-0.11	-0.19	-0.24	-0.07	-0.18	N/A	-0.33
<u>Barley to Minneapolis</u>							
$E_{TT}$	-11.7	-3.87	-2.42	-1.49	-1.21	-0.62	-1.13
$E_{RR}$	-0.39	-0.51	-0.66	-0.98	-1.19	-2.68	-1.29
<u>Barley to Duluth</u>							
$E_{TT}$	-3.04	-15.3	-2.26	-1.92	-2.76	N/A	-1.25
$E_{RR}$	-0.45	-0.30	-0.54	-0.61	-0.47	N/A	-0.90
<u>Durum to Minneapolis</u>							
$E_{TT}$	-5.79	-1.69	-2.04	-0.93	-1.13	-2.67	-1.16
$E_{RR}$	-0.47	-0.92	-0.79	-1.68	-1.35	-0.66	-1.32
<u>Durum to Duluth</u>							
$E_{TT}$	-8.97	-3.10	-1.79	-2.78	-2.01	-2.91	-2.06
$E_{RR}$	-0.84	-1.25	-1.97	-1.35	-1.76	-0.73	-1.71

## **CHAPTER V**

### **SUMMARY AND CONCLUSIONS**

This chapter summarizes the research project and draws conclusions about the results obtained from this study. The first part of this chapter reviews the need for study, research objectives, and methods of the study. Conclusions and implications drawn from the research are discussed in the next section followed by the limitations of this study. The final section discusses the need for further study based on the research limitations.

#### **Reasons for Study**

A current and accurate estimation of the elasticity of demand for grain transportation services is necessary for several reasons. First, a firm needs to know the elasticity of demand when making production and pricing decisions. This knowledge allows the firm to realize the impact of pricing change decision on revenue. If a firm faces inelastic demand, a price increase will increase revenue. Conversely, if the firm faces elastic demand, a price reduction will increase revenue.

The elasticity of demand is also of use in making regulatory decisions. When regulators attempt to minimize DWL by regulating transportation prices, knowledge of the nature of demand is necessary to determine the amount of DWL and the proper rate structure to minimize it. Determining impact of present and future mergers on social welfare is also a use for the elasticity of demand.

Finally, the effects of transportation firm input prices are likely to affect transportation rates. Knowledge of the elasticity of demand relative to the elasticity of

supply allows a researcher information on the likely increase or decrease in rates due to changes in input prices.

### **Objectives**

Changes in the grain transportation environment may have affected the demand for grain transportation services. The overall objective of this thesis was to estimate elasticity of demand for rail and truck transportation, and compare the estimated values to past studies. Specific objectives of this thesis were to

1. Estimate own-price and cross-price elasticities for truck and rail grain transportation.
2. Identify shipment and shipping characteristics that may affect demand for transportation and include them in the estimation.
3. Estimate characteristic elasticities to determine estimated effect of characteristic on demand for each respective mode.

### **Data Sources**

Grain shipment data were obtained from the Grain Movement Database at the Upper Great Plains Transportation Institute at North Dakota State University. Rail rate data was obtained from BNSF rate books through the website <http://www.bnsf.com>. A weighted average of these rates was taken by CRD to represent an accurate price facing North Dakota shippers. Truck rate data was estimated using diesel fuel, fertilizer, and truck producer price indices obtained through the Bureau of Labor Statistics (BLS). The base rate per mile was obtained through reports from grain elevators across the state of North Dakota.

### **Methodology**

The demand for grain transportation was treated as a derived demand and estimated from a cost approach. Through Shephard's Lemma, the modal shares were obtained from the transportation function. The translog functional form was chosen for the transportation cost function due to the fact that the translog form is flexible and does not impose many restrictions on what the function should look like. In addition to the rate variables, several service characteristics were added to the function. These variables included time, length of haul, and average track capacity.

Six models were estimated using a Seemingly Unrelated Regression approach in SAS. The transportation cost function and one modal share equation were estimated simultaneously. Once the initial results were obtained, truck and rail rates were tested for endogeneity using a Hausman F-Test. Five of the six models indicated endogeneity in truck and rail rates and were estimated using a 3 Stage Least-Squares approach to correct for endogeneity. The remaining model, which did not indicate endogeneity, was estimated using an SUR approach. From the estimated cost and share equations, the own-price, cross-price, and service characteristic elasticities were obtained using the formulas from Berndt and Wood (1975).

