

DERIVED DEMAND FOR GRAIN FREIGHT TRANSPORTATION, RAIL-TRUCK
COMPETITION, AND MODE CHOICE AND ALLOCATIVE EFFICIENCY

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Derived Demand for Grain Freight Transportation, Rail-Truck Competition,
and Mode Choice and Allocative Efficiency

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ABSTRACT

The demand for grain freight transportation is a derived demand; consequently changes in the grain supply chain in production and handling, and those in the transportation domain will affect the demand for grain transportation. The U.S. transportation industry (e.g. railroad and trucking), and the grain supply chain in general have witnessed structural changes over the years that have potential long-run implications for demand, intermodal competition, and grain shippers mode choices both nationally and regionally. Deregulation of the railroad and trucking industries initiated innovations (e.g. shuttle trains) that have revolutionized the way grain is marketed.

These and other related trends in agriculture including bioenergy suggest a dynamic environment surrounding grain transportation and the need to revisit agricultural transportation demand and evaluate changes over time. A majority of freight demand studies are based on aggregate data (e.g. regional) due to lack of disaggregate data. Aggregation of shippers over large geographic regions leads to loss of information with potential erroneous elasticity estimates. This study develops a method to estimate transportation rates at the grain elevator level to estimate a shipper link specific cost function for barley, corn, durum, hard red spring wheat, and soybeans shippers.

The aim of this study is to assess and characterize the nature of rail-truck competition for the transportation of five commodities over distance and time as well as to assess whether North Dakota grain shippers' mode choices reflect an allocatively efficient mix assuming the choice of mode is based on shipping rates. Our findings indicate that in general, rail dominates most of the grain traffic, however, the degree of dominance is variable by commodity. Additional findings suggest that grain shippers utilize more rail than they would if they chose modes based on rates. This may suggest unmeasured service quality advantages of rail in comparison to truck.

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DEDICATION

This research is dedicated to my beloved family: my son Monamme, my daughter Enjema, and my wife Gladys.

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CHAPTER 1. INTRODUCTION

1.1. Background

The United States General Accounting Office (GAO 2003) has indicated that the economic vitality of the U.S. is to a great extent dependent on the security, availability and dependability of its transportation system. Transportation plays a vital role in the delivery of raw materials and component parts to finished goods producers, in the delivery of finished goods to domestic consumers, in the export of raw materials, finished goods and intermediate goods, and in the import of goods to domestic producers and consumers. An illustration of the importance of the transportation system to the economy can be seen in its critical role of moving agricultural products to domestic users and for export. Agricultural products are carried using three principal modes of transportation, including trucks, barges, and railroads. Agriculture is an important source of demand for transportation in the U.S., accounting for close to 1 in 5 ton-miles of highway freight and 1 in 10 ton-miles of rail and barge freight transported in 2010 (Casavant et al. 2010). The demand for transportation in general is derived from the demand for other activities or goods. Specifically, in agricultural transportation, this means factors that alter agricultural demand and supply in production areas and export demand will shift the demand for agricultural transportation (Boyer 1997). The U.S. railroad, trucking, and grain supply industries have witnessed structural changes over the years that have potential implications for demand, pricing, and intermodal competition for grain transportation, both nationally and regionally.

1.2. Changes in the Railroad Industry

Major structural changes have occurred in the railroad transportation industry, particularly those related to regulatory changes in the late 1970's and early 1980's. Concerns about financial stability and the apparent lack of competition following decades of regulation led

to passage of the Railroad Revitalization and Regulatory Reform (4R) Act in 1976 and the Staggers Act in 1980, which deregulated the railroad industry. Ellig (2002) notes that in the late 1970s, more than twenty percent of railroads in the United States were operated by bankrupt firms. Consequently, deregulation was in direct reaction to the idea that the industry was in need of greater pricing and operating freedom to protect against further bankruptcies (Meyer 1973).

Following deregulation, U.S. Class I Railroads adopted various cost reduction strategies to enhance their profitability including the sale or lease of unprofitable branch lines to short line railroads and the abandonment of other branch lines (Babcock and Bunch 2003). The abandonment and sale of unprofitable lines by Class I railroads following deregulation spurred the growth of short line railroads. The American Short Line and Regional Railroad Association (ASLRRA) notes that nationally, short line railroads have expanded their networks from 8,000 miles in 1980 to 50,000 miles presently.

Moreover, the pricing freedom given to railroads has led to several productivity enhancing innovations. Gallamore (1999) observes that regulation stifled innovation. He notes that deregulation has led to improvement of railroad operation in several areas, including safety standards, track structure, locomotives, and containerization. Annual productivity and cost savings significantly improved after the passage of the Staggers Act. Wilson (1997) finds significant productivity improvement after deregulation, but that these effects have tended to diminish in the long term. Bitzan and Keeler (2003) note that overall productivity growth accelerated slightly between 1983 and 1997 and innovations that led to elimination of cabooses and related crew reduced Class I Railroad costs by 5 - 8% in 1997, corresponding to annual industry cost savings of between \$2billion and \$3.3billion.

Costs reducing strategies and innovations in the railroad industry have noticeably increased the average rate of return on investment for the railroad industry from 2.5% during the 1970s to above 10% during 2006 – 2007 according to the Association of American Railroads (AAR 2008). In fact, Waters (2007) notes that some major railroads are approaching or reaching normal rates of return; posing an imminent regulatory challenge for differential pricing (higher rates for shippers with inelastic demand).

Deregulation has benefitted shippers as well. Shippers have witnessed falling rail rates as well as improved service quality in the form of speed, reliability, and availability of railcars since deregulation of the rail industry (Grimm and Smith 1986). Quality of service improvement (speed and reliability) stemming from rerouting flexibility and contracts between shippers and carriers was an unpredicted effect of rail deregulation (Ellig 2000). Grimm and Winston (2000) estimate that the benefits to shippers in the first ten years after deregulation was greater than \$12 billion in 1999 dollars (\$14.7 billion in 2007 dollars). According to Dennis (2000), rate reductions between 1982 and 1996 enabled shippers to save an estimated \$28 billion per annum. These accrued benefits have been realized by all grain producers and shippers, although more so in regions with more transport competition (Bitzan et al. 2003).

Specifically in the grain shipping domain, Wilson and Dahl (2010) identify five major technological innovations that have resulted in improved efficiency. These include demurrage provisions for grain loading, forward instruments for car allocation, a shift from box-car shipping to covered hoppers adoption of short line railroads, and increases in shipment size following adoption of multi-car, unit, and shuttle trains. Shuttle trains were introduced by Burlington Northern (Burlington Northern Santa Fe since 1996) in the late 1990s. They are considered more efficient than all other service types including unit trains, multi-car, and single-car movements,

due to operational differences. For example, the primary operational difference between shuttle and unit trains is side track capacity in terms of the number of railcars that can be loaded or assembled for loading. Side track capacity is measured in equivalent number of cars according to the North Dakota Department of Transportation (NDDOT 2007). An elevator requires 6,600 feet of track space to hold 110-railcars (shuttle train) with the total track requirement exceeding 7,000 feet to accommodate dedicated locomotive power and spotting clearance (NDDOT 2007). Unit trains (typically 52 railcars), on the other hand, require half that amount of space. Multicar trains (usually 26 railcars) require less than half the space for unit trains. Additionally, The U.S. Senate, Committee on Commerce, Science, and Transportation (2002) notes that unit trains typically have to be matched with one of a similar size or with several smaller multi-car blocks before a large grain train can be put together. Shuttle trains do not require putting a train together. Dedicated power, locomotives, and railcars involved in shuttle movements remain in a single block as they move from origin to destination, thus enhancing rail car utilization. Shuttle trains are a more dedicated service than unit train services. Prater et al. (2013) note that efficiency stemming from shuttle train implementation has benefitted both the railroad (in the form of lower cost) and agricultural producers located in close proximity to shuttle loading elevators (in the form of lower rates). For example, the construction of elevators with larger capacities and subsequent shipment in shuttle trains have played a role in reducing rail rates charged to wheat shippers in North Dakota (Ndembe 2015). Wilson and Dahl (2010) observe that the number of shuttle origin rail elevators on BNSF lines more than doubled between 2000 and 2010 from 118 to 263.

Despite its benefits, railroad deregulation may have had some unintended consequences. Various forms of restructuring following enactment, including mergers, purchases,

consolidation, and acquisitions have increased the concentration of the railroad industry from 43 Class I carriers in 1980 to 7 in 1997 (Miljkovic 2001). Consolidation concerns in concentrated industries were initially raised in the seminal article by Williamson (1968) in which attention was drawn to the fact that horizontal mergers can lead to higher rates and related deadweight losses. He also showed the tradeoff between cost savings and reduced competition. Some argue that concentration, represented by reduction in the number of carriers, has meant shippers have fewer options to choose from. This has likely reduced the level or perceived level of competition, raising various concerns by shippers; especially those so called “captive shippers” (Larson and Spraggins 1998; U.S. Senate, Committee on Commerce, Science, and Transportation 2002; Davidson USA Today 2007). It should also be noted that a large amount of research suggests that mergers have resulted in cost savings in the rail industry (Bitzan and Wilson 2007).

Agricultural producers and shippers have continued to express worries about reduction in rail to rail competition, rising rail rates, poor rail service, rail capacity constraints, and unfair allocation of rail capacity (Prater et al. 2010). Whereas rates have declined for commodities like coal, motor vehicles and miscellaneous mixed shipments, those for grains rose 9 percent between 1987 and 2004 (GAO 2006). On the other hand, Bitzan and Keeler (2014) find that the revenue cost margins for those commodities thought to be most captive did not increase between 1986 and 2008, while those for commodities thought to be non-captive rose. Earlier, Grimm and Winston (2000) found that the overall welfare loss from potential higher rates paid by captive shippers compared to those by non-captive shippers was small with minimal redistribution effects.

Despite the fact that regulation of competitive shipments was observed to stifle railroad innovation and reduce intermodal and intramodal competition (Gallamore 1999), the Staggers Rail Act which deregulated the railroad industry retained rate regulation in captive markets

(MacDonald 1989). This suggests that the Act acknowledged the fact that not all rail markets are competitive, giving the ICC (STB since 1996) the jurisdiction to regulate maximum rates charged to captive shippers (MacDonald 1989). Modal Competition has historically been observed to be limited in states like Montana and North Dakota (MacDonald 1989, Babcock et al. 2014, Prater et al. 2013). MacDonald (1989) observed that competition is weakest in North Dakota and Montana based on the number of railroads in wheat crop reporting districts (CRD). Additionally, agricultural shippers in both states are highly dependent on rail transportation given their long distance from inland waterways and the significantly higher cost of transporting grain for long distances to markets by truck (Prater et al. 2013), limiting rail-truck competition.

1.3. Changes in the Trucking Industry

In the trucking domain, route restrictions and limited entry stemming from regulation gave trucking firms monopoly power over certain routes, providing impetus for them to charge rates that exceeded competitive rates (Moore 1986). Under regulation, regional trucking carriers benefitted from prevention of potential new entrants in their markets; and in return, they had to fulfill the common carrier obligation (provide services to all communities under their jurisdiction) even though some of these markets were unprofitable relative to others (Allen 1981). Opponents of trucking deregulation argued that deregulation would terminate common carrier service obligations and thereby lead to the cessation or deterioration of for-hire motor carrier service at “reasonable rates” to small isolated communities (Allen 1981). On the other hand, advocates of regulatory freedom anticipated that greater rate freedom, entry of new firms, and removal of regulatory constraints would lead trucking firms to reduce costs (Ying 1990) and lower prices (Ying and Keeler 1991). Consequently, the rationale behind deregulation of the

trucking industry by the Motor Carrier Act of 1980 was to provide shippers and other users with efficient truck freight rates (Ying and Keeler 1991).

Operational flexibility stemming from the elimination of route restrictions permitted many carriers to reduce empty backhauls, consequently lowering cost (Keeler 1986). Using cost simulations, Ying (1990) shows that following a year of higher expenditures, efforts to stay competitive led to substantial cost savings over time from 1% in 1981 to 23% in 1984. Additionally, Ying and Keeler (1991) in their simulations point out that deregulation lowered truck rates from the beginning, with the effects getting bigger over time. Their result shows that truck rates dropped 15 -20% by 1983, and by 25-35% by 1985. Additionally, larger trucks, coupled with the interstate highways have significantly improved truck transit times and operating cost performance (Gallamore 1999). Improvements in trucking have fostered intermodal and intramodal competition with resultant benefits to shippers and consumers.

1.4. Changes in the Grain Supply Chain

In addition to changes in the transportation industries, significant changes have been observed in the U.S. grain supply chain in cultivation, processing, and handling. These have far-reaching implications for demand and intermodal competition in the transportation of agricultural commodities. Noticeable increases in grain transportation by truck in tons have been observed, while those for rail and barge have remained fairly flat over the years between 1978 and 2013. USDA attributes observed changes in grain movement patterns to substantial increases in annual production of corn, due to emerging markets for the grain (e.g. ethanol and other biofuels). This change has had an impact on grain transportation because many of the emerging markets that have induced the changes in commodities produced (e.g. local ethanol and biofuel facilities) entail local (short distance) movements, often dominated by truck transport. Trucks

accounted for 31 percent of all U.S grain movement in 1978. However, by 2013, they represented 64 percent, more than doubling that for 1978. Modal changes in grain transportation based on USDA modal share analysis data from 1978 to 2013 in the U.S are shown in Figure 1.

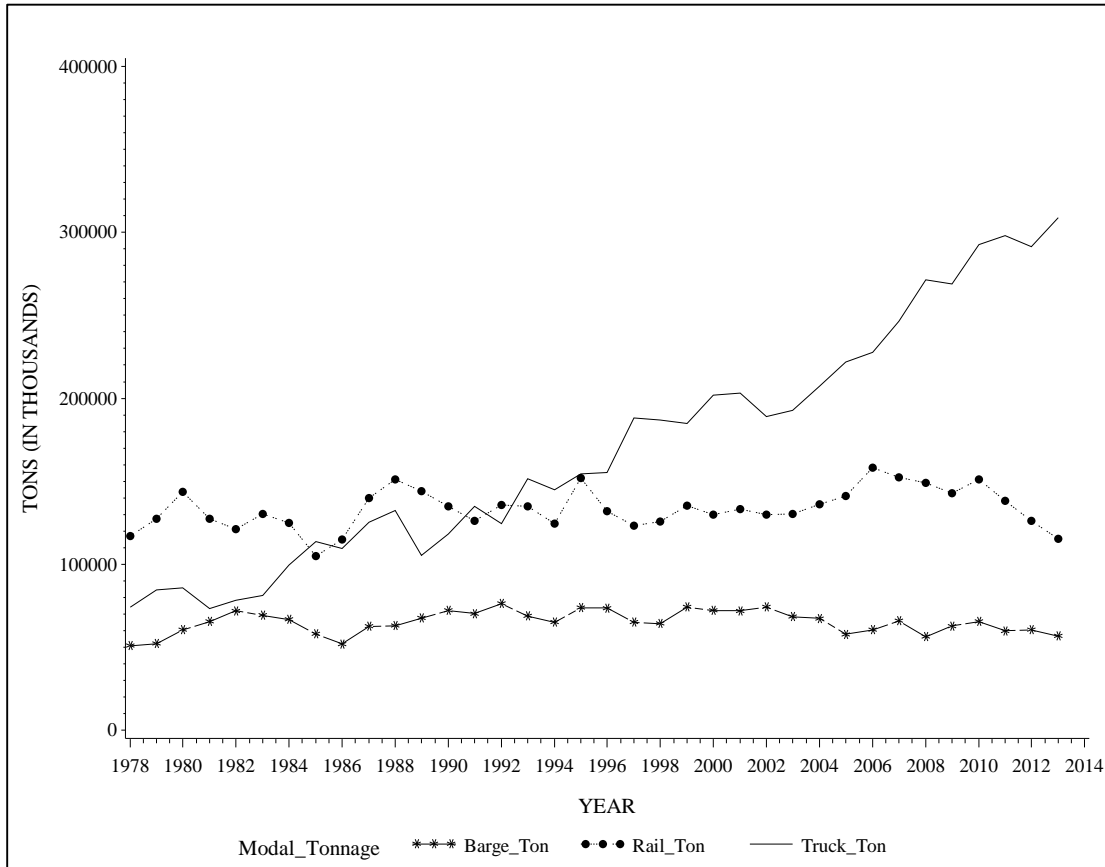


Figure 1: Trend in U.S Modal Grain Transportation 1978- 2013

Concurrently with changes in the types of commodities produced and handled and with changes in grain markets, there has been an increase in the size of rail shipments. Grain elevators facilitate grain accumulation that creates economies of shipment size. Owing to this advantage, railroads have been abandoning lines and shifting their service to larger elevators, called shuttles. These facilities have sufficient track space and capacity to load more than 100 railcars. Increasing use of these facilities has led to the closure of many smaller country elevators, as farmers and shippers move grains longer distances on rural roads to shuttle elevators often to

benefit from comparatively lower rates (Casavant et al. 2010). USDA (2013) shows that shuttle train movements (which they describe as those with 75 railcars and above) of grains by tonnage have increased substantially since 1994. They note that the percentage of rail grains and oilseeds (by tonnage) moved by shuttle trains have increased from 12.9 percent in 1994 to 49.5 percent in 2011 with an observed peak of 50.6 percent in 2010.

While the lower rates afforded by elevator consolidation have enhanced rail's advantage over truck in long distance movements, increased production of biofuels has provided farmers and shippers with options to sell their grains locally, potentially affecting grains available for shipment by rail. In the U.S, Rail had been the dominant mode of grain transportation over barge and truck from 1978 to 1992, only facing slight dips below truck in 1985 and 1991. However, from 1993 onward, trucks have dominated rail in the percentage of tons of grain movement (see Figure 1). These observed changes in the transportation industry and the grain supply chain have potential regional impacts.

1.5. The Case of North Dakota

The importance of transportation to agriculture is more pronounced in states that are highly dependent on production agriculture, and those with fewer competitive modes to get their products to far away markets. North Dakota has been described as an agricultural state which, historically, is highly dependent on railroads for out of state shipment of grains. Leistriz et al. (2002) indicate that agriculture has ranked consistently at the top of North Dakota's economic base; second only to Federal payments. Only recently with the growth in oil production has mining and mining related activities (e.g. oil and gas extraction) overtaken Agriculture as the state's top gross state product (GSP) contributor. In 2014, agriculture, forestry, fishing, and hunting accounted for close to 7 percent of the state's GSP while mining and related activities

including oil and gas extraction made up approximately 16 percent (Bureau of Economic Analysis 2015). Agricultural shippers in North Dakota are significantly dependent on rail transportation, owing to their long distances from consumption centers, terminal markets, and barge loading facilities (Prater et al. 2010). Figure 2 shows North Dakota Grain Supply Chain.

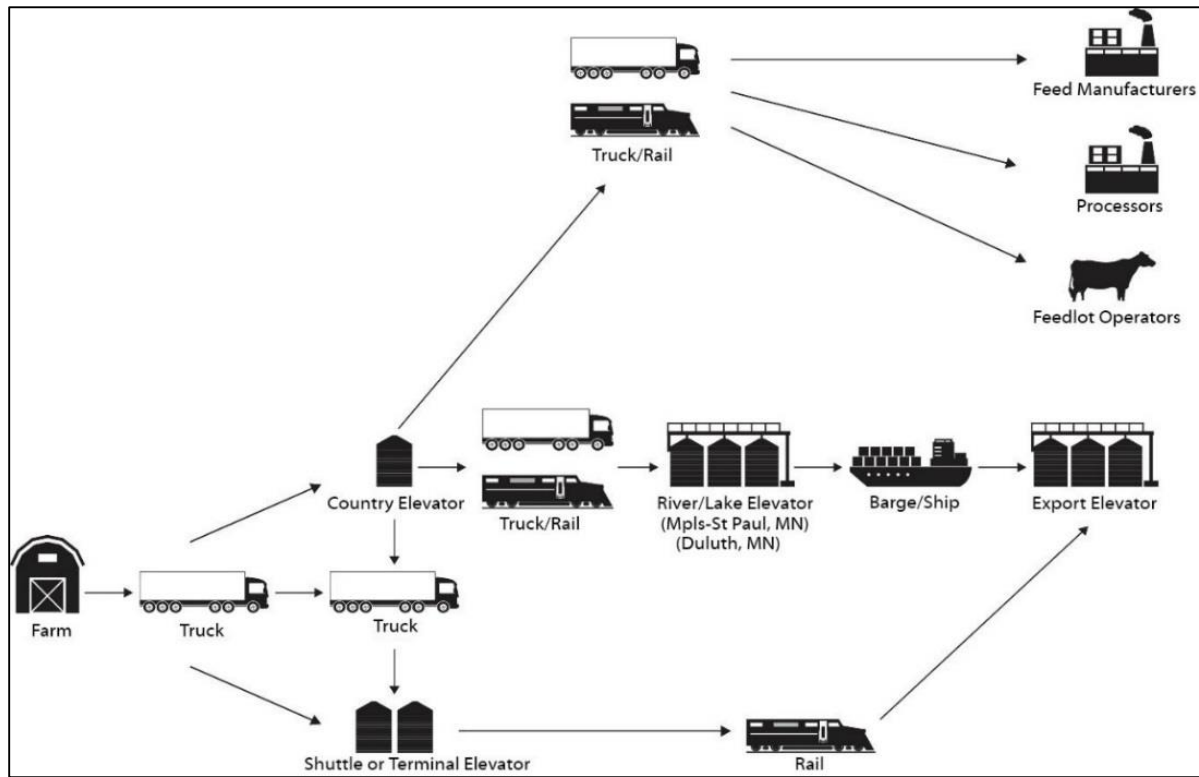


Figure 2: Depiction of North Dakota Grain Supply Chain

Vachal and Button (2003) point out that a majority of the 600 million bushels of grain produced yearly in North Dakota is marketed to destinations out of state. Research by Tolliver and Dybing (2007) finds that railroads transported an estimated 78 percent by tons of North Dakota grains during the 2004 crop marketing year. This is similar to observations by Casavant et al. (2010) that show that railroads transported 70% of grains and oilseeds produced in North Dakota in 2010. Most recently, Vachal (2012) shows that 75% of North Dakota elevator shipment of major crops is transported by rail, while 25 percent goes by truck. Shippers willing

to use water (barge) to haul their commodities have to ship them to the closest barge facility in Minneapolis/St Paul or Duluth in Minnesota, incurring additional transportation cost.

In addition to this observed dependency of North Dakota grain shippers on railroads, there has been a reduction in rail transportation options due to increased abandonment of branch lines. In fact, a total of 1774 miles of railroad have been abandoned in North Dakota since 1936. Before 1980, only 144 miles were abandoned. A total of 1630 were abandoned between 1980 and 2009 following passage of the Staggers Act in 1980. Dependency on a single mode and a perceived reduction in competition between railroads stemming from industry concentration has raised concerns about captivity.

However, Bitzan et al. (2003) find that railroad concentration at the county level has played a smaller role in determining rates over time. They attribute this unexpected result to an increase in truck sizes and the ensuing potential for trucks to compete over longer distances. Longer truck competition has extended the size of markets over which railroads compete. They conclude that if inter railroad competition exists over larger geographic areas due to the ability of trucks to move freight at lower costs for longer distances, then railroad concentration in a given county is irrelevant.

Additionally, some have argued that increasing abandonment and sale of unprofitable routes has fostered intramodal competition within the state amongst short line railroads. Short line railroads operating in the state act as subsidiaries of the two carriers and hence do not directly compete their affiliated Class I (Babcock et al. 2014). However, by operating in areas not served by their affiliated Class I, they compete in drawing grain from the Class I with which they are not affiliated. For example, Dakota Missouri Valley and Western (DMVW), a local subsidiary of Canadian Pacific (CP), serves areas in the state that BNSF does as well, but not CP

(Babcock et al. 2014). As such DMVW competes with BNSF for this traffic. Additionally, the Red River Valley and Western (RRVW), a subsidiary for BNSF in North Dakota, operates in areas of the state where CP has a strong presence (Babcock et al. 2014). In that case, RRVW competes with CP for traffic. In this way, regional and local affiliates compete on behalf of both Class I railroads (Babcock et al. 2014).

Prater et al. (2010) indicate that shippers in states like North Dakota with less rail-rail competition pay the highest rail rates in the U.S. Sparger and Marathon (2015) estimate that the revenue-variable cost (R/VC) ratio of rail shipments, which is a reflection of differential pricing, was above 300 percent for three states, including North Dakota; almost doubling the 180 percent statutory threshold of potentially competitive traffic. The 180% threshold was set by law to protect shippers from railroad market power (180% is the threshold for potentially captive traffic). On the other hand, rail consolidation has been fostered by the growth and construction of shuttle facilities and the resulting consolidation of the grain elevator system trend that has benefitted shippers. The Congressional Research Service (CRS 2005) notes that by consolidating their network and rolling stock around shuttles, Class I Railroads are increasingly exploiting operational efficiencies and enhancing their profitability. Carriers' efficiency enhancement is likely reflected as better rates to shippers.

Sarmiento and Wilson (2005) note that equipment utilization and availability are enhanced by shuttle services, making them two or three times more productive than single and multi-car movements. They add that grain cycle times have almost been cut in half in some regions with annual trips increasing from between 14 and 18 trips to 30 trips with some carriers pointing to a 30% reduction in car placement costs. To benefit from these rates, shippers are required to be able to load 110 or more 111-ton hopper cars within 15 hours; in some instances

as often as three times per month, requiring 400,000 bushels for each shipment (NDDOT, 2007). The importance of storage capacity, therefore, required shippers to construct new facilities or upgrade existing facilities to meet carrier requirements (e.g. storage and track space to handle 100 or more rail cars). Increasing use of shuttle elevators has potentially enabled some shippers to benefit from economies of size in shipping in the form of lower rates. Vachal and Button (2003) show that shuttle grain elevators offer relatively favorable rates, and consequently they are likely to attract more grain and expand their draw area. Apart from favorable rates, the Upper Great Plains Transportation Institute (UGPTI 2012) identifies service quality as a distinguishing characteristic of shuttle elevators as reflected in shorter delays in deliveries. On average between 2006 and 2013, shuttle trains had 12 days delay on deliveries while other rail services had a 17 days delay based on Elevator Transportation Activities and Service Surveys from UGPTI. The effect of elevator consolidation can be observed with the decrease in the number of licensed grain elevators over time. Figure 3 shows the trend in the number of licensed elevators between 1990 and 2013 based on data from North Dakota Grain Movement database. The number of licensed elevators has dropped from 448 in 1990 to 199 in 2013.

Due to the central role played by agriculture in the state, North Dakota grain transportation has also likely been affected by increasing demand for grains for industrial usage (e.g. biofuels). Changes identified nationally by Casavant (2010) have also been observed within North Dakota. Despite the dominance of traditional crops, including wheat (hard red spring and durum) and barley, corn and soybeans have been showing significant growth over the years; partly attributable to increased demand for ethanol and biodiesel both nationally and locally. Ethanol and biodiesel constitute the two principal biofuels which use corn and soybeans as inputs. The increasing production of biofuel, particularly ethanol, has meant increased movement

of corn locally to ethanol plants. Higher premiums offered by ethanol plants relative to elevators are likely to attract more grains and provide more options for local shippers (Schill 2007). Most elevators delivering corn to ethanol plants are within 50 miles, which is cost efficient for trucking (Shapouri et al. 1995).

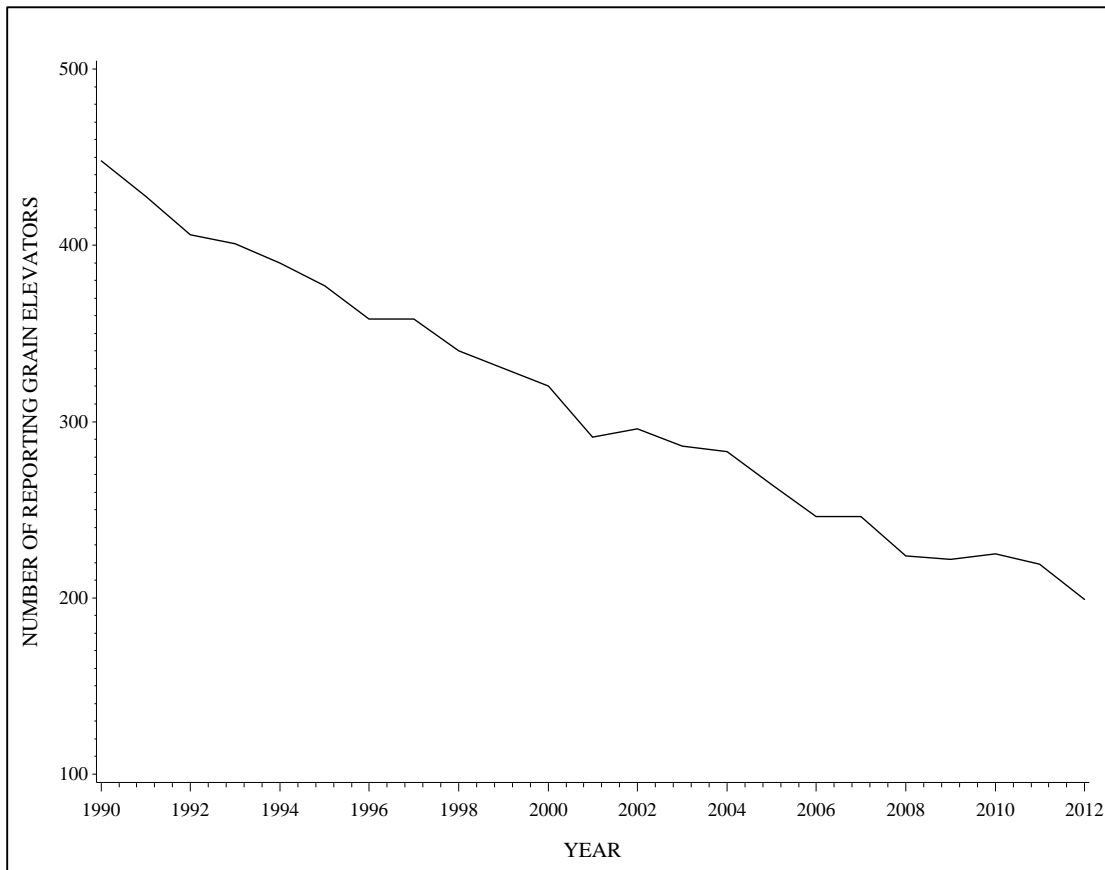


Figure 3: Trend in Licensed Grain Elevators in North Dakota 1990-2013

Corn production in North Dakota has risen from approximately 37 million bushels in 1990 to 396 million bushels in 2013 based on data from USDA National Agricultural Statistics. Similarly, within the same time period, soybean production has increased from approximately 13 million bushels to a little over 141 million bushels. On the other hand, hard red spring wheat production fell from 277 million bushels in 1990 to 235 million bushels in 2013, while durum wheat saw a bigger decline falling to 29 million bushels in 2013 from 104 million bushels in

1990. Barley production has seen the greatest decline, falling from close to 130 million bushels in 1990 to 46 million bushels in 2013.

The use of corn ethanol has also diverted corn from the export market. USDA projected that 2.6 billion bushels of corn that the ethanol industry consumed in 2010 would be diverted from U.S. exports. The increasing usage of corn in general has meant corn production has replaced other grains in many instances. This observation has been echoed in the local media. The Forum of Fargo-Moorhead (a local newspaper) of April 02, 2013 had the caption “*Wheat losing ground to corn in North Dakota*”. It observed that since 1997, corn production has increased tremendously relative to other crops. An increase use of corn or soybeans locally is likely to alter the derived demand for rail transportation, as trucks dominate short distance movements. Production trends for barley, corn, durum, hard red spring and soybeans in North Dakota between 1990 and 2013 based on data from USDA, NASS are shown in Figure 4.

Presently, there are five ethanol plants in North Dakota, producing 440 million gallons of ethanol using 156 million bushels of corn annually (North Dakota Ethanol Council NDEC). NDEC indicates that most of the corn used to produce ethanol (80 percent) is bought locally from farmers. The increasing demand for corn locally can be observed from changes in local corn transportation. Based on data from the North Dakota Grain Movement database, local corn movements have increased from close to 160 thousand bushels in 1990 to almost 5 million bushels in 2013. This increasing trend in local corn consumption coincides with increasing industrial usage locally (e.g. ethanol production).

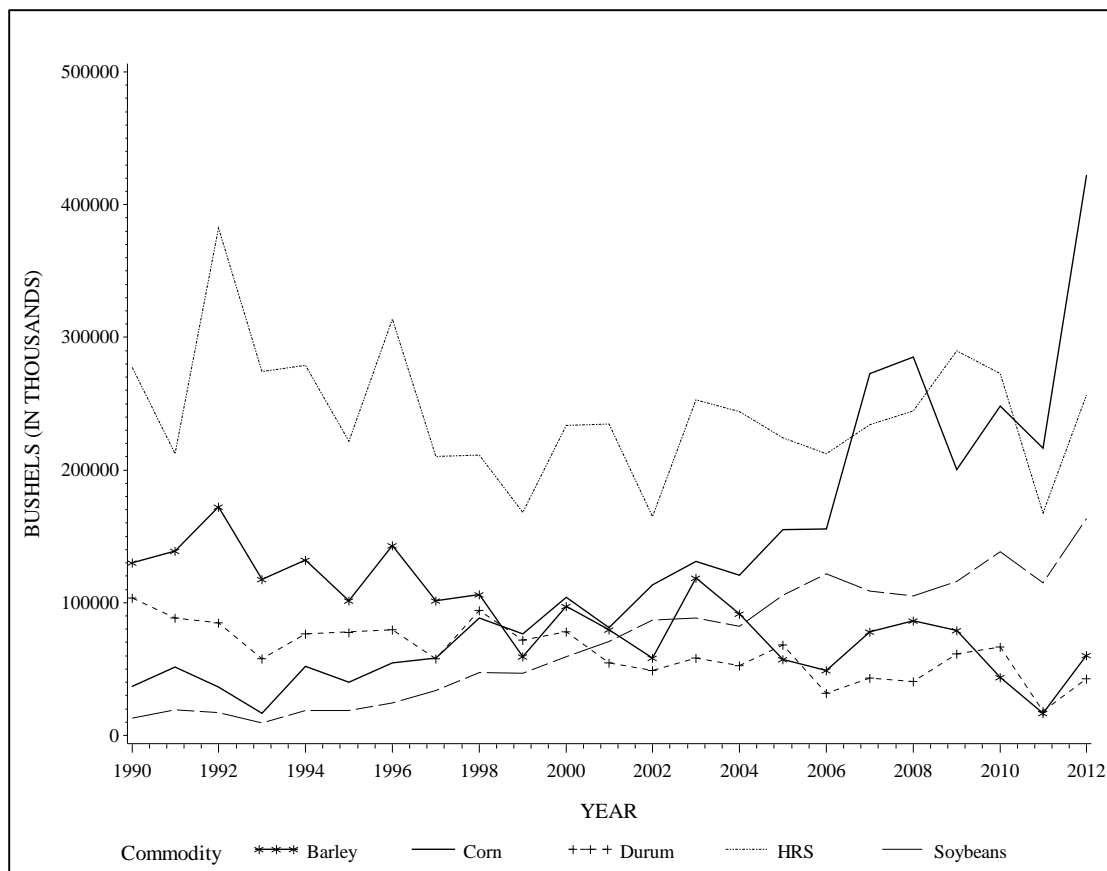


Figure 4: North Dakota Grain Production Trend (000) Bushels, 1990 and 2013

1.6. Objectives

The main objectives of this research are to estimate freight transportation demand and changes over time for five principal grains: barley, corn, durum, hard red spring wheat, and soybeans shipped from North Dakota to four main destinations: Duluth, MN; Minneapolis, MN; GULF (New Orleans, LA) and Pacific North West (Portland, OR) between 2006 and 2013. Emphasis will be placed on evaluating changes in shipper captivity, changes in the nature of intermodal competition, and changes in modal service quality for North Dakota shippers. To do this, a link-specific transportation demand model is estimated. The links involve individual grain elevators within North Dakota and four principal destinations for grains outlined above. Unlike previous freight transportation models undertaken in the state which use aggregate data often

involving whole regions, this study uses a disaggregate approach involving grain elevators as the primary unit of observation. Special attention is placed on distinguishing rail rates by elevator types related to grain elevator shipment capabilities (e.g. shuttle, unit, and multi-car shipments). This distinction is important due to distinct differences between shuttle elevators and non-shuttle elevators. In addition to the benefits to shippers from lower rates stemming from economies of shipment size compared to those of other shipment types, shuttle trains have been identified as having relatively better quality of service reflected as shorter delivery time in days (UGPTI 2012). These may suggest a change in shipper demand for rail accompanying the shift of rail service to the shuttle orientation. The specific objectives of this study are threefold as follows:

- (1) To estimate modal transportation demand elasticities over time.
- (2) To identify the distances for which rail and truck compete and changes over time.
- (3) To assess whether North Dakota grain shippers' transportation choices reflect an "Allocatively" efficient mix of transportation assuming the choice of mode is based on shipping rates ("Allocative" Efficiency and Mode Choice).

Objectives 1 and 2 will be accomplished by estimating the derived demand for transportation assuming firms minimize the cost of goods transportation, whereas the cost minimization objective will be tested in objective 3 and it will help to identify the role of service quality in transportation mode choice, as well as changes over time.

1.7. Rationale

Structural changes occurring in the U.S. railroad and trucking industries (e.g. rising track abandonment) stemming from deregulation, coupled with those in the grain supply chain in production (e.g. shift towards corn), processing (e.g. surge in biofuel production), and handling

(e.g. development, growth and expansion of shuttle grain elevators) have potential transportation demand implications for North Dakota grain marketing. The Staggers Rail Act that deregulated the railroad industry initiated fundamental changes in the railroad industry relative to previous policies (e.g. 4R, 3R, Inter State Commerce Act). In fact, Keeler (1983) describes the Staggers Act as a more drastic modification in federal policy towards the railroads compared to the Interstate Commerce Act of 1887. MacDonald (1989) points to the impact of railroad deregulation on grain transportation, noting that the impacts of deregulation are more noticeable in Great Plains states (e.g. North Dakota) given that unregulated barge competition in the Corn Belt made regulation ineffective. He summarizes the principal goals of the 1980 Staggers Act as follows:

- (1) Elimination of rate bureaus.
- (2) Provide more freedom to restructure rates; use of shipment specific contract rates.
- (3) Permit easier abandonment of unprofitable lines.
- (4) Retain rate regulation only where a rail carrier has market dominance.

One of the most important provisions of the Staggers Act is its limitation of regulation to cases where market dominance exists (goal 4). Essentially, the ICC defined market dominance to mean situations where a railroad does not face effective competition - that is, where the shipper is considered captive. North Dakota has been used extensively as an example of “captive market” (MacDonald 1989, Koo et al. 1993, Prater et al. 2010, and Sparger and Marathon 2015). This view is related to the comparatively limited level of intramodal, intermodal, geographic, and product competition in North Dakota relative to other states or regions. Limited competition, in most cases, is reflected in the form of higher shipping rates paid by North Dakota shippers.

Intramodal competition describes competition between two or more rail railroads often reflected in the form of price competition. Unlike the trucking industry which is characterized by many operators or firms (perfect competition), the railroad industry in North Dakota is highly concentrated. Two U.S class I railroads, the Burlington Northern Santa Fe (BNSF) and the Canadian Pacific (SOO-line) are responsible for all out of state rail grain movements.

In addition to being highly dependent on two carriers, shippers in North Dakota are located long distances from barge transportation - an alternative competitor mode to rail. Shippers willing to use barge transportation have to truck their commodities to the closest barge terminal, incurring additional costs on the way. The truck/barge combination using the Mississippi waterway alternative, although feasible, is limited because waterways only serve specific markets (e.g. it is unreasonable to ship to PNW using the Mississippi waterway). Consequently, intermodal competition, reflected by competition between railroads and barge transportation is limited. However, deregulation has increased intermodal competition between rail and truck. Furthermore, increases in local processing (e.g. ethanol) have increased rail truck competition. An illustration of the nature of shipment cost is useful to understanding the reason for limited intermodal competition, particularly for rail grain shipments out of North Dakota. Koo et al. (1993) and the Congressional Research Service (CRS 2005) provide a hypothetical cost curve for the three main modes involved in grain transportation in the U.S shown in Figure 5 to illustrate competition between modes according to distance between an origin and destination.

The illustration in Figure 5 shows that, generally, trucking has a relative advantage for shorter-distance traffic while rail and barge dominate longer-distance hauls [(Koo et al. (1993), Congressional Research Service (CRS 2005)]. Potential trucking dominance of the short haul stems from the fact that it has relatively small fixed and terminal costs that offset comparatively

higher line haul cost over short distances. Line haul cost refers to those costs that vary with operations (e.g. fuel, labor, tire wear). The hypothetical cost curve of trucking is shown as TT' . The cost curve for barge traffic, depicted as WW' , suggests that water transportation has the lowest distance-related unit cost as well as higher terminal or fixed cost compared to other modes. Consequently, barge transportation has considerable advantages for long-distance trips relative to short-distances trips. As alluded to earlier, barge operations are confined to U.S. waterways including the Mississippi, Illinois, Ohio, and the Columbia and Snake Rivers.

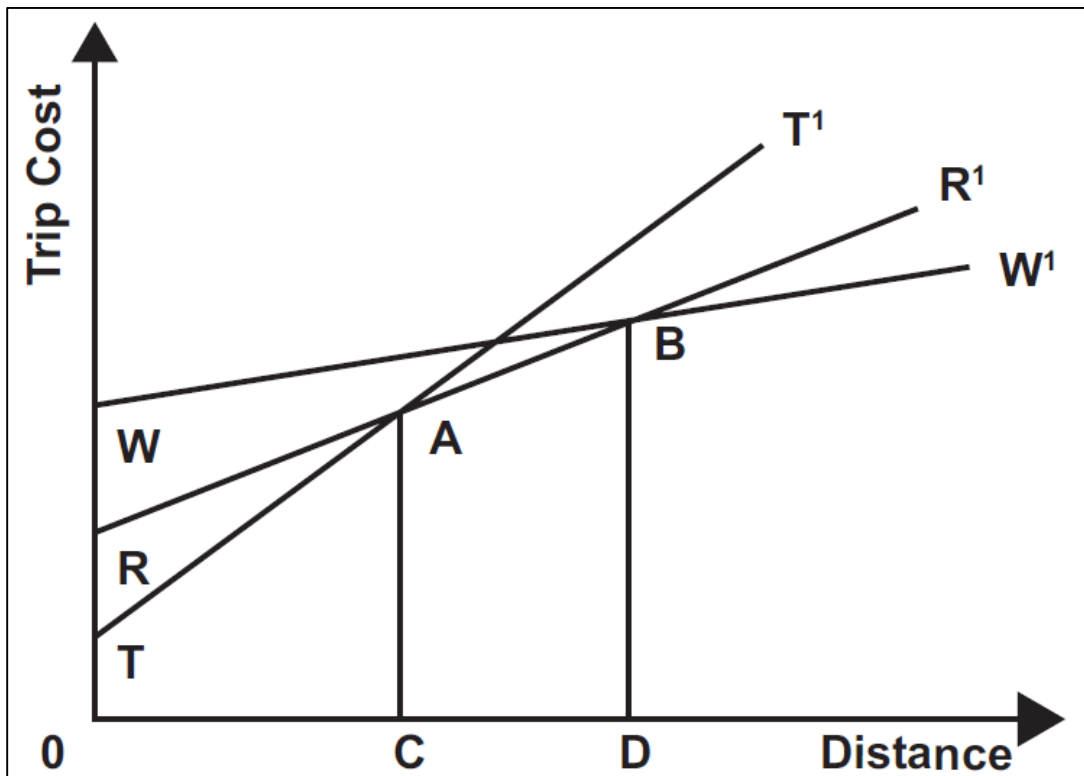


Figure 5: Hypothetical Shipment Cost Curve (Koo et al. 1993)

This benefits shippers in close proximity to these waterways. Given the lack of waterways in North Dakota, the only other mode comparable to barge serving shippers in the state is railroad transportation. The cost curve for railroad traffic RR' lies between that for truck and barge transportation. Koo and Uhm (1984) noted that the shape of the railroad cost curve is a

reflection of the “rate taper” concept which they described as rates which increase at a decreasing rate with distance attributable to economies of long haul. They noted that railroad firms realize economies of haul as distance increases, specifically because fixed terminal cost can be spread over greater mileage. Because most destinations for North Dakota grain (e.g. Portland, OR) are located at distances in which rail transport has a cost advantage, intermodal competition between rail and truck is limited in North Dakota.

Geographic and product competition are also likely limited. Bitzan and Tolliver (1998) note that geographic and product competition can be viewed as different forms of intramodal competition. Intramodal competition in the pure sense looks at how railroad firms compete in a similar location to haul a given commodity to market. Generally, on the other hand, Geographic and product competition looks at railroad firms competing at different locations to haul the same commodity or similar commodities to market (Bitzan and Tolliver 1998).

Geographic competition is defined in two different ways. First, it represents competition between railroads that are able to provide services for similar products to a given destination from different origins. Second, Geographic competition defines competition between railroads shipping freight from the same origin to different destinations. In the U.S, railroad network ownership is not separate from operation (e.g. railroad firms own, operate, and maintain their own networks). Although there are some areas where railroads have shared networks for interconnectivity, the large class I railroads are often described as regional duopolies (e.g. BNSF and UP in the West, and NS and CSX in the East). The limited number of railroads and shared network for railroads originating commodities out of North Dakota potentially means low intramodal competition. However, the fact that similar wheat is grown in other geographic regions presents an opportunity for geographic competition. For example, if BNSF charges

higher rates for shipping hard red spring wheat to the Pacific North West (e.g. Portland, OR) then receivers in that area can decide to get their wheat shipments from Canada using the Canadian National railroad. In this case, Geographic competition can substitute for intramodal competition in North Dakota.

Product competition represents competition at different locations in shipping substitute products. North Dakota has historically led U.S hard red spring wheat production. Winter wheat can serve as a substitute for hard red spring wheat. Kansas is the largest producer of winter wheat. Similarly, if BNSF increases rates for shipping hard red spring wheat from North Dakota, then a receiver in Portland, OR, might switch from hard red spring wheat to winter wheat from Kansas. This is also an indication that product competition can be effective in North Dakota. Vachal (1993) indicates that these and other related issues make transportation issues in North Dakota unique compared to other areas.

Agricultural transportation demand evaluations are necessary for transportation policy analysis and carriers' business operation decisions. Specifically, elasticities obtained from grain transportation demand studies can help regulators assess the nature of competition and help carriers in pricing decisions. Although a number of authors have characterized North Dakota grain shippers as "captive", the degree of captivity realized by such shippers is an empirical issue. An assessment of transport demand elasticities allows informed consideration of the degree of captivity in policy and provides carriers with better information in pricing.

Railroads are an example of multi-product industry characterized by a large amount of common costs. Significant parts of the railroads' costs do not fluctuate with the level or types of outputs (Waters 2007). This makes marginal cost pricing undesirable and in some instances unfeasible (requiring government subsidies) and average cost (full cost) pricing will likely lead

to loss of traffic to other modes (MacDonald 1989). Consequently, second best pricing (e.g. differential pricing) is necessary for carriers to recoup their cost of providing services. Studies have shown that shippers with less viable alternative competitive modes like North Dakota grain shippers pay comparatively higher rail rates. Rail transportation demand for such traffic is often fairly inelastic.

However, it is likely that the nature of the demand for transport services has changed over time or in the long-run for several reasons. First, observed efficiency improvements stemming from innovations in the transportation industries, and railroads in particular (increasing use of longer trains), have potentially led to lower rates and improved quality of service for shippers. Satar and Peoples (2010) note that shippers who are limited to rail services are not disadvantaged compared to those that have access to both rail and barge services if high rail rates are followed with superior transportation services. Second, the development and growth of industrial usage for grains locally, including corn ethanol and soybeans for biofuels, are likely to provide nearby alternatives to shippers, reducing their need for railroads to ship commodities. Third, improvements in operational efficiency in the trucking industry (e.g. improved fuel efficiency) have likely enabled trucks to compete for longer distances, enhancing intermodal competition.

On the other hand, recent stories of highway infrastructure deterioration and congestion may suggest that trucks have been less effective in competing with railroads over longer distances (Bitzan and Keeler 2014). Similarly, the recent increase in the transportation of crude oil from the Bakken in western North Dakota has led to observed delays in agricultural rail shipments and related losses to shippers. Railroads point to both capacity issues and bad weather to explain delays (cold weather can sometimes freeze rail tracks and locomotive engine oil). Increasing oil activity has also likely had a negative impact on truck transportation. Road

deterioration from heavy truck movements servicing the oil patch region has potentially increased delays for grain truck movements as well. The gravity of the issue led policy makers to organize a conference in December 2015 in Fargo, ND bringing together carriers and shipper groups. During the conference titled “*Post-Harvest Handling and Transportation for Agricultural Products: Issues and Alternatives*” representatives for the two Class I railroads in the state promised to make improvements to their system to better serve shippers. All of these trends suggests a dynamic environment surrounding grain transportation. Consequently, there is a need to revisit agricultural transportation demand in North Dakota, and examine changes over time.

As illustrated previously, rail carriers use information embedded in elasticities for pricing their services. Policy makers also use this information in regulatory decisions as the best way to assess captivity is to look at the relevant demand elasticities. This is particularly important for agricultural commodities, given that they move long distances to markets and the cost of transportation often constitutes a significant proportion of the value of commodities at destinations.

CHAPTER 2. LITERATURE REVIEW

2.1. Review of Freight Transportation Studies

Attempts to understand the reasons behind the steady decline in rail share of freight traffic and the rise of that of motor carriers and issues concerning the welfare impacts of the Interstate Commerce Commission (ICC) value-of-service pricing were two main motivations behind economists' interest in developing intercity freight demand models (Winston 1981). After the Second World War, rail share of freight traffic fell by almost 32 percent from 68.6 to 36.7 percent while that for motor carriers rose from 5.4 percent to 22.6 percent. In the case of value-of-service pricing, the interest was on the scale of traffic misallocation attributable to ICC rate regulation. These and other related factors created interest in freight demand models that aimed to provide policy recommendations to enable railroads to regain traffic that was lost to motor carriers (Winston 1981).

Early aggregate freight demand models (e.g. Miklius et al. 1976 and Boyer 1977) used linear logit models to estimate modal elasticities for freight services. Miklius et al. (1976) used two separate linear binary logit choice models to estimate the elasticities and cross price elasticities for cherry shipments from Washington, Oregon, and Montana and for apple shipments from Washington. Shippers' choices in the logit model were specified as a function of modal rates (truck and rail), transit times, and dependability of transit time. The selection of commodity (cherries and apples) and inclusion of transit time and transit time dependability served to evaluate quality of service. Quality of service was expected to be an important consideration in shippers' mode choice selection for cherries given the relatively higher perishability of cherries compared to apples. As expected, the own price elasticity for truck and rail service as well as the elasticities for both modes with respect to transit time were found to be

relatively elastic (price sensitive) for cherries. The elasticity with respect to transit time was more sensitive (elastic) than own price elasticity for both modes. Results for the apple model were less conclusive due to an unexpected positive sign for rail transit time and the statistical insignificance for truck transit time. The authors pointed to incomplete specification and the lack of interrelationship between inventory and transport mode decisions as potential explanations for unsatisfactory results with the apple model.

Boyer (1977) applied a linear logit model to estimate potential modal split fluctuations in freight traffic between rail and truck stemming from freight rate deregulation for a cross-section of 17 class of manufactured commodities transported between two states. His dependent variable included rail share of total output (ton-miles); the annual sum total for rail and truckload motor carriers. Independent variables included relative freight rates, length of haul, tons, and commodity value. Two different forms of freight rate were used: one involving the ratio of rail and truck modal rates (price-ratio) and the other involving the difference between the two modal rates (price-difference). Commodity dummy variables were included to evaluate potential modal choice selection unrelated to the value per ton of the commodities hauled. Results using either of the freight rates were similar. Some dummy variables representing commodity groups were significant indicating potential differences between commodities. Modal split sensitivity analysis showed that there was moderate change in in rail share of total traffic stemming from percentage changes in the relative rate variables.

Oum (1979) examined both the price-ratio and price-difference models and showed that both models have weaknesses and should only be used to estimate choice probabilities and that they are unsuitable in evaluating price responsiveness of demand for freight transportation. These shortcomings motivated the development (Friedlander and Spady 1980 and Oum 1979)

and use of more sophisticated models with underlying microeconomic theory in estimating demand for agricultural transportation (Buckley and Westbrook 1991). A review of these pioneering studies (Friedlaender and Spady 1980 and Oum 1979) is presented in the methodology section. Freight demand models that have been estimated for grain transportation in North Dakota in the past are highlighted below.

2.1.1. Review of North Dakota Freight Transportation Studies

A number of grain transportation demand studies of North Dakota shippers have been undertaken in the past. While all of these studies provide useful insights, none provide a complete picture of grain transportation demand in North Dakota. Some evaluate demand only at one point in time, others do not consider regional differences within the state (e.g. using disaggregate model approach), and some only evaluate demand for one or two of the principal destinations for North Dakota grains. A review of the approaches and principal findings of some North Dakota transportation demand studies done in the past is necessary for comparative analysis and to elucidate the peculiarities of evaluations done herein.

Wilson (1984) assessed shippers' derived demand to analyze intermodal competition for North Dakota wheat and barley shipments to Duluth and Minneapolis using data between 1973 and 1982. He introduced dummy variables to test for the impact of rail car shortages and the introduction of multi-car rates on intermodal competition. He estimated a total of four separate models for each of the two commodities and destination pairs and tested hypotheses to determine the effects of rail car shortages and multi-car rates separately and jointly on the structure and the cost and derived demand. Results indicated that rail car shortages have caused a change in relative prices and modal shares. However at the time of the study, they did not have substantial effects on the structure of cost and derived demand. This served as an indication that structural

changes in cost and derived demand had not yet been observed. The railroad own-rate elasticities were different across origin-destination pairs and commodities and for the most part were inelastic. With respect to motor carriers, own rate elasticities for wheat movements to Duluth and barley movements to Minneapolis were elastic whereas wheat shipments to Minneapolis and barley shipments to Duluth were inelastic. He concluded that estimated effects were a reflection of intermodal competition.

Wilson et al. (1988) developed a system of behavioral equations including demand and supply functions to analyze the market for transportation services, modal rate behavior, and determinants of railroad market power and pricing decisions for transportation of wheat (including HRS wheat and durum) from North Dakota to Minneapolis and Duluth using monthly data from 1973 to 1983. They used the same time period as in Wilson (1984) that represent periods before and after partial deregulation of the railroad industry. The theoretical foundation of their model was based on a generalization of dominant-firm price-leadership in which the railroad is considered the dominant firm and motor carrier industry forming the competitive fringe. Three sets of hypotheses were posed and dummy variables introduced to test them, including whether more railcars and the availability of multi-car services imply better services, if monthly shifts in the functions were observed in the structural equations, and likely interaction between the index representing railcar availability and modal prices. Their output data represented aggregated quantities shipped from each CRD aggregated across the state and converted to ton-miles. Monthly rail and truck rates were collected from a central point chosen from each CRD and a weighted average state rate was obtained based on the CRD's proportion of total ton-mile traffic for the state for that period. Their results indicated that following deregulation, rail rates were affected more by competitive conditions than cost. It was observed

that own and cross price elasticities for both rail and truck services increased during the deregulation period. Estimated price elasticities for rail service were all above unity in absolute value whereas those for truck were highly dependent on the availability of rail cars. Results pointed to the importance of supply elasticity of truck services. They attributed the observed rightward shift in the truck supply function and through equilibrium a leftward movement in the railroad demand function to reduction in real price of fuel and technological improvements during that period. The culminating effects have seen the railroads move into the more elastic portion of their demand function in the deregulated period. They concluded that the long run capacity for trucking to serve as a competitor for railroads in a given market is reliant on the price of fuel, technological improvements on the supply side, and the availability of railcars on the demand side. In addition to using a derived demand model based on shippers cost which is embedded in economic theory, this study makes several improvements to previous North Dakota agricultural freight transportation demand studies in particular and other related studies in general.

Dybing (2002) used a shipper derived transportation demand model similar to that by (Wilson 1984) to estimate North Dakota HRS wheat, durum, and barley shippers' demand for transportation services to Minneapolis and Duluth. However, the shipper cost function so derived was link specific involving the state's CRDs and the two destinations. He estimated a separate model for each commodity and destination pair for a total of six models using a pooled cross-sectional and time series data (panel) from 1996-2001. Input variables included truck and rail rates while track capacity was used as a proxy for quality of service. Last, distance to destination was used as another important factor affecting modal demand. Rail rates were obtained from BNSF and weighted by elevator capacity in each CRD to get a weighted average rate. Truck

rates, on the other hand were estimated from a survey of elevators across the state and adjusted to reflect past rates using the trucking producer price index from the Bureau of Labor Statistics. Results indicated that the demand for truck transportation was elastic (absolute value of own price elasticity greater than 1 or value less than -1) for all cases except for HRS wheat transportation to Duluth.

CHAPTER 3. METHODOLOGY

3.1. Derived Demand for Freight Transportation

Transportation demand studies play an important role in the development and enactment of transportation policies. Specifically, freight transportation demand models have been used extensively to evaluate the impact of regulatory changes in the rail and truck transportation sectors. They have also been used to forecast and to evaluate shippers' responsiveness to changes in prices and modal attributes (e.g. quality of services). The multi-attribute nature of freight, including the diversity of modes and outputs (e.g. hauling agricultural commodities is different from moving crude oil) has led to a variety of freight transportation demand models. Based on the data used, Winston (1983) classifies freight transportation demand models into two broad categories; aggregate and disaggregate categories. He describes disaggregate models as those having an individual decision maker's distinct choice of a given freight mode for a given shipment as their basic unit of observation. Aggregate models, on the other hand, have the combined share of a specific freight mode at the regional or national level as their primary unit of observation. Additionally, he notes that aggregate models like those initially developed by Friedlander and Spady (1980) and Oum (1979) which arose due to limitations of aggregate split models derive a given firm's transportation demand for particular modes by estimating a cost function with a specified functional form.

Freight transportation demand models have utilized a multiplicity of functional forms in their evaluations. Oum (1989) notes that the choice of the model, hence functional form used, is likely to affect potential forecast and related estimates including elasticities of demand with respect to price and quality of service attributes. He classifies functional forms, especially those used to estimate aggregate transportation demand models into four main categories including:

- (1) Linear demand model
- (2) Log-linear demand model
- (3) Logit model applied to aggregate market share data
- (4) Transcendental logarithmic (translog) demand system

Oum (1989 and 1979) describes freight transportation demand models involving functional forms (1) - (3) as *ad hoc* due to their lack of formal economic theory. He adds that this principal limitation makes results obtained from such evaluations inadequate for several reasons. In the case of linear models, the assumption of linearity in effects may be unrealistic. For the log-linear or Cobb-Douglas models, elasticity does not change across the range of data points and is not reliant on the location of the demand curve. Such a restriction makes it impractical, particularly in cases where the aim of the estimation involves calculating elasticities over cross-sectional links and over time within a link. In the case of the logit model, he provides three reasons why they are not appropriate to use in evaluating the nature of demand (e.g. price responsiveness). First, logit models impose numerous rigid restrictions on estimated price responsiveness of demand parameters including substitution and cross price elasticities. Second, in linear logit models that involve a ratio of prices as an explanatory variable, price responsiveness of demand parameters do not change with respect to the mode selected as the base which serves as the denominator in logit equations. Third, the technology underlining the linear logit model for use in freight demand is irregular and inconsistent.

The transcendental logarithmic functional form (4), originally developed by Christensen et al. (1971), is an example of a family of functions described as “flexible functions”. Thompson (1988) notes that their development was driven by the need for functional forms that imposed

fewer maintained assumptions like those imposed by the Cobb-Douglas function. The notion of “flexibility” of functional forms was formalized by Diewert (1971). His definition of a flexible functional form entails that the function have parameter values in such a manner that its first and second derivatives are respectively the same as those of the arbitrary function for any given point in the range of the function. Friedlander and Spady (1980) show that the translog cost function is a second order Taylor series expansion of an arbitrary function. Other flexible forms representing a second order Taylor series expansion that have the capability of providing a quadratic estimate of the unknown true function include the generalized Leontief (Diewert 1971) and normalized quadratic functional forms (Thompson 1988 and Oum 1979).

Beginning with Oum (1989 and 1979) and Friedlander and Spady (1980), who derive shipper demand for freight transportation using the translog demand system, a plethora of other studies including (Wilson 1984 and 1982, Dybing 2002, Buckley and Westbrook 1991) have used a similar approach to estimate agricultural shipper demand for freight transportation. Friedlander and Spady (1980), following from Oum (1979a and 1979b), point to three important factors to consider in analyzing freight transportation demand. Freight transportation demand is a productive input; hence it should be viewed and treated analytically like any other input. Second, the total cost of transportation encompasses the rate and cost of inventory related to shipping and storage. Third, the rate and shipment characteristics that affect inventory costs (e.g. shipment size, length of haul) are often determined together by the firm. As such, they suggested that the best approach to analyze freight demand is to derive explicitly input demand equations from the firm’s cost function that includes rates and factors reflecting shipment characteristics using estimation techniques that correct for endogeneity.

3.1.1. Theoretical Framework

To derive the demand for freight transportation and estimate intermodal competition, Oum (1979b) considers freight transportation services as productive inputs to firms' production and distribution of goods and services. He assumed that there exists a twice continuously differentiable production function which involves using inputs: capital (K), labor (L), and freight transportation to produce aggregate output(Q). Two main assumptions were made about the production function. First, the function is linearly homogenous (exhibiting constant returns to scale), increasing, and quasi-concave in inputs. Second, the freight transportation services (T) are separable from other inputs involved in the production process. Given these assumptions, the production process is represented as:

$$Q = f(K, L, \bar{f}(T)) \quad (1)$$

Where,

Q = firm level output

$T = R, H, W$

R = freight hauled by railway

H = freight hauled by highway

W = freight hauled by waterway

$\bar{f}(T)$ is linear homogenous in T , other variables defined are as defined previously.

Based on the duality theorem initially proposed by Shephard (1973), if producers minimize input cost, the ensuing cost function has sufficient information to entirely represent the production process. Consequently, rather than undertake the two-step process of specifying a production functional form and then solving the constrained cost minimizing problem, it is more reasonable to directly specify a cost function. The cost function can be specified as follows:

$$C = f(Q, W_L, W_K, W_T) \quad (2)$$

Where,

- C = total cost
- W_L = price of labor
- W_K = price of capital
- W_T = price of freight transportation services

C is linear homogenous in aggregate output Q and satisfies regularity conditions above.

Binswanger (1974) points to the advantages of using cost rather than production functions to estimate production parameters (e.g. cost functions are homogenous in prices notwithstanding the homogeneity properties of the production function).

Oum (1979b) points to the homothetic separability equivalence theorem by Blackorby et al. (1977) for justification of his model. This theorem indicates that if a production function is increasing and satisfies conditions for continuity, monotonicity and quasi-concavity, the homothetic separability of transportation services T from other inputs in the production process including capital and labor (K, L) is equal to the separability of the freight transportation service input price W_T from those of capital and labor (W_K, W_L) and aggregate output Q in the cost function (C). Friedlander and Spady (1980) develop a similar approach to estimate derived demand for freight transportation. The transportation sectoral cost function (C^T) which conserves the regularity conditions of the cost function in (2) can be described as follows:

$$C^T = (W_R, W_H, W_W) \quad (3)$$

Where,

- W_R = price of railraod freight services
- W_H = price of highway freight services
- W_W = price of waterway freight services

3.1.1.2. Empirical Specification

Following developments from (1), (2) and (3) where estimating firms' demand for freight transportation assumes that their transportation costs are separable from their total cost, the total

transportation cost of North Dakota grain shippers can be estimated similarly. Their total transportation cost can be described as a function of rail and truck prices (W_R, W_T), quantity shipped (Q), distance (D), and whether the elevators is a shuttle elevator all of which are likely to influencing mode choice (including the shuttle dummy will allow distinguishing shuttle elevator demand from non-shuttle elevator demand). North Dakota grain shippers' transportation cost function can be specified as:

$$TC = f(W_R, W_T, Q, D, SHUT) \quad (4)$$

Where,

- TC = total transportation cost
- W_R = price of rail transportation
- W_T = price of truck transportation
- Q = quantity shipped (tons)
- D = distance
- $SHUT$ = shuttle elevator dummy

Following Shephard's Lemma (1973), modal input demand functions can be derived from shippers total transportation cost as follows:

$$\frac{\partial TC}{\partial W_i} = X_i, \quad i = T, R \quad (5)$$

Where,

- X_i = quantity of rail or truck transportation

This study utilizes a link specific cost function involving individual grain elevators in the state to evaluate agricultural freight demand for five principal commodities shipped from North Dakota including barley, corn, hard red spring and durum wheat, and soybeans. The link specific transportation cost model is similar to that by Oum (1979) given as:

$$TC_l = f(W_{il}, Q, D_l, T, SHUT) \quad (6)$$

Where,

TC_l = total rail and truck transportation cost on link l ;

W_{il} = $i \times l$ vector of prices of i modes on link l ;

Q = total output on link l (tonmiles);

D_l = distance of link

T = time trend

$SHUT$ = shuttle elevator dummy

$l = 1, 2, \dots, l$

The links involve grain elevators within the state shipping to the four principal destinations for North Dakota grain, including Duluth, MN; Minneapolis, MN; New Orleans, LA and Portland, OR. New Orleans, LA and Portland, OR are used to represent both the Gulf and Pacific Northwest respectively. Oum (1979a) used aggregate data for estimation due to the lack of data at the disaggregate level. He noted that the use of disaggregate data is useful in the analyses of multi modal demand for freight transportation, especially in the evaluation of intermodal competition because it more precisely models individual shipper's production and distribution activities. By using disaggregate data at the level of the country elevators; the model in equation (6) closely represents the marketing and distribution process of North Dakota grain shippers. Moreover, it allows us to distinguish shuttle elevator demand from non-shuttle demand.

To estimate the link specific transportation cost in equation (6), it needs to be specified in a given functional form. Oum (1979a) indicates that for the study of intermodal substitutability (intermodal competition), such a functional form should be able to permit free variability of Allen partial elasticities of substitution and be "flexible" enough to provide a valid second order estimation to an arbitrary differentiable function. He adds that the translog function originally developed by Christensen et al. (1971), in addition to being consistent with neoclassical theory of production, provides a system of costs and demand functions that are most conveniently estimable. The translog form of the link specific model is given as:

$$\begin{aligned}
\ln TC_l = & \alpha_0 + \sum_i \alpha_i \ln(W_{il}) + \rho_q \ln(Q) + \beta_t \ln(D_l) + \psi_\phi T + \varpi_\zeta SHUT + \frac{1}{2} \sum_{ij} \tau_{ij} \ln(W_{il}) \ln(W_{jl}) + \\
& \sum_i \tau_{iq} \ln(W_{il}) \ln(Q_l) + \sum_i \tau_{it} \ln(W_{il}) \ln(D_l) + \sum_i \tau_{i\phi} \ln(W_{il}) T + \frac{1}{2} \sum_i \tau_{i\zeta} \ln(W_{il}) SHUT + \\
& \frac{1}{2} \tau_{qq} (\ln Q_{il})^2 + \tau_{qt} \ln Q_{il} \ln D_l + \frac{1}{2} \tau_{tt} (\ln D_l)^2 + \frac{1}{2} \tau_{\phi\phi} (T)^2 + \tau_{q\phi} \ln Q_{il} T + \tau_{q\zeta} \ln Q_{il} SHUT + \\
& \tau_{t\phi} \ln(D_l) T + \tau_{t\zeta} \ln(D_l) SHUT + \tau_{t\phi} \ln(D_l) T + \tau_{t\zeta} \ln(D_l) SHUT + \tau_{\phi\zeta} T SHUT \quad (7)
\end{aligned}$$

Where, all independent variables are divided by their means. The translog cost function has the same properties as the usual translog cost function, including homogeneity of degree one in input prices. A proportional change in rates of all transportation modes used in shipping grain on a particular link will alter shippers' total cost proportionately on that link. Necessary and sufficient homogeneity and symmetry conditions for specifying a cost function with linear homogeneity in shipping rates are:

$$\sum_i \alpha_i = 1,$$

$$\sum_i \tau_{ij} = \sum_j \tau_{ij} = 0,$$

$$\sum_i \tau_{iq} = \sum_i \tau_{it} = \sum_i \tau_{i\phi} = \sum_i \tau_{i\zeta} = 0, \quad \tau_{ij} = \tau_{ji}$$

Input share equations for rail and truck can be obtained from the translog cost function using Shephard's Lemma and logarithmic differentiation. From Shephard's lemma:

$$\frac{\partial c}{\partial w_i} = x_i \quad (8)$$

Similarly, for the link specific transportation cost function, we have:

$$\frac{\partial TC_l}{\partial w_{il}} = x_{il} \quad (9)$$

Where, x_{il} is the quantity of rail or truck transportation on link, l . In logarithmic form we have:

$$\frac{\partial \ln TC_l}{\partial \ln(w_{il})} = \frac{\partial TC_l}{\partial w_{il}} \times \frac{w_{il}}{c} \quad (10)$$

Substituting for $\frac{\partial TC_l}{\partial w_{il}}$ in (10), we get

$$\frac{\partial \ln TC_l}{\partial \ln(w_{il})} = x_{il} \frac{w_{il}}{c} = S_{il} \quad (11)$$

Where, S_{il} is the expenditure factor share for rail or truck transportation on a particular link. The total cost function (7) is estimated together with factor share equations (11) using Zellner's Seemingly Unrelated Regression or Three Stage Least Squares (3SLS) after testing for potential endogeneity of input prices (rail and truck rates) using the omitted variable version of the Hausman test. Endogeneity arises when one or more explanatory variable is correlated with the error term either due to an omitted variable, measurement error, or simultaneity (Wooldridge, 2006). The omitted variable version of the Hausman test involves two steps. First ordinary least square (OLS) is used to separately regress each of the input prices being tested for endogeneity on instruments (crop production and fuel prices) for rail and truck rates and other exogenous variables in the translog cost function excluding endogenous variable interactions. Total cost is then regressed on predicted values obtained from the first stage process together with interactions of predicted values and other exogenous variables in the original cost function including original input prices to obtain unrestricted residual sum of square using OLS. A second OLS regression which excludes predicted values and their interactions with exogenous variables is undertaken to obtain a restricted residual sum of squares. An F-test is used to test the joint significance of the slopes of generated predicted values and interaction of the predicted values with other variables in the cost function. The F-test is given as:

$$F = \frac{(RSS_R - RSS_U) / \text{num.of restrictions}}{RSS_U / d.f.U} \quad (12.1)$$

Where,

- RSS_U = Unrestricted residual sum of squares;
- RSS_R = Restricted residual sum of squares ;
- $d.f.U$ = Degree of freedom for unrestricted model;

Given that the factor shares sum up to 1, one of the factor share equations is dropped to avoid perfect collinearity. Results remain the same no matter which equation is dropped. North Dakota grain movement data between 2006 and 2013 are used to estimate separate models for all five commodities. The link specific cost function is also tested for concavity in modal factor prices by taking the characteristics roots of the hessian matrix. Concavity requires that the link specific cost function satisfies first and second order conditions. The first order condition requires that the cost function be non-decreasing in modal input prices. The second order conditions entails that the Hessian matrix be negative definite given in terms of characteristic roots. The Transcendental Logarithmic parameters are transformed to obtain the Hessian matrix given that parameters in the cost function are in natural logs. The two by two (two modal input prices) Hessian matrix is shown below.

$$H = \begin{bmatrix} \frac{\partial^2 TC_l}{\partial W_{il}^2} & \frac{\partial^2 TC_l}{\partial W_{il} \partial W_{jl}} \\ \frac{\partial^2 TC_l}{\partial W_{il} \partial W_{jl}} & \frac{\partial^2 TC_l}{\partial W_{jl}^2} \end{bmatrix} \quad (12.2)$$

Where,

$$\frac{\partial^2 TC_l}{\partial W_{il}^2} = \frac{TC_l}{W_{il}^2} \left[\frac{\partial^2 \ln TC_l}{\partial \ln W_{il}^2} - \frac{\partial \ln TC_l}{\partial W_{il}} + \frac{\partial \ln TC_l}{\partial W_{il}} * \frac{\partial \ln TC_l}{\partial W_{il}} \right]$$

$$\frac{\partial^2 TC_l}{\partial W_{il} \partial W_{jl}} = \frac{TC_l}{W_{il} W_{jl}} \left[\frac{\partial^2 \ln TC_l}{\partial \ln W_{il} \partial \ln W_{jl}} + \frac{\partial \ln TC_l}{\partial W_{il}} * \frac{\partial \ln TC_l}{\partial W_{jl}} \right]$$

The link specific model with two input prices (rail and truck rates), one output (ton-miles), link distance (miles) and a time trend to be estimated is given as:

$$\begin{aligned}
InTC_l = & \alpha_0 + \alpha_1 In(Rail_l) + \alpha_2 In(Truck_l) + \rho_1 In(TM_l) + \rho_2 In(Dist_l) + \rho_3 time + \rho_4 SHUT \\
& + \tau_{11} \frac{1}{2} (In rail_l)^2 + \tau_{22} \frac{1}{2} (In truck_l)^2 + \beta_{11} \frac{1}{2} (In TM_l)^2 + \beta_{22} \frac{1}{2} (Dist_l)^2 + \beta_{33} \frac{1}{2} time^2 \\
& + \tau_{12} In(rail_l). In(truck_l) + \chi_{11} In(rail_l). In(TM_l) + \chi_{12} In(rail_l). In(Dist_l) \\
& + \chi_{13} In(rail_l). time + \chi_{14} In(rail_l). SHUT + \chi_{21} In(truck_l). In(TM_l) \\
& + \chi_{22} In(truck_l). In(Dist_l) + \chi_{23} In(truck_l). time + \chi_{24} In(truck_l). SHUT \\
& + \beta_{12} In(TM_l). In(Dist_l) + \beta_{13} In(TM_l). time + \beta_{14} In(TM_l). SHUT + \beta_{23} In(Dist_l). time \\
& + \beta_{24} In(Dist_l). SHUT + \beta_{34} time. SHUT + \omega_f \sum_f ELEV_e + \varepsilon_i
\end{aligned} \tag{13}$$

Where,

- TC_l = total rail and truck transportation cost on link l;
- $rail_l$ = rail rate on link l;
- $truck_l$ = truck rate on link l;
- TM_l = tonmiles on link l;
- $Dist_l$ = average link distance;
- $time$ = time trend
- $ELEV_e$ = elevator fixed effects dummies
- $SHUT$ = shuttle elevator dummy (shuttle = 1, 0 otherwise)

Following Shephard's Lemma (1973) the corresponding cost share equations for each input rail and truck, S_{1l}, S_{2l} respectively are shown below:

$$\begin{aligned}
S_{1l} = & \alpha_1 + \tau_{11} In(rail_l) + \tau_{12} In(truck_l) + \chi_{11} In(TM_l) + \chi_{12} In(Dist_l) + \chi_{13} time + \chi_{14} SHUT \\
S_{2l} = & \alpha_2 + \tau_{22} In(truck_l) + \tau_{12} In(rail_l) + \chi_{21} In(TM_l) + \chi_{22} In(Dist_l) + \chi_{23} time + \chi_{24} SHUT
\end{aligned}$$

Where, TC_l is obtained by summing all transportation modal costs as specified in Buckley and Westbrook (1991). The other variables are as defined previously. For ease of interpretation, and given that the translog function is a Taylor series expansion, all independent variables except the time trend and the shuttle dummy are normalized (divided) by their means.

The estimated coefficients on the first-order terms of the cost equation ($\alpha_1, \alpha_2, \rho_1, \rho_2$) represent cost elasticity with respect to that variable, while all variables are at their sample mean time is at the first year and shuttle dummy is zero. Additionally, for the transportation shipping rate (rail, and truck) these estimated coefficients (α_1 , and α_2) depict each mode's share of total transportation cost at the means of all variables except time and the shuttle dummy.

Satar and Peoples (2010) indicate that knowledge about the substitutability and complementarity of various modes is vital in understanding whether shippers can possibly view different modes of transportation as a choice of competing shipping services or as a set of services used together. For cost minimizing firms, the elasticity of substitution between two inputs measures the proportional change in the input ratio for a related change in the input price ratio. Consequently, the elasticity of substitution between rail and truck services for example measures the shift in traffic brought about by a change in the relative price, giving a measure of the level of competition between the two modes (Buckley and Westbrook 1991). In the case of North Dakota grain shippers, this shows the level of competition between rail and truck.

The Allen-Uzawa (1962) elasticity of substitution shown in equation (14) provides information whether two inputs are substitutes or complements:

$$\sigma_{ij} = \left(\tau_{ij} / S_i S_j \right) + 1 \quad i \neq j \quad (14)$$

Inputs i and j are “Allen substitutes” and complements if $\sigma_{ij} > 0$ and $\sigma_{ij} < 0$ respectively. For “Allen substitutes”, an increase in the price of one input causes the increase in the usage of another. On the other hand, if an increase in price of one input leads to the decrease in utilization of the other, the inputs are described as complements. The elasticity of input demand with respect to the price of another input (cross price elasticity) and own price are shown in equation (15) and (16) respectively below:

$$\varepsilon_{ij} = \left(\frac{\tau_{ij}}{S_i} \right) + S_j = \sigma_{ij} S_j \quad (15)$$

$$\varepsilon_{ii} = \left(\frac{\tau_{ii}}{S_i} \right) - 1 + S_i \quad (16)$$

Estimated elasticities in equations (15) and (16) do not take into account changes in the quantity demanded of the final product in response to changes in freight rates. It is compensated (Hicks) demand elasticity.

Modal demand elasticities can be used to assess the perceived dependence on a given mode and changes in the dependence over time. Consider that $i = 1$ and 2 for rail and truck transportation respectively. If the own price elasticity of demand for rail services $|\varepsilon_{11}|$ decreases in absolute value over time, then North Dakota shippers are increasingly dependent on rail for transport services (they view truck services as less viable alternatives). Oum (1979) shows that for the two mode case, the cross price elasticity of rail with respect to truck price ε_{12} , or the cross price elasticity of truck with respect to rail price ε_{21} is given by the absolute value of the own price elasticity of rail ε_{11} or the absolute value of the own price elasticity truck ε_{22} respectively. This is the case because the elasticities are conditional demand (calculated from a compensated or Hicksian demand function) elasticities- conditional on output level. They do not account for the impact of price change on total output shipped (or change in elasticity of demand for the product). A general representation is given as:

$$\varepsilon_{ij} = |\varepsilon_{ii}| \quad (17)$$

Equation (17) shows that a relationship exists between own and cross price elasticity in the two mode case. Knowledge about cross price elasticities can be used to calculate own price elasticity of rail and truck. Conditional elasticities mean a one percent price increase in all prices will not change the amount of a mode used. These can be specified for rail and truck respectively below:

$$\text{rail:} \quad \varepsilon_{11} + \varepsilon_{12} = 0 \quad \rightarrow \quad |\varepsilon_{11}| = \varepsilon_{12} \quad (18)$$

$$\text{truck: } \quad \varepsilon_{22} + \varepsilon_{21} = 0 \quad \rightarrow \quad |\varepsilon_{22}| = \varepsilon_{21} \quad (19)$$

3.1.1.3. Potential Outcomes

Considering rail, if the absolute value of the own price elasticity of rail, $|\varepsilon_{11}|$, is low this suggests that rail can increase its prices without a big reduction in traffic. Moreover, reductions in truck prices won't have much of an impact on rail traffic as reflected by a low cross-price elasticity, (ε_{12}) thus, rail is the dominant mode for that traffic. On the other hand, if the absolute value of the own price elasticity of demand for rail, $|\varepsilon_{11}|$ increases over time, then North Dakota shippers are less dependent on rail for transport services (they view truck services as a more viable alternative). The latter case is likely if grain elevators are increasingly shipping for shorter distances or if trucking improvements make it seem like a more viable option at longer distance. The determination of likely distances where rail and truck compete is an empirical issue (we do not know what constitutes shorter distances). Similarly, decreasing and increasing own price elasticity of demand for truck will have related outcomes to those explained above.

Oum (1979) shows a method for calculating unconditional (ordinary or Marshallian) demand elasticities. Ordinary demand elasticities account for the impact of price change on total output shipped. The Marshallian elasticity of demand, M_{ij} for one mode (ith) with respect to the price of another mode (jth) is given as:

$$M_{ij} = (\sigma_{ij} + \gamma_j \Omega) \hat{S}_j \quad (20)$$

Where,

$\hat{S}_j =$ expenditure share of the jth mode predicted by the model

$\Omega =$ own price elasticity of consumer demand for transported commodity

$\gamma_j = \frac{dp_j}{dp_j} \frac{p_j}{p} =$ proportionate change in price of the commodity w.r.t to a change in the price of the jth mode

σ_{ij} = elasticity of *ith* – *jth* mode substitution

To calculate the ordinary demand elasticities shown in equation (19), the own price elasticity of demand for the commodity (Ω), and the proportionate change in the price of the commodity with respect to a change in the price of the transportation mode (γ_j), were both arbitrary assumed to be unity by Oum. Oum (1979) further noted that the level of competition does not vary only by commodity type, but there is potential variability in modal competition at different distances. To ascertain the level of competition at different distances and points where one mode dominates another, he provides a rule of thumb linking the relationship between distances, mode shares, and elasticities.

3.1.1.4. Distance Competition Rule of Thumb

Following the rule of thumb by Oum (1979) where, *i* or *j* = 1, 2, stands for rail and truck respectively the following can be deduced: Using equation (14) it can be observed that the elasticity of substitution between the *ith* mode and the *jth* mode: $\sigma_{ij} = \left(\frac{\tau_{ij}}{S_i S_j} \right) + 1$ gets bigger as the absolute deviation between the mode shares $|S_i - S_j|$ increases. For example, the elasticity of substitution between rail and truck: $\sigma_{12} = \left(\frac{\tau_{12}}{S_1 S_2} \right) + 1$, gets bigger as the absolute deviation between the two mode share, $|S_1 - S_2|$, increases.

Oum (1979) shows that, it is also the case that if $|S_1 - S_2|$ is large and $S_1 > S_2$ in a given freight market, own price elasticity for trucking will be high and consequently, so will cross price elasticity of demand for trucking with respect rail price. Two things cause an increase in the cross price elasticity of demand for trucking services with respect to rail services and own price elasticity of demand for trucking when, $|S_1 - S_2|$ is large and $S_1 > S_2$:

First, σ_{21} becomes larger as, $|S_1 - S_2|$ becomes large. Second, S_1 is larger (Recall $\varepsilon_{21} = \sigma_{21}S_1$). Recall from equation (18) that the absolute value of the own price elasticity of trucking is equal to the cross price elasticity of truck with respect to rail: $(|\varepsilon_{22}| = \varepsilon_{21}$.

This suggests that $|\varepsilon_{22}|$ will also be large, since ε_{21} is large and positive. High own price elasticity for trucking is likely to occur on longer hauls dominated by rail (Oum 1979).

If $|S_1 - S_2|$ is large and $S_1 < S_2$ in a given freight market, Oum (1979) shows that own price elasticity of demand for rail services will be high. He notes that two factors increase the cross price elasticity of demand for rail services with respect to trucking as follows: First, σ_{12} becomes larger. Second, S_2 is larger. Recall $\varepsilon_{12} = \sigma_{12}S_2$. From equation (17) the absolute value of the own price elasticity for rail is obtained from cross price elasticity of rail with respect to truck: $(|\varepsilon_{11}| = \varepsilon_{12}$. This suggests that $|\varepsilon_{11}|$ will also be large since ε_{12} is large. Depending on the commodity type and the quality of service needed by shippers, trucks have been shown to dominate short hauls. This may occur for shipments from grain elevators in the East of the state to Duluth and Minneapolis, MN.

Oum (1979) suggests that, as distance increases, the rail elasticity of demand decreases while that for truck increases. Also, as shipping distance becomes shorter, the truck elasticity of demand decreases (becomes more inelastic) while that for rail increases (becomes more elastic). For example, on links from grain elevators to PNW and Gulf destinations where rail is likely to dominate the majority of the traffic with no significant or existing intermodal competition, demand for truck is likely to be highly price-elastic.

In summary, the own price elasticity of rail demand ε_{11} is likely to decrease with distance, while that for truck, ε_{22} will likely increase with distance. Rail will likely dominate long hauls and trucks short hauls, leaving the medium haul as the likely market for intermodal

competition. In this case, we are unsure what the medium haul distance is. Oum (1979) identifies for each commodity group in his study the upper bound of the distance for which truck mode dominates and the lower bound of distance that rail dominates. This study will use similar criteria for each of the five commodities under evaluation. Most studies arbitrarily state the distance which a given mode dominates (CRS 2005) or develop conceptual models on modal distance competition (Koo et al. 1993) without calculating these distances or showing the relationship between elasticities and distance or changes over time. This study actually shows the distances in which one mode dominates the other by commodity and changes in elasticity by distance and over time. The criteria for modal dominance are given as follows:

A link is described as truck dominated if the absolute value of the own price elasticity of rail is greater than one and twice that of the own price elasticity of truck:

$$|\varepsilon_{11}| > 1 \text{ and } |\varepsilon_{11}| > 2|\varepsilon_{22}|$$

A link is rail dominated if the absolute value of the own price elasticity of truck is greater than one and twice the absolute value of the own price elasticity of rail:

$$|\varepsilon_{22}| > 1 \text{ and } |\varepsilon_{22}| > 2|\varepsilon_{11}|$$

After establishing the criteria for link dominance, it is also essential to assess how elasticities change over distance and time. This will provide insight into the relative usage of different modes for different distances and over time.

Rail own price elasticity estimate by link distance is given as:

$$\text{Rail: } (\varepsilon_{11})_{ld} = \left(\frac{\hat{\tau}_{11}}{Rshare_{ld}} \right) - 1 + Rshare_{ld} \quad (21)$$

Where,

$\hat{\tau}_{11}$ = estimated second order rail term in link specific cost function

$Rshare_{ld}$ = rail share by link distance

$$Rshare_{ld} = \alpha_1 + \hat{X}_{12} * \ln\left(\frac{ld}{avdist}\right) + \hat{X}_{11} * \ln\left(\frac{tm}{avtms}\right)$$

\hat{X}_{12} = rail rate link distance interaction estimate

\hat{X}_{11} = rail rate output interaction estimate
 ld = assigned link distance in 50 miles increment based on range in dataset
 $avdist$ = simple average link distances for all links in dataset
 $tm = ld * avtons$ (avtons = simple average tons shipped for all links)
 $avtmls$ = simple average output for all links in dataset

Truck own price elasticity estimate by link distance is given as:

$$Truck: (\varepsilon_{22})_{ld} = \left(\frac{\hat{\tau}_{22}}{Tshare_{ld}} \right) - 1 + Tshare_{ld} \quad (22)$$

Where,

$\hat{\tau}_{22}$ = estimated second order truck term in link specific cost function
 $Tshare_{ld}$ = truck share by link distance
 $Tshare_{ld} = \alpha_2 + \hat{X}_{22} * \ln\left(\frac{ld}{avdist}\right) + \hat{X}_{21} * \ln\left(\frac{tm}{avtmls}\right)$
 \hat{X}_{22} = rail rate link distance interaction estimate
 \hat{X}_{21} = rail rate output interaction estimate
 ld = assigned link distance in 50 miles increment based on range in dataset
 $avdist$ = simple average link distances for all links in dataset
 $tm = ld * avtons$ (avtons = simple average tons shipped for all links)
 $avtmls$ = simple average output for all links in dataset

Rail own price elasticity estimate over time is given as:

$$Rail: (\varepsilon_{11})_{tim} = \left(\frac{\hat{\tau}_{11}}{Rshare_{tim}} \right) - 1 + Rshare_{tim} \quad (23)$$

Where,

$Rshare_{tim} = \alpha_1 + \hat{X}_{13} * (time)$
 \hat{X}_{13} = rail rate time trend interaction parameter estimate
 $time$ = time trend
 all other parameters are as defined previously

Truck own price elasticity estimate over time is given as:

$$Truck: (\varepsilon_{22})_{tim} = \left(\frac{\hat{\tau}_{22}}{Tshare_{tim}} \right) - 1 + Tshare_{tim} \quad (24)$$

Where,

$Tshare_{tim} = \alpha_2 + \hat{X}_{23} * (time)$
 \hat{X}_{23} = truck rate time trend interaction parameter estimate
 $time$ = time trend
 all other variables are as defined previously

The potential impact of shuttle elevators on grain transportation can be evaluated by looking at the variation in intermodal competition (truck-rail competition) exhibited by elasticities of different elevator types (shuttle and non-shuttle) over distance and time. The rail and truck own-price elasticities by link distance presented in equations (21) and (22) can be modified for shuttle elevators as shown in equation (25) and (26) respectively.

Rail own price elasticity estimate by link distance for shuttle elevators is given as:

$$\text{Rail: } (\varepsilon_{11})_{shut-ld} = \left(\frac{\hat{\tau}_{11}}{Rshare_{shut-ld}} \right) - 1 + Rshare_{shut-ld} \quad (25)$$

Where,

$Rshare_{shut-ld}$ = rail share by link distance

$Rshare_{ld} = \alpha_1 + \hat{X}_{12} * \ln\left(\frac{ld}{avdist}\right) + \hat{X}_{11} * \ln\left(\frac{tm}{avtmls}\right) + \hat{X}_{14}(\text{SHUT})$

\hat{X}_{14} = rail rate shuttle dummy interaction estimate

SHUT = shuttle dummy variable

All other variables defined previously

Truck own price elasticity estimate by link distance for shuttle elevators is given as:

$$\text{Truck: } (\varepsilon_{22})_{shut-ld} = \left(\frac{\hat{\tau}_{22}}{Tshare_{shut-ld}} \right) - 1 + Tshare_{shut-ld} \quad (26)$$

Where,

$Tshare_{shut-ld}$ = truck share by link distance

$Tshare_{shut-ld} = \alpha_2 + \hat{X}_{22} * \ln\left(\frac{ld}{avdist}\right) + \hat{X}_{21} * \ln\left(\frac{tm}{avtmls}\right) + \hat{X}_{24}(\text{SHUT})$

\hat{X}_{24} = rail rate shuttle dummy interaction estimate

SHUT = shuttle dummy variable

All other variables defined previously

3.2. Mode Choice and Allocative Efficiency

Railroads play a value-added role in agriculture by moving commodities (especially bulk) for long distances from production regions often located in rural areas to consumption centers or ports for export. Railroads have increased emphasis on larger capacity grain elevators. This has led to widespread implementation and use of longer trains (e.g. shuttle train). This technological

improvement in grain transportation and logistics has reduced carrier costs and provided better rates to shippers. Moreover, it has been shown by surveys undertaken by UGPTI (2012) to improve the quality of service provided by railroads to grain shippers.

Several studies have evaluated and found improvements in the quality of service stemming from innovations in the railroad industry following partial deregulation including improvements in speed, reliability and railcar availability. Other studies have found productivity gains (Grimm and Smith 1986, Ellig 2000, Bitzan and Keeler 2003, Prater et al. 2010). However, despite observed innovations in the transportation and logistics of grains, Wilson and Dahl (2010) and Sarmiento and Wilson (2005) note that only a few studies have evaluated technology adoption in grain shipping (Vachal et al. 1999; Vachal and Button 2003, Wilson and Wilson 2001, MacDonald 1989). Vachal et al. (1999) assess the potential of marketing hard red spring wheat in 100 plus car trains in North Dakota and indicate that the increased flexibility brought about by their use will benefit market participants. They concluded that the advent of larger trains is likely to lead to further rationalization of the state's grain procurement system, ultimately leading to fewer elevators, increasing rail line abandonment, and longer producer deliveries. Vachal and Button (2003) provide a market based synopsis of the likely impact of shuttle rates on grain flow in North Dakota using different scenarios. In the base scenario, with 10 shuttle facilities accounting for 45% of the state land area, two percent of the elevators are able to handle a third of the grains produced. They surmise that potential concentration of bushels around these facilities will have future potential impacts for local roads, short line railroads, bridge infrastructure, local processors and communities, and the North Dakota elevator industry. Wilson and Wilson (2001) evaluate efficiency gains related to innovation in the

marketing of agricultural commodities. They find that rates for all five main grains transported by rail fell significantly and have diminished over time after passage of the Staggers Act.

Studies aimed at evaluating shippers' quality of service evaluations including those related to transportation of agricultural commodities often rely heavily on surveys to elicit shippers' evaluation of quality of service attributes. Such undertakings are subjective and may not accurately reflect the importance of service quality in mode choice. A more objective evaluation will be to empirically analyze their utilization of different modes at given prices.

Additionally, it is likely that potential service quality improvements brought about by the shuttle innovation is an important consideration to grain shippers in markets like North Dakota with limited shipping options. Satar and Peoples (2010), using a generalized shipper transportation cost function, find that shippers with access to all major transportation modes (barge, truck, and rail) attain "allocative efficiency" with respect to market price, while those with limited access (truck and rail) choose an "allocatively inefficient" mix. Specifically, they find that shippers use more trucking than they should if their choice of mode is based on minimizing costs. They interpret these results to mean that capacity constraints or poor service quality on routes not facing barge competition leads to a shadow price of using rail services that is higher than its market price.

Similarly, if limited rail capacity and/or inconsistent rail service quality in North Dakota increases the shadow price of using rail services, we might expect to see an underutilization of rail services. To the extent that shuttles have allowed an improved use of rail capacity and enhance the predictability /consistency of rail service quality, we might expect North Dakota shippers to use a less "allocatively inefficient" mix of rail and truck that reflects optimization based increasingly on market rates. This would suggest that shuttles have resulted in service

improvement in addition to lower transportation rates. Another possibility is that increasing highway congestion and infrastructure deterioration has led to a reduction in service quality by trucks.

Additionally, Satar and Peoples (2010) note that rail carriers have expanded the US rail system by increasing their investment in infrastructure. Consequently, shippers who are constrained to using rail, in this case North Dakota grain shippers, likely do not face a significant disadvantage relative to those with rail and barge access if high rail costs are followed with superior transportation services. Beginning from 2000, railroads have spent \$10 Billion to expand tracks, construct freight yards and add locomotives with more than \$12 Billion planned in upgrades (Machalaba 2008). BNSF, one of the two main class I railroads serving the state announced plans to spend \$250 Million to expand rail traffic on its network in North Dakota following agricultural shippers complaints about delays (Kyle, 2014). By the end of 2014 it was also announced that BNSF had completed a \$400 Million track upgrade project in North Dakota that included placing 55 miles of new double track between Williston and Minot, and other siding projects for the Dickinson, Jamestown, Devils Lake, and Hillsboro North Dakota rail subdivisions respectively (Bonham, 2014).

3.2.1. Theoretical Model

Studies of freight demand often use the neoclassical cost approach, which assumes that firms minimize cost subject to their output constraint with market rates for different modes used as input prices (shippers' perspective). Atkinson and Halvorsen (1984) argue that the existence of additional constraints may cause a firm to fail to minimize costs. That is, firms may not use an "allocatively efficient" mix of inputs when choosing inputs based on market input prices alone.

It is generally assumed that shippers will employ each input until the marginal product of a single dollar paid for one input is equal to the marginal product of the value of a dollar of another so as to minimize cost and employ an allocatively efficient mix of inputs. In this case, for a shipper with rail and truck transportation as inputs, we have:

$$\frac{MP_r}{R_r} = \frac{MP_t}{R_t} \quad (25)$$

MP_r and MP_t represent the marginal products of rail and truck transportation and R_r and R_t are input prices representing rates paid for rail and truck services, respectively. However, unreliable and unpredictable service or capacity constraints may cause the true price of using a particular mode to be above that reflected by market price. Alternatively, it may reduce the actual productivity of a particular mode. The actual marginal productivities, and input prices that shippers are faced with (those that exist taking into account the effects of service quality are characterized as shadow marginal productivities) (MP_r^* and MP_t^*) and shadow input prices (R_r^* and R_t^*). Thus shippers select a mix of inputs such that:

$$\frac{MP_r^*}{R_r^*} = \frac{MP_t^*}{R_t^*} \quad (26)$$

If poor service quality decreases the productivity of a shipper's input (rail or truck) or raises the cost of acquiring an additional unit of input, the shadow marginal product of the dollar value of that input will be less than the marginal product of the dollar value of that input as reflected by market price (when hiring the same amount of inputs). For example for rail we have:

$$\frac{MP_r^*}{R_r^*} < \frac{MP_r}{R_r} \quad (27)$$

This would result in the shipper using less rail transportation than if based on market price. Consider a generalized shipper transport cost function with two input prices (rates paid by

shippers for rail and truck transportation), one output, one technology characteristic (distance), and a time trend given below:

$$TC = C(W_r, W_t, Q, D, T) \quad (28)$$

Where,

TC = total transportation cost
W_r = price of rail transportation
W_t = price of truck transportation
Q = amount shipped (ton – miles)
D = distance
T = time trend

Previous research undertaken to test for “allocative efficiency” including Atkinson and Halvorsen (1984) and Oum and Zhang (1995) have shown that allocative efficiency can be tested by estimating a firm’s cost function with an embedded “shadow cost function”. If unpredictable service quality or capacity constraints changes the cost of using rail or truck, the actual price (shadow price) of using any of these two inputs will diverge from the market price (existing rate). Shippers are assumed to base their input utilization decisions on these unobserved shadow prices, consequently minimizing total shadow costs. Shippers’ shadow cost function in this study is given as:

$$C^S = C^S(kW_{il}, Q, D_l, T) \quad (29)$$

Where,

C^S = shippers’ shadow cost on link *l*;
w_{il} = *i* × *l* vector of shadow prices of *i*th modes on link *l*;
Q_l = total output on link *l* (tonmiles);
D_l = distance of link;
T = time trend;

Input shadow prices can be defined by the factor of proportionality *k* times the market input price (Lau and Yotopolous 1971) represented as:

$$W_i^* = k_i W_i \quad (30)$$

The factor of proportionality (K_i) is a measure of the existing linkage between the true input prices (shadow prices) and the market prices (existing rate shippers pay for rail or truck transportation) for inputs. The factor proportionality is represented as below:

$$k_i = \frac{W_i^*}{W_i} \quad (31)$$

3.2.2. Empirical Model

To test if North Dakota shippers are using an “allocatively efficient” mix of transportation with respect to observed market prices (shipping rate), the allocative efficiency model will closely follow that undertaken by Bitzan and Peoples (2013) to evaluate “allocative efficiency” in the airline industry. Factors of proportionality are estimated for transportation rates for all five commodities under evaluation. This will enable a comparative analysis of different commodities and the potential effect of shuttle elevators on shippers’ allocative efficiency. For example the primary commodity handled by shuttle elevators in North Dakota is hard red spring wheat. Other than corn, shuttle shipments rarely occur for the other four commodities under evaluation. Consequently, if there is an underutilization of rail, it is likely that the factor proportionality (k_i) for the rail input for hard red spring wheat may move closer to unity over time due to improved capacity and consistency in service quality identified with shuttle movements.

Applying Shephard’s Lemma (1973) to the shadow cost function as shown in Atkinson and Halvorsen (1984) provides input demand of the following form:

$$\frac{\partial C^S}{\partial W_i^*} = X_i \quad (32)$$

The total actual cost becomes:

$$C = \sum_i W_i X_i = \sum_i W_i \frac{\partial C^S}{\partial W_i^*} \quad (33)$$

Atkinson and Halvorsen (1984) also show that the share of shadow cost attributed to input i is:

$$\frac{k_i W_i x_i}{C^S} = S_i^S \quad (34)$$

Input X_i therefore is:

$$\frac{S_i^S C^S}{k_i W_i} = X_i \quad (35)$$

The total actual cost function becomes:

$$C = \sum_i W_i \frac{S_i^S C^S}{k_i W_i} = C^S \sum_i \frac{S_i^S}{k_i} \quad (36)$$

Taking the logarithm, we get:

$$\ln C = \ln C^S + \ln \sum_i \left(\frac{S_i^S}{k_i} \right) \quad (37)$$

Estimating the shadow cost function as an embedded part of the total cost function using the translog functional form we get the following shadow cost function:

$$\begin{aligned} \ln C^S = & \alpha_0 + \sum_i \alpha_i \ln(k_i W_i) + \rho_0 \ln Q_0 + \beta_n \ln(D_l) + \psi_\phi T + \frac{1}{2} \sum_{ij} \tau_{ij} \ln(k_i W_i) \ln(k_j W_j) + \\ & \sum_{i0} \tau_{i0} \ln(k_i W_i) \ln Q_0 + \sum_{in} \tau_{in} \ln(k_i W_i) \ln(D_l) + \sum_{i\phi} \tau_{i\phi} \ln(W_{il}) T + \frac{1}{2} \tau_{00} (\ln Q_0)^2 + \\ & \partial_{0n} \ln Q_0 \ln(D_l) + \frac{1}{2} \tau_{nn} (\ln D_l)^2 + \frac{1}{2} \tau_{\phi\phi} (T)^2 + \tau_{0\phi} \ln Q_0 T + \tau_{n\phi} \ln(D_l) T \end{aligned} \quad (38)$$

The translog shadow cost function has the same properties AS the usual translog cost function, including homogeneity of degree one in shadow input prices. A proportional change in shadow rates of all transportation modes used in shipping grain will alter the shippers' total cost proportionately. Necessary and sufficient homogeneity and symmetry conditions for specifying a cost function with linear homogeneity in shipping rates are:

$$\sum_i \alpha_i = 1,$$

$$\sum_i \tau_{ij} = \sum_j \tau_{ij} = 0,$$

$$\sum_i \tau_{i0} = \sum_i \tau_{in} = \sum_i \tau_{i\phi} = 0, \quad \tau_{ij} = \tau_{ji}$$

The shadow cost share equations can be obtained from the shadow cost function using Shephard's Lemma (1973) and logarithmic differentiation as follows:

$$\frac{\partial \ln C^S}{\partial \ln(k_i W_i)} = \frac{\partial \ln C^S}{\partial C^S} \frac{\partial C}{\partial(k_i W_i)} \frac{\partial(k_i W_i)}{\partial \ln(k_i W_i)} = \frac{1}{C^S} X_i(k_i W_i) = S_i^S \quad (39)$$

$$S_i^S = \alpha_i + \sum_j \tau_{ij} \ln(k_j W_j) + \sum_0 \tau_{i0} \ln Q_0 + \sum_n \tau_{in} \ln(D) \quad (40)$$

From equation (37), (38), and (40) we can get the total cost function:

$$\begin{aligned} \ln C = & \alpha_0 + \sum_i \alpha_i \ln(k_i W_i) + \rho_0 \ln Q_0 + \beta_n \ln(D_l) + \psi_\phi T + \frac{1}{2} \sum_{ij} \tau_{ij} \ln(k_i W_i) \ln(k_j W_j) + \\ & \sum_{i0} \tau_{i0} \ln(k_i W_i) \ln Q_0 + \sum_{in} \tau_{in} \ln(k_i W_i) \ln(D_l) + \sum_{i\phi} \tau_{i\phi} \ln(W_{il}) T + \frac{1}{2} \tau_{00} (\ln Q_0)^2 + \\ & \partial_{0n} \ln Q_0 \ln(D_l) + \frac{1}{2} \tau_{nn} (\ln D_l)^2 + \tau_{\phi\phi} (T)^2 + \tau_{o\phi} \ln Q_0 T + \tau_{n\phi} \ln(D_l) T + \\ & \ln \left(\sum_i \frac{\alpha_i + \sum_j \tau_{ij} \ln(k_j W_j) + \sum_0 \tau_{i0} \ln Q_0 + \sum_n \tau_{in} \ln(D_l)}{k_i} \right) \end{aligned} \quad (41)$$

The total cost is jointly estimated with factor share equations in a seemingly unrelated system of equations. To obtain the factor share equations, it is worthy to note that shippers' expenditure share on factor i is given as:

$$S_i^A = \frac{W_i X_i}{C} \quad (42)$$

The actual share expenditure can be put in terms of shadow share equations as stipulated by Atkinson and Halvorsen (1984) using equations (34) and (36):

$$S_i^A = \frac{S_i^S / k_i}{\sum_i (S_i^S / k_i)} \quad (43)$$

Substituting for S_i^S from equation (40) we get:

$$S_i^A = \frac{(\alpha_i + \sum_j \tau_{ij} \ln(k_j W_j) + \sum_0 \tau_{i0} \ln Q_0 + \sum_n \tau_{in} \ln(D_l)) / k_i}{\sum_i (\alpha_i + \sum_j \tau_{ij} \ln(k_j W_j) + \sum_0 \tau_{i0} \ln Q_0 + \sum_n \tau_{in} \ln(D)) / k_i} \quad (44)$$

The total cost function 41) is estimated together with factor share equations (44) using Zellner's Seemingly Unrelated Regression. However, given that the factor shares sum up to 1,

one of the cost share equations is dropped to avoid perfect collinearity. Results are invariant as to which equation is dropped. Additionally, given homogeneity of degree zero in factor of proportionality(k_i), the absolute value of all k_i cannot be estimated. Consequently, one k_i is normalized to one and all other k_i 's are measured relative to the normalized factor proportionality (Atkinson and Halvorsen 1984). The “allocative efficiency” model, with two inputs (rail and truck), one output (ton-miles), link distance (miles), and a time trend is shown in equation 45:

$$\begin{aligned}
\ln TC_l = & \alpha_0 + \alpha_1 \ln(k_1 \text{ rail}_l) + \alpha_2 \ln(k_2 \text{ truck}_l) + \rho_1 \ln(TM_l) + \rho_2 \ln(\text{Dist}_l) + \rho_3 \text{time} + \\
& \tau_{11} \frac{1}{2} \ln(k_1 \text{ rail}_l)^2 + \tau_{22} \frac{1}{2} \ln(k_2 \text{ truck}_l)^2 + \beta_{11} \frac{1}{2} (\ln TM_l)^2 + \beta_{22} \frac{1}{2} (\ln \text{Dist}_l)^2 + \beta_{33} \frac{1}{2} \text{time}^2 + \\
& \tau_{12} \ln(k_1 \text{ rail}_l) \cdot \ln(k_2 \text{ truck}_l) + \chi_{11} \ln(k_1 \text{ rail}_l) \cdot \ln(TM_l) + \chi_{12} \ln(k_1 \text{ rail}_l) \cdot \ln(\text{Dist}_l) + \\
& \chi_{13} \ln(k_1 \text{ rail}_l) \cdot \text{time} + \chi_{21} \ln(k_2 \text{ truck}_l) \cdot \ln(TM_l) + \chi_{22} \ln(k_2 \text{ truck}_l) \cdot \ln(\text{Dist}_l) + \\
& \chi_{23} \ln(k_2 \text{ truck}_l) \cdot \text{time} + \beta_{12} \ln(TM_l) \cdot \ln(\text{Dist}_l) + \beta_{13} \ln(TM_l) \cdot \text{time} + \beta_{23} \ln(\text{Dist}_l) \cdot \text{time} + \\
& \ln \left[\frac{\alpha_1 + \tau_{11} \ln(k_1 \text{ rail}_l) + \tau_{12} \ln(k_2 \text{ truck}_l) + \chi_{11} \ln(TM_l) + \chi_{12} \ln(\text{Dist}_l) + \chi_{13} \text{time}}{k_1} \right. \\
& \left. \frac{(\alpha_2 + \tau_{21} \ln(k_1 \text{ rail}_l) + \tau_{22} \ln(k_2 \text{ truck}_l) + \chi_{21} \ln(TM_l) + \chi_{22} \ln(\text{Dist}_l) + \chi_{23} \text{time})}{k_2} \right] \quad (45)
\end{aligned}$$

Where,

- TC_l = total rail and truck transportation cost on link l ;
- rail_l = rail rate on link l ;
- truck_l = truck rate on link l ;
- TM_l = tonmiles on link l ;
- Dist_l = average link distance;
- time = time trend

All independent variables except the time trend are normalized (divided) by their means.

The cost share equations for rail and truck represented by S_{1l} , and S_{2l} , and with k_1 , and k_2 representing corresponding factors of proportionality are shown below:

$$S_{1l} = \frac{(\alpha_1 + \tau_{11} \ln(k_1 \text{rail}_l) + \tau_{12} \ln(k_2 \text{truck}_l) + \chi_{11} \ln(TM_l) + \chi_{12} \ln(\text{Dist}_l) + \chi_{13} \text{time}) / k_1}{(\alpha_1 + \tau_{11} \ln(k_1 \text{rail}_l) + \tau_{12} \ln(k_2 \text{truck}_l) + \chi_{11} \ln(TM_l) + \chi_{12} \ln(\text{Dist}_l) + \chi_{13} \text{time}) / k_1 + (\alpha_2 + \tau_{22} \ln(k_2 \text{truck}_l) + \tau_{12} \ln(k_1 \text{rail}_l) + \chi_{21} \ln(TM_l) + \chi_{22} \ln(\text{Dist}_l) + \chi_{23} \text{time}) / k_2} \quad (46)$$

$$S_{2l} = \frac{(\alpha_2 + \tau_{22} \ln(k_2 \text{truck}_l) + \tau_{12} \ln(k_1 \text{rail}_l) + \chi_{21} \ln(TM_l) + \chi_{22} \ln(\text{Dist}_l) + \chi_{23} \text{time}) / k_2}{(\alpha_2 + \tau_{22} \ln(k_2 \text{truck}_l) + \tau_{12} \ln(k_1 \text{rail}_l) + \chi_{21} \ln(TM_l) + \chi_{22} \ln(\text{Dist}_l) + \chi_{23} \text{time}) / k_2 + (\alpha_1 + \tau_{11} \ln(k_1 \text{rail}_l) + \tau_{12} \ln(k_2 \text{truck}_l) + \chi_{11} \ln(TM_l) + \chi_{12} \ln(\text{Dist}_l) + \chi_{13} \text{time}) / k_1} \quad (47)$$

3.2.3. Potential Outcomes

Since one k_i is normalized to one, a value of k_i greater than unity (> 1) for the other k_i is an indication that shippers' shadow price for that input is greater than the market price. In the context of North Dakota grain shippers, using rail transportation, it would suggest that the transport rate does not fully reflect the cost of using that mode. Shippers use less of that mode than they would if optimizing based on rates. Consequently, if truck is the normalized mode, and k_i for rail is greater than 1, it suggests an underutilization of rail. In this situation, a decrease in k_i over time would reflect an improvement in rail service quality (less underutilization of rail).

On the other hand, a value of k_i less than one (< 1) for the non-normalized k_i suggests that the shadow price for that normalized mode is higher than market price (i.e. there is a disadvantage to using the normalized mode not reflected in market price). This will additionally suggest using less of that mode than if optimizing based on rates.

If the factor of proportionality k_i increasingly gets closer to one or is one, this will mean North Dakota shippers increasingly or entirely base their mode choice decision on rates alone, utilizing the "allocatively" efficient mix of inputs. This would suggest that shadow prices of the modes reflect actual market rates.

CHAPTER 4. DATA AND VARIABLE CONSTRUCTION

4.1. Introduction

This study, unlike other agricultural freight transportation demand studies, undertaken in North Dakota and elsewhere, uses individual grain elevators as the primary unit of observation. Data for other related studies have been aggregated by arbitrarily choosing a central point of a region (e.g. CRD) as the primary unit of observation (Dybing 2002; Wilson 1984; Wilson et al. 1988). This aggregation process may fail to capture individual elevator decisions and how they vary based on the rates they experience. Using individual elevators enables potential isolation of quality of service effects and those related to variability in rate structures by elevator type.

Railroads use four main service types in grain shipments including single car, multi-car, unit, and shuttle services. These services are related to the type of grain elevator and are classified according to the number of railcars that can be generated as shuttle (100 or more), unit (between 52 and 99), multi-car (26 to 52), and single-car elevators (between 1 and 25). Grain elevators able to generate longer trains can use other service types as well. For example, shuttle elevators can use 100 cars or more services as well as those involving services for less than 100 cars. However, elevators that have the capacity to only use services involving relatively shorter trains cannot generate longer trains due to capacity and track space limitations. For example, unit train elevators cannot use shuttle services. The same applies to the other service types.

Apart from being an indication of the number of cars generated by a shipment, rail services type (type of elevator) also reflect rail rates. Longer trains (shuttles) offer comparatively lower rates relative to other service types because cost can be split over a larger number of cars (economies of shipment size). The link specific cost function, involving elevator shipments to the major destinations of North Dakota grain facilitates uses estimated elevator-specific rail rates

per period. These estimated rates are a better reflection of the spatial nature of transportation compared to using rates for aggregated regions. Shuttle elevator locations based on data from the North Dakota grain movement database are shown in Figure 6.

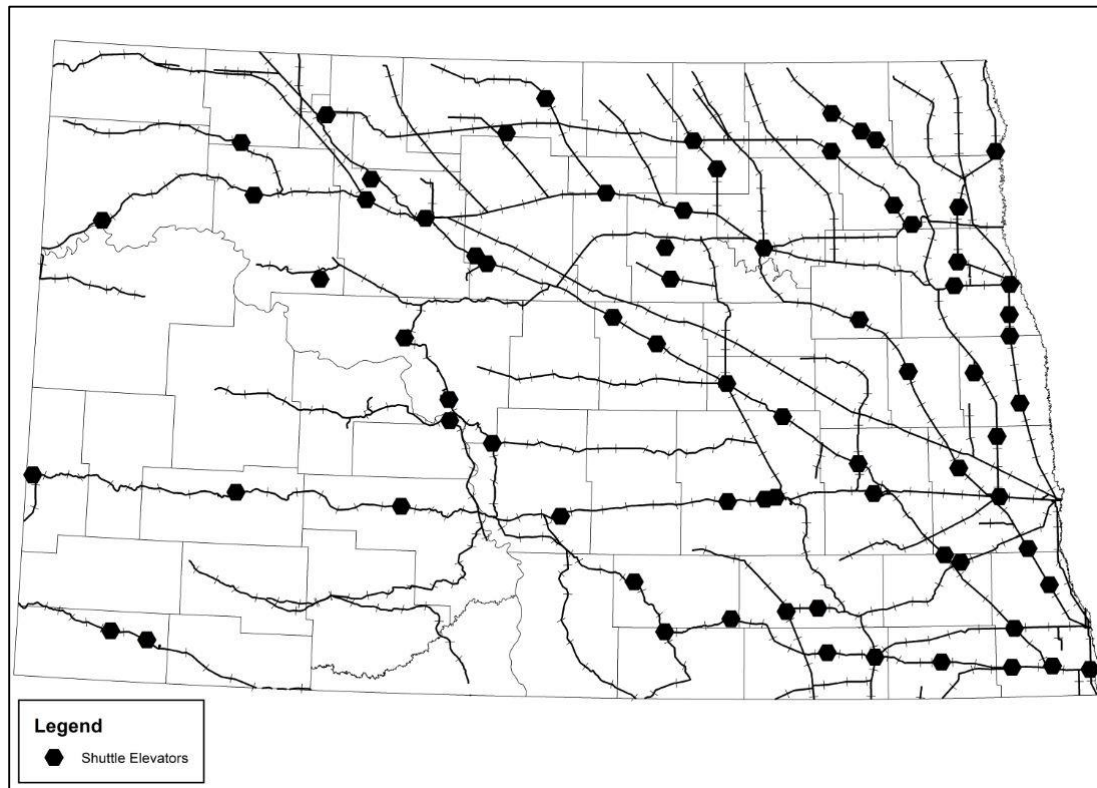


Figure 6: North Dakota Shuttle Elevator Facilities 2006-2013

To our knowledge, no study has evaluated agricultural transportation demand using the elevator as the primary unit of observation. In addition to improving the quality of results obtained, using individual elevators will help identify potential changes (e.g. lower rates and better service) brought about by the increasing use of longer trains. This is important given that the state is viewed as a captive market in theory (Koo et al. 1993).

In addition, agricultural freight transportation demand for North Dakota has often been done for two of the four principal destinations for the states' grains. These analyses have often been undertaken for at most two commodities. For example Dybing (2002), Wilson (1984), and Wilson et al. (1988) all use Minneapolis and Duluth, MN as the only destinations in their

models. Dybing (2002), and Wilson (1984) both looked at wheat (hard red spring) and barley shippers, while Wilson et al. (1988) looked at wheat shipments (hard red spring wheat).

This study evaluates transportation demand for five commodities including barley, corn, durum wheat, hard red spring wheat, and soybeans to all four principal destinations for North Dakota grains (Minneapolis, Duluth, Gulf, and Pacific North West). Looking at different commodities and destinations has several advantages. As alluded to previously, the increasing demand for biofuel has led to a surge in corn and soybean production as they are two principal ingredients for making ethanol and biodiesel. This increase has potential implications for the demand for traditional commodities (e.g. wheat and barley) by taking acreage away as farmers increase corn and soybean production to reap benefits associated with bioenergy. Moreover, bioenergy provides grain producers with an alternative market for their commodities both locally and to out of state destinations.

The five commodities under consideration are grown at varying levels in different regions of the state. This variation in crop production means highway and railroad distances, which play a determining role in shippers' mode choice decisions and a critical factor in carriers' cost structure, are likely to vary. Additionally, taking potential variation in shipping distance into consideration enables proper evaluation of the distances in which one mode dominates the other (intermodal competition).

Data used for this study, including grain movement, rail, and truck rates are obtained from the North Dakota grain movement database at the Upper Great Plains Transportation Institute (UGPTI), the STB railroad annual public use waybill sample, and the USDA, Agricultural Marketing Service, Grain Truck and Ocean Rate Advisory (GTOR). The grain movement database contains grain elevator information submitted to the North Dakota Public

Service Commission by all licensed grain elevators in the state. This includes elevator number (identifier); grain type hauled (identifier); location (city, crop reporting district); volume shipped (bushels); mode (truck and four rail service types); period of shipment (month and year) and destination of shipment including within North Dakota and to four major out of state destinations Duluth, MN (DUL), Minneapolis, MN (MPLS); Gulf; and Pacific Northwest (PNW). Table 1 contains a summary of tons (thousands) and percentages of tons shipped to various destinations for each commodity. The table also shows percentage shipped by each mode (rail and truck) by destination for each of the five commodities involved in this study between 2006 and 2013.

Table 1: Tonnage and Percentage Shipped by Destination and Mode (2006-2013)

Commodity	DUL, MN	MPLS, MN	Gulf	PNW
	Tons (%) [Rail: Truck, %]	Tons (%) [Rail: Truck, %]	Tons (%) [Rail: Truck, %]	Tons (%) [Rail: Truck, %]
Barley	238 (6) [99: 1]	2,645 (69) [59:41]	577 (15) [68:32]	363 (10) [98:2]
Corn	50 (0.3) [98: 2]	1,582 (9) [97: 3]	2,317 (13) [81: 19]	13,734 (77.7) [99: 1]
Durum	1,965 (40) [99:1]	1,431 (30) [91:9]	1,347 (28) [98:2]	92 (2) [98:2]
Hard Red Spring	3,562 (10) [99: 1]	13,809 (39) [96: 4]	6,132 (17) [95: 5]	12,075 (34) [99.6: 0.4]
Soybean	150 (0.6) [96: 4]	1,519 (6) [98: 2]	829 (3.4) [88: 12]	22,255 (90) [99.9: 0.1]

*Tonnage for destination described as “Other Minnesota” not included due to lack of destination point specificity

The waybill sample contains railroad shipment data from a stratified sample. Railroads are mandated to submit this information the Surface Transportation Board (STB) which replaced the ICC in 1996 for regulatory purposes. The annual rail waybill sample contains rail transportation information for different commodities transported from one Bureau of Economic Analysis region (BEA) to another. BEA regions incorporate several counties within a state, and

in some instances they overlap to include more than one state. Information from the waybill used to calculate rates in this study includes Standard Transportation Commodity Code identifier, date of shipment (month and year), origin Bureau of Economic Analysis region (OBEA), destination Bureau of Economic Analysis region (TBEA), distance of shipment; tons shipped, number of railcars in shipment, and revenue for the specific movement. GTOR provides quarterly truck rates for five U.S regions based on surveys indexed by diesel prices. GTOR notes that fuel prices (diesel) constitute 37% (largest input) of the operational cost for commercial trucks. Construction of input prices and other variables used in the link specific cost function are presented in the next sections.

4.2. Link Distance

The Standard Point Location Code (SPLC) and the ZIP code for cities with grain elevators were identified and used in PCMILER[®] to calculate direct rail and highway distances from individual origin elevators to two cities, Duluth, MN and Minneapolis, and two U.S regions, Pacific North West and the Gulf. Two major port cities, Portland, OR, and New Orleans, LA were used as representative destinations for the PNW and Gulf regions respectively. SPLC provides information on all ports served by rail or motor carriers. However, ZIP codes were preferred to calculate highway distances because some rail ports are not linked by highways. PCMILER[®] contains updated map information, enhancing the accuracy of calculations. The distance of a link in the link specific cost function involving individual elevators and a given out of state destination is calculated by taking the simple average between rail and highway distance for individual elevators. The average link distance is estimated as:

$$ALD_{ed} \left(\frac{RD_{ed} + TD_{ed}}{2} \right) \quad (48)$$

Where,

ALD_{ed} = average link distance elevator e to destination d

RD_{ed} = rail distance elevator e , to destination d

TD_{ed} = truck distance elevator e to destination d

4.3. Rail Rates

The public use railroad waybill sample provides railroad shipment information for individual shipments between BEAs. In terms of rail shipments, North Dakota is divided into four OBEA regions, namely: Fargo-Moorhead (113), Grand Forks (110), Bismarck (112), and Minot regions (111). A map representing the four regions is shown in Figure 7. Given the disaggregate nature of the analysis in this study, a railroad pricing model was developed to estimate rail rates at the grain elevator level rather than using rates at the BEA level to represent all elevators located within that region. In this way, rates were allowed to vary based on distance and elevator size.

The railroad pricing model was estimated for each commodity and origin BEA. For example, to estimate wheat rates four separate models were estimated (one for each OBEA). Estimated parameters from the pricing model are used in a second step to approximate rates by elevator type (e.g. elevators with shuttle, unit, and multi-car shipment capabilities) and distance from destination. The pricing model has revenue-per ton-mile as the dependent variable and railroad supply and demand determinants as regressors, including distance of shipment (length of haul); load factor (weight per railcar); type of service (number of rail cars in shipment including shuttle, unit, and multi-car services), a time trend, and seasonal variables (months of the year).

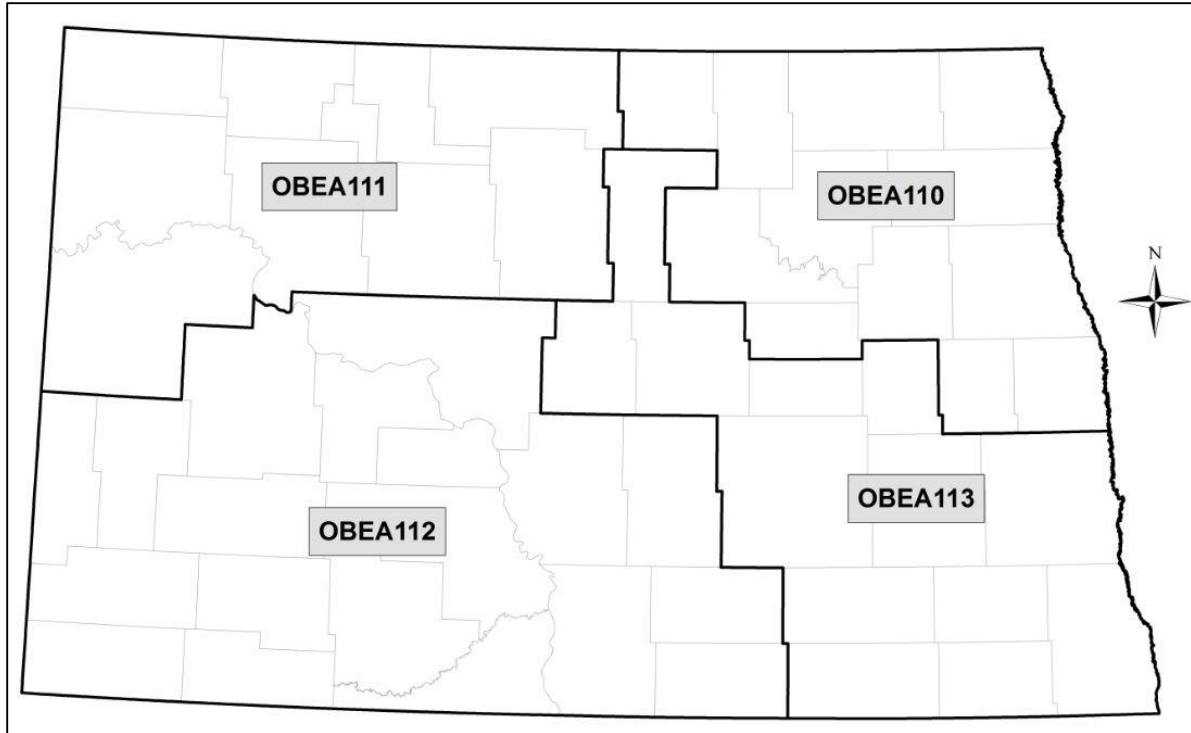


Figure 7: North Dakota Origin Bureau of Economic Analysis Regions

The model is estimated using Ordinary Least Squares (OLS). The general form of the double log rail rate regression model for each commodity and origin BEA is given as:

$$\ln(RRPTM) = \beta_0 + \beta_d \ln(SHRT) + \beta_l \ln(LOAD) + \beta_s SHUT + \beta_u UNIT + \beta_t TIME + \delta \sum MONTH + \varepsilon \quad (49)$$

Where,

- RRPTM* = real revenue per ton – mile (in 2010 prices)
- SHRT* = length of haul in short – line miles
- LOAD* = load factor representing weight per railcar
- SHUT* = dummy variable shuttle train shipment, 100 cars or more
- UNIT* = dummy variable unit train shipment, 52 and 99 railcars
- Time* = time trend, year of shipment
- MONTH* = dummy variable month of shipment
- ε = normal effect error term

Revenue per ton-mile and load factor used in the regression in equation (49) are calculated as:

$$RRPTM = \frac{UREV}{(UTON) * (SHRT)} \quad (50)$$

$$LOAD = \frac{UREV}{(UCAR)} \quad (51)$$

Where,

UREV = total revenue for shipment

UTON = total tons shipped

UCAR = number of railcars in shipment

All other variables are as defined previously

Estimating the pricing model for each commodity by OBEA reflects potential variation in rates brought about by regional differences. For example rates for corn shipments originating in the east of the state might be different from those in western regions given that more corn is grown in the eastern region and given differences in transport options among eastern and western shippers. Regressors included in the model have varying effects on rates charged by railroads. From the specified model in equation (49), the natural log of length of haul in short-line miles is expected to have a negative effect on the natural log of real revenue per ton-mile. The literature on the influence of distance on transportation rates suggests that as distances increases, the rate per ton-mile of freight decreases. This is particularly the case with railroads, because a significant part of rail shipment cost is constant regardless of the distance. MacDonald (1989) noted that cost components such as switching, classification, and loading of cars are not impacted by the distance of shipment. Additionally, some costs associated with movement (e.g. cost of reaching a traveling speed) do not increase at the same rate with mileage.

Railroads previously used 100-ton covered hopper cars. However, because of innovations related to track composition, the weight limit and load per car has increased substantially. In the 1970s, a significant portion of rail branch lines were limited to gross car weights of 220,000 pounds which permitted net loads of 70 to 80 tons (NDDOT 2007). Presently, Class I railroad main line tracks are able to support 286,000-pound cars, enabling freight loads of between 110

and 115 tons. Some railroads operate 315,000 pound cars with corresponding net loads of 125 tons in particular corridors (NDDOT 2007).

Similarly, the natural log of load factor is expected to have a negative effect on the natural log of rate per ton-mile due to economies of shipment size (railroad cost does not increase proportionately with shipment size). Economies of shipment size have increasingly benefited carriers and shippers alike given technological advances. For example, the increasing use of larger-capacity rail cars has led to increasing railroad revenue per car without a corresponding direct increase in cost to shippers (increase per car payload). Shippers are often charged for total capacity so if \$3,000 is charged per car, then a shipper that loads 110 tons in a car pays \$27.2 per ton whereas another shipper that loads 100 tons pays \$30 per ton. This way, the load factor is a reflection of rail car capacity utilization. The latter shipper pays for unused car capacity. These facts mean the natural log of rate per ton-mile should decrease at a decreasing rate with the increasing number of rail cars and load factor. The load factor measures the average weight per car. Because the shuttle and unit train dummy variables are a reflection of a larger number of cars in a shipment, relative to multi-car shipments (including single car) which serves as the basis for comparison, both are expected to have a negative sign reflecting their relative rate advantage over multi-car services.

The time trend and monthly dummy variables are included to indicate changes over time and likely changes in rates by month. The time trend is expected to have an indeterminate sign for different commodities. Rates might be increasing or decreasing over time. Signs for monthly dummy variables are expected to vary by month by commodity owing to differences stemming from seasonal variations (e.g. planting, harvesting, and off seasons). For example hard red spring wheat is often planted from April to early June with harvest taking place between August and

September. As such, the demand for rail transportation of hard red spring wheat is likely to increase in late September and peak in the fourth quarter (October, November, and December). Rates for the fourth quarter of the year are expected to be relatively higher than those in the first three quarters of the year. Estimated rail equations are used in conjunction with shipment distances and elevator capacities to estimate rates by elevator. Equations for the second stage process for estimating elevator specific rail rates by elevator type (shuttle, unit, and multi-car elevator rates) are shown in equation (52), (53), and (54) below:

Shuttle elevator rate estimate:

$$\begin{aligned}
 (SRR\widehat{P\overline{T}M}_{eod}) = & \text{Exp} [\widehat{\beta}_0 + \widehat{\beta}_d \ln(DIST_{eod}) + \widehat{\beta}_l \ln(\overline{LOAD}_{ot}) + \widehat{\beta}_s(SHUT) + \widehat{\beta}_t(TIME) \\
 & + \widehat{\delta}_{feb}(FEB) + \widehat{\delta}_{mar}(MAR) + \widehat{\delta}_{apr}(APR) + \widehat{\delta}_{may}(MAY) + \widehat{\delta}_{jun}(JUN) + \widehat{\delta}_{jul}(JUL) \\
 & + \widehat{\delta}_{aug}(AUG) + \widehat{\delta}_{sep}(SEP) + \widehat{\delta}_{oct}(OCT) + \widehat{\delta}_{nov}(NOV) + \widehat{\delta}_{dec}(DEC)] \tag{52}
 \end{aligned}$$

Unit elevator rate estimate:

$$\begin{aligned}
 (URR\widehat{P\overline{T}M}_{eod}) = & \text{Exp} [\widehat{\beta}_0 + \widehat{\beta}_d \ln(DIST_{eod}) + \widehat{\beta}_l \ln(\overline{LOAD}_{ot}) + \widehat{\beta}_u(UNIT) + \widehat{\beta}_t(TIME) \\
 & + \widehat{\delta}_{feb}(FEB) + \widehat{\delta}_{mar}(MAR) + \widehat{\delta}_{apr}(APR) + \widehat{\delta}_{may}(MAY) + \widehat{\delta}_{jun}(JUN) + \widehat{\delta}_{jul}(JUL) \\
 & + \widehat{\delta}_{aug}(AUG) + \widehat{\delta}_{sep}(SEP) + \widehat{\delta}_{oct}(OCT) + \widehat{\delta}_{nov}(NOV) + \widehat{\delta}_{dec}(DEC)] \tag{53}
 \end{aligned}$$

Multi-car elevator rate estimate:

$$\begin{aligned}
 (MRR\widehat{P\overline{T}M}_{eod}) = & \text{Exp} [\widehat{\beta}_0 + \widehat{\beta}_d \ln(DIST_{eod}) + \widehat{\beta}_l \ln(\overline{LOAD}_{ot}) + \widehat{\beta}_t(TIME) \\
 & + \widehat{\delta}_{feb}(FEB) + \widehat{\delta}_{mar}(MAR) + \widehat{\delta}_{apr}(APR) + \widehat{\delta}_{may}(MAY) + \widehat{\delta}_{jun}(JUN) + \widehat{\delta}_{jul}(JUL) \\
 & + \widehat{\delta}_{aug}(AUG) + \widehat{\delta}_{sep}(SEP) + \widehat{\delta}_{oct}(OCT) + \widehat{\delta}_{nov}(NOV) + \widehat{\delta}_{dec}(DEC)] \tag{54}
 \end{aligned}$$

Where,

- $SRR\widehat{P\overline{T}M}_{eod}$ = shuttle rate for elevator e in obea o and destination, d
- $URR\widehat{P\overline{T}M}_{eod}$ = unit rate for elevator e in obea o and destination, d
- $MRR\widehat{P\overline{T}M}_{eod}$ = multi – car rate for elevator e in obea o and destination d
- $DIST_{eod}$ = actual distance elevator e in obea o and destination d
- \overline{LOAD}_{ot} = mean load factor between 2006 and 2013

$\widehat{\beta}_0$ = intercept estimate
 $\widehat{\beta}_d$ = distance estimate
 $\widehat{\beta}_l$ = load factor estimate
 $\widehat{\beta}_s$ = shuttle train estimate
 $\widehat{\beta}_u$ = unit train estimate
 $\widehat{\beta}_t$ = time trend estimate
 $\widehat{\delta}_i$ = monthly estimate (base = January)
All rates in 2010 dollars

4.3.1. Rail Rates by Commodity

One of the principal issues with using the waybill to estimate rail rates is data availability. The waybill is a stratified sample; hence there is a disparity in data reporting by origin-destination region and commodity. Some regions and commodities are more represented (higher number of observations) than others. For this reason, the origin bureau of economic analysis regions that make up the state were redefined for some commodities, while others remained as originally defined for rail rate assignment purposes. An effort was made to ensure that this division matches with region crop production pattern. For corn and barley, the state was split into two regions. The first region is obtained by combining the Fargo-Moorhead (OBEA-113) and the Grand-Forks (OBEA-110) regions, while the second represents a combination the Minot (OBEA-111) and Bismarck (112) regions. In the case of soybeans, the state was split into three regions Fargo-Moorhead (OBEA-113), Grand-Forks (OBEA-110) and a combination of Minot (OBEA-111) and Bismarck (112) regions. Wheat originating from North Dakota has the largest number of observations in the waybill. Sufficient observations were available to estimate rail rates for all four origin bureau of economic analysis regions that make up the state. Consequently, these four regions were left unchanged for wheat rail rate estimation. Redefined regions for corn and barley, soybeans and unchanged wheat (hard red spring wheat and durum) regions are shown in Figures 8, 9, and 10 respectively.

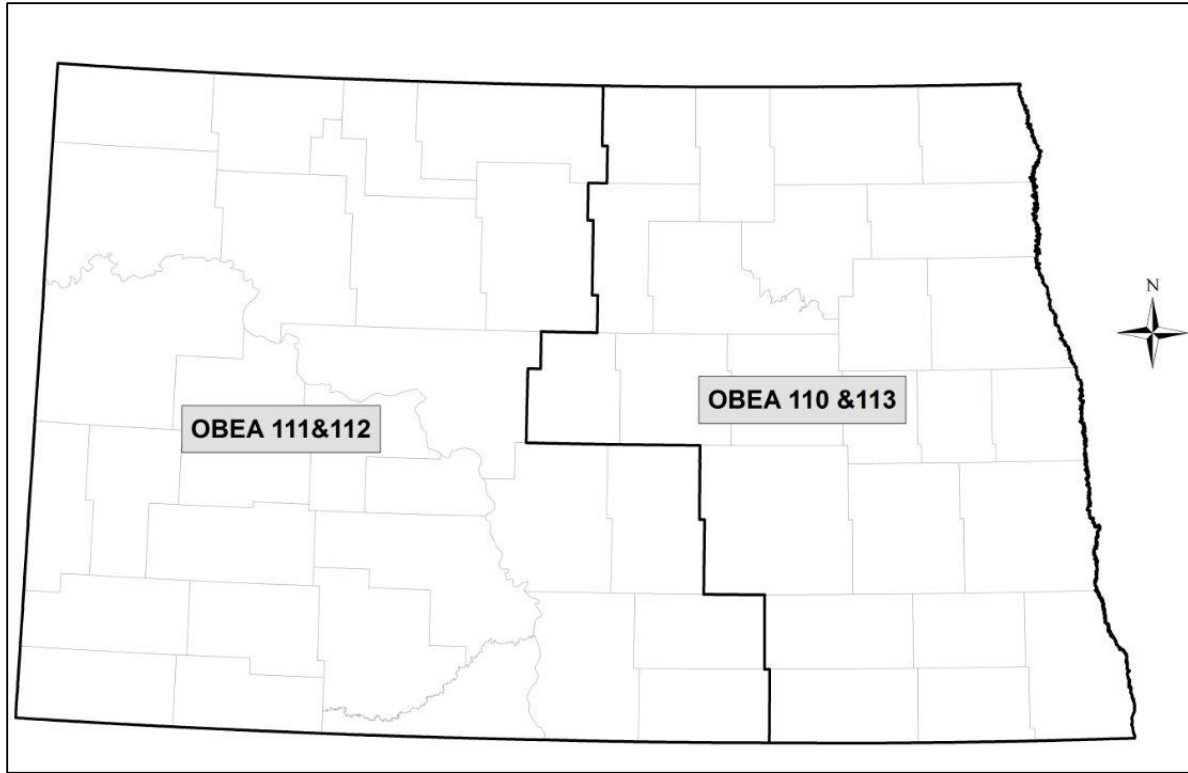


Figure 8: Corn and Barley Redefined Bureau of Economic Analysis Regions

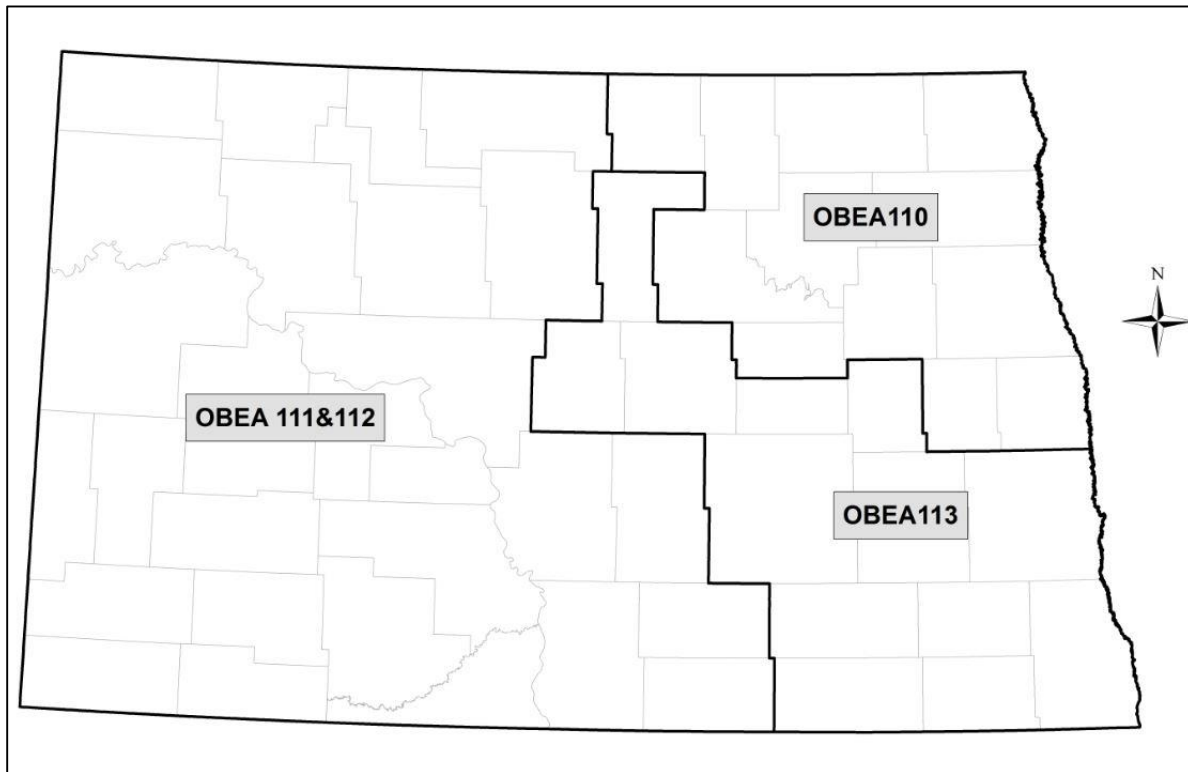


Figure 9: Soybeans Redefined Origin Bureau of Economic Analysis Regions

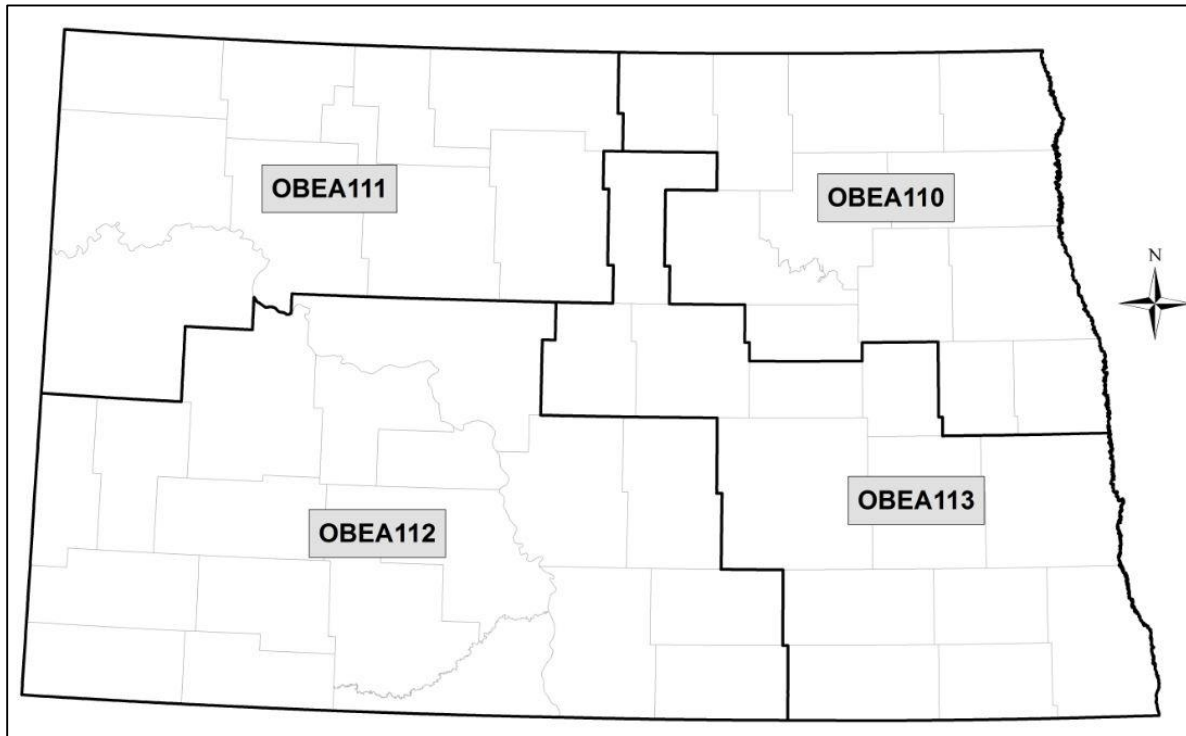


Figure 10: Wheat Bureau of Economic Analysis Regions

Due to different rail pricing by commodity, separate estimations are performed by commodity. Also, in analyzing the grain elevator link specific cost function, rail rates are assigned to grain elevators based on their shipment service capabilities. For example a grain elevator capable of making a shuttle shipment (more than 100 railcars) is assigned a shuttle rate. The same applies for grain elevators with unit train shipment capabilities; they are assigned unit rail rates. Since elevators with multi-car shipment capabilities cannot make unit or shuttle shipments, multi-car grain elevators are assigned only multi-car rail rates. The North Dakota Grain movement database and the waybill sample were used to determine commodities that benefit from longer train transportation, particularly shuttle and those that do not. For example rail transport of barley from North Dakota is mainly undertaken by multi-car rail services, while wheat and corn benefit from shuttle transportation. A very limited amount of soybeans

transported from OBEA-110 benefit from shuttle services. Therefore, soybean rates were based on unit and multi-car rail estimates. The first and second stage rate estimation equations by commodity with all variables as defined previously are shown in equation 55 to 58 with t-statistics in brackets below parameter estimates.

4.3.1.1. Barley

Rail rate regression general form:

$$\ln(RRPTM) = \beta_0 + \beta_d \ln(SHRT) + \beta_l \log(LOAD) + \beta_t TIME + \delta \sum MONTH + \varepsilon \quad (55)$$

Rail rate regression estimate (OBEA: 110, 113):

$$\begin{aligned} (\widehat{RRPTM}) = \text{Exp}[& 2.045 - 0.6235 * \ln(DIST) - 0.259 * \ln(\overline{LOAD}) + 0.042 * (TIME) \\ & \quad (1.82) \quad (-34.97) \quad \quad \quad (-1.03) \quad \quad \quad (7.98) \\ & -0.0302 * (FEB) + 0.019 * (MAR) + 0.149 * (APR) + 0.026 * (MAY) + 0.072 * (JUN) \\ & \quad (-0.5) \quad \quad (0.34) \quad \quad (2.13) \quad \quad (0.42) \quad \quad (1.06) \\ & +0.042 * (JUL) + 0.007 * (AUG) + 0.023 * (SEP) + 0.015 * (OCT) + 0.050 * (NOV) \\ & \quad (.56) \quad \quad (0.12) \quad \quad (0.43) \quad \quad (0.24) \quad \quad (0.85) \\ & +0.031 * (DEC)] \quad \quad \quad (55.1) \\ & \quad (0.56) \end{aligned}$$

$$n = 172, SSR = 3.130, R^2 = 0.904$$

Rail rate regression estimate (OBEA: 111, 112):

$$\begin{aligned} (\widehat{RRPTM}) = \text{Exp}[& 6.477 - 0.656 * \ln(DIST) - 1.172 * \ln(\overline{LOAD}) + 0.024 * (TIME) \\ & \quad (4.32) \quad (-19.54) \quad \quad \quad (-3.57) \quad \quad \quad (3.574) \\ & +0.112 * (FEB) + 0.173 * (MAR) - 0.042 * (APR) + 0.125 * (MAY) + 0.183 * (JUN) \\ & \quad (1.16.) \quad \quad (1.93) \quad \quad (0.33) \quad \quad (1.22) \quad \quad (1.65) \\ & +0.220 * (JUL) + 0.161 * (AUG) + 0.056 * (SEP) + 0.106 * (OCT) + 0.056 * (NOV) \\ & \quad (2.51) \quad \quad (1.99) \quad \quad (0.73) \quad \quad (1.38) \quad \quad (0.75) \\ & +0.036 * (DEC)] \quad \quad \quad (55.2) \\ & \quad (0.46) \end{aligned}$$

$$n = 127, SSR = 2.562, R^2 = 0.831$$

4.3.1.2. Corn

Rail rate regression general form:

$$\ln(RRPTM) = \beta_0 + \beta_d \ln(DIST) + \beta_l \ln(LOAD) + \beta_s SHUT + \beta_u UNIT + \beta_t TIME + \delta \sum MONTH + \varepsilon \quad (56)$$

Rail rate regression estimate (OBEA: 110, 113)

$$\begin{aligned} (\widehat{RRPTM}) = & \text{Exp} [7.289 - 0.695 * \ln(DIST) - 1.266 * \ln(\overline{LOAD}) - 0.020(SHUT) \\ & \quad (15.19) \quad (-16.02) \quad (-18.50) \quad (-1.19) \\ & + 0.075 * (UNIT) + 0.038 * (TIME) - 0.032 * (FEB) - 0.006 * (MAR) - 0.008 * (APR) \\ & \quad (-1.19) \quad (13.48) \quad (-1.05) \quad (-0.18) \quad (-0.25) \\ & + 0.039 * (MAY) + 0.044 * (JUN) + 0.042 * (JUL) + 0.029 * (AUG) + 0.067 * (SEP) \\ & \quad (1.03) \quad (1.38) \quad (1.34) \quad (0.76) \quad (1.63) \\ & + 0.089 * (OCT) + 0.026 * (NOV) + 0.044 * (DEC)] \quad (56.1) \\ & \quad (2.62) \quad (0.96) \quad (1.63) \end{aligned}$$

$$n = 423, SSR = 6.885, R^2 = 0.647$$

Rail rate regression estimate (OBEA: 111, 112)

$$\begin{aligned} (\widehat{RRPTM}) = & \text{Exp} [2.087 - 0.184 * \ln(DIST) - 1.536 * \ln(\overline{LOAD}) - 0.105 * (SHUT) \\ & \quad (0.82) \quad (0.428) \quad (-4.58) \quad (-3.41) \\ & - 0.085 * (UNIT) + 0.056 * (TIME) + 0.053 * (FEB) - 0.033 * (MAR) + 0.029 * (APR) \\ & \quad (-3.41) \quad (14.81) \quad (1.41) \quad (-0.85) \quad (0.63) \\ & + 0.019 * (MAY) + 0.037 * (JUN) + 0.074 * (JUL) - 0.006 * (AUG) - 0.026 * (SEP) \\ & \quad (0.46) \quad (1.08) \quad (1.94) \quad (-0.14) \quad (-0.49) \\ & + 0.013 * (OCT) + 0.060 * (NOV) + 0.100 * (DEC)] \quad (56.2) \\ & \quad (0.29) \quad (1.96) \quad (3.34) \end{aligned}$$

$$n = 108, SSR = 0.542, R^2 = 0.790$$

4.3.1.3. Soybeans

Rail rate regression general form:

$$\ln(RRPTM) = \beta_0 + \beta_d \ln(DIST) + \beta_l \ln(LOAD) + \beta_u UNIT + TIME + \delta \sum MONTH + \varepsilon \quad (57)$$

Rail rate regression estimate (OBEA: 110):

$$\begin{aligned} (\widehat{RRPTM}) = & \text{Exp}[4.134 - 0.418 * \ln(DIST) - 1.024 * \ln(\overline{LOAD}) - 0.040(UNIT) \\ & (5.88) \quad (-11.94) \quad (-7.40) \quad (-1.48) \\ & +0.050 * (TIME) + 0.039 * (FEB) - 0.005 * (MAR) - 0.001 * (APR) - 0.016 * (MAY) \\ & (10.72) \quad (1.37) \quad (-0.16) \quad (-0.03) \quad (-0.27) \\ & +0.067 * (JUN) + 0.061 * (JUL) + 0.058 * (AUG) + 0.009 * (SEP) + 0.056 * (OCT) \\ & (1.29) \quad (1.40) \quad (1.29) \quad (0.32) \quad (2.51) \\ & +0.060 * (NOV) + 0.028 * (DEC)] \quad (57.1) \\ & (2.54) \quad (1.03) \end{aligned}$$

$n = 289, SSR = 3.205, R^2 = 0.540$

Rail rate regression estimate (OBEA: 111, 112):

$$\begin{aligned} (\widehat{RRPTM}) = & \text{Exp}[0.271 - 0.334 * \ln(DIST) - 0.143 * \ln(\overline{LOAD}) - 0.217(UNIT) \\ & (-0.16) \quad (-8.20) \quad (-0.39) \quad (-3.25) \\ & +0.020 * (TIME) + 0.040 * (FEB) - 0.027 * (MAR) - 0.101 * (APR) - 0.070 * (MAY) \\ & (2.35) \quad (0.65) \quad (-0.42) \quad (-1.25) \quad (-0.89) \\ & +0.164 * (JUN) - 0.024 * (JUL) - 0.038 * (AUG) - 0.015 * (SEP) + 0.037 * (OCT) \\ & (1.65) \quad (-0.26) \quad (-0.34) \quad (-0.21) \quad (0.79) \\ & +0.022 * (NOV) + 0.068 * (DEC)] \quad (57.2) \\ & (0.46) \quad (0.97) \end{aligned}$$

$n = 188, SSR = 5.725, R^2 = 0.750$

Rail rate regression estimate (OBEA: 113):

$$\begin{aligned} (\widehat{RRPTM}) = & \text{Exp}[2.752 - 0.445 * \ln(DIST) - 0.682 * \ln(\overline{LOAD}) - 0.036 * (UNIT) \\ & (5.66) \quad (-19.15) \quad (-6.69) \quad (-1.45) \\ & +0.0467 * (TIME) - 0.005 * (FEB) + 0.017 * (MAR) - 0.040 * (APR) - 0.005 * (MAY) \\ & (14.93) \quad (-0.26) \quad (0.91) \quad (-1.39) \quad (-0.14) \end{aligned}$$

$$\begin{aligned}
& -0.0002 * (JUN) - 0.054 * (JUL) + 0.047 * (AUG) - 0.042 * (SEP) + 0.045 * (