### **Conclusions and Implications**

The descriptive statistics presented in the Results chapter demonstrate that the dominant mode is rail transportation. By modal shares, across all models, at least three-quarters of all shipments are shipped by rail. By shares of transportation cost, rail accounts

for the largest share. The majority of shipments and the majority of transportation cost are attributed to rail transportation.

The own-price elasticities back up the statement made in the previous paragraph. Truck own-price elasticities are, with the exception of one case (spring wheat to Duluth), greater than unit elastic, where rail own-price elasticities are mostly inelastic. As mentioned in the Introduction, a mode with a high own-price elasticity indicates that the mode is dominated by its competitor.

A truck carrier may look at the elasticity of demand for its service and notice that a one-percent decrease in price will bring about a greater than one-percent increase in truck shipments, therefore increasing revenue. It is likely that such carriers are not able to reduce rates since they are already near marginal cost. The own-price elasticities for truck transportation seem to indicate that the trucking firms are pricing near to marginal cost, and a further price reduction would result in decreased profits.

By the same token, a rail service provider faces inelastic demand for rail transportation in all cases except durum to Duluth. A one-percent increase in rail rate would result in a less than one-percent decrease in traffic, therefore increasing revenue. The situation is the exact opposite of truck providers. The maximum reasonable rate (MRR) guidelines serve as a deterrent for unwarranted rate increases. If a rate increase is deemed unacceptable by shippers or other organizations, it can be challenged and possibly reversed. The fact that the rail providers do not substantially raise rail rates to the point where demand is elastic may show that regulation or the threat of regulation is effective in minimizing rate increases.

Increased fuel prices may or may not have an effect on the rates for transportation services. Whether or how much they might depend on the relative shape of supply and demand. Figure 5.1 demonstrates the effects of increased fuel prices on the price of transportation services. It is a simplified model used to demonstrate the concept rather than a representation of the current situation due to the lack of information on the current supply elasticities for transportation.

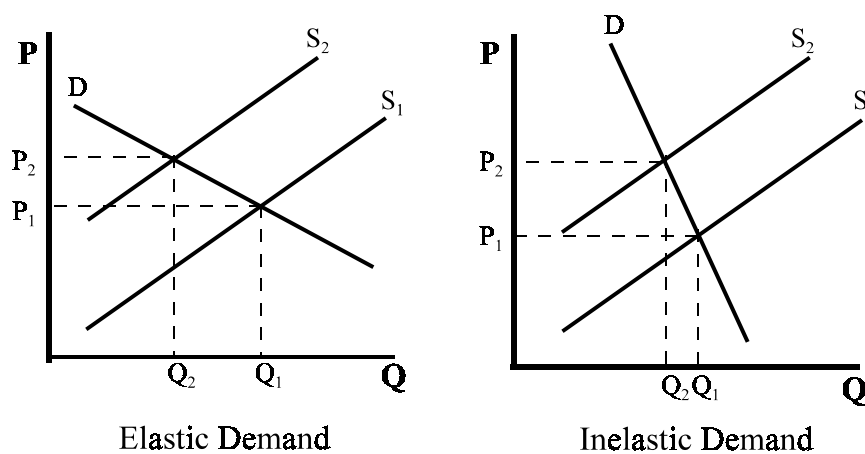


Figure 5.1. Demonstration of Effects of Increased Fuel Prices.

Figure 5.1 shows two different supply and demand scenarios for transportation. In both situations, supply is held constant to demonstrate the principle. An increase in fuel price would result in a shift in supply from  $S_1$  to  $S_2$ . Demand would remain constant. When demand is elastic, the magnitude of the change in price due to the supply shift is small in comparison to the shift when demand is inelastic. If demand is inelastic, the fuel

price increases are passed on to the consumers through increased prices. If there is inelastic demand, the producer bears the price increase.

In the two modes examined in this study, one is elastic, and the other is inelastic. While the actual elasticity of supply for each mode is not known, the possible effects of a fuel price increase can be approximated assuming the elasticities of supply are similar. Since truck demand is elastic, it is reasonable to assume that an increase in fuel prices would be primarily absorbed by trucking firms. Rail transportation has an inelastic demand. Therefore, increases in fuel prices would be passed on to rail transportation consumers through increases in rail rates.

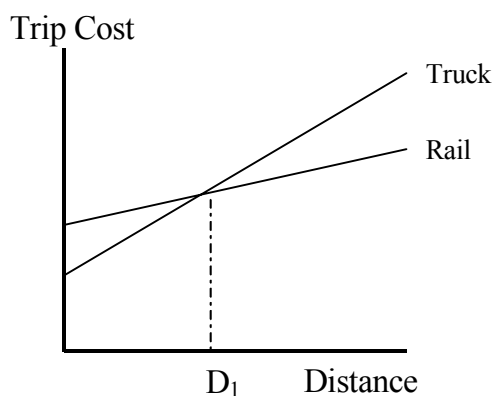
### **Service Characteristic Elasticities**

The first characteristic elasticity measured the change in demand for rail or truck brought about by changes in the total quantity shipped from an elevator. As the Results chapter showed, the elasticity for rail service with respect to quantity shipped was always greater than unit elastic while the truck elasticities were always inelastic. There are two possible implications of this difference in mode elasticities. First, it demonstrates that if an elevator increases volume of shipped grain, in all likelihood, it will ship a greater proportion of the increased quantity by rail than by truck. Secondly, if an elevator has a higher quantity of grain to ship, it likely uses the rail mode.

The elasticity for the demand of truck and rail service with respect to distance provided the results expected. It is expected that, as length of haul increases, the usage of truck transportation will decrease. In most cases, the elasticity of demand for truck transportation with respect to distance is negative, with large elasticities common. These

elasticities show that, as distance increases, the demand for truck transportation decreases. Koo, Tolliver, and Bitzan (1993, pg. 8) show that “trucks have a comparative advantage for short hauls because they have relatively insignificant fixed and terminal cost components compared to other modes of transportation which offset relatively higher linehaul costs over short distances.” Figure 5.2 shows a demonstration of this concept.

Figure 5.2. Demonstration of the Impact of Linehaul vs. Terminal Costs.



Truck transportation starts at a lower point on the Y axis due to the significantly lower terminal costs mentioned above. The slope of the line representing truck is higher than the line representing rail, which demonstrates the higher variable cost per unit shipped by truck. At distance  $D_1$ , the trip cost for truck and rail is equal and for all distances; past this point, rail will become the least cost mode of shipment.

The elasticities of demand for rail transportation with respect to distance are predominately positive and less than one. As distance increases by one percent, the amount of rail transportation increases less than one percent, but increases nevertheless.

As distance from Minneapolis and Duluth increases, rail becomes the dominant mode of transportation to a greater degree.

### **Limitations and Suggestions for Further Study**

There are a number of limitations to this study. First, actual rates for truck and shipments were not known, and were estimated. The estimation of truck rates did include indexes for fuel price, harvest, and fertilizer, which adds to the accuracy of the seasonality of truck rates, but still is not as accurate as the actual rates. A comprehensive survey of North Dakota elevators would be needed to obtain such data.

A second limitation that arises from a lack of rate data is additional markets. There are wheat and barley shipments made to the Pacific Northwest, but due to a lack of truck rate information, the demand for grain transportation could not be estimated. However, the portion of North Dakota grain that is shipped to the Pacific Northwest is small in comparison to the amount that is shipped to Minnesota. As mentioned above, a comprehensive survey of North Dakota elevators would provide these useful data.

This study only considers grain transportation from North Dakota. This limitation also should serve as a warning that the results presented in this study are specifically designed to estimate demand for grain transportation from North Dakota to Minneapolis and Duluth. The results are not applicable to other geographic areas or destinations. A suggestion for further research is to apply the methods outlined in this study to a larger geographic area such as North Dakota, Minnesota, and South Dakota; or to a separate geographically different area. The results for grain transportation are expected to vary as the geographic location changes.

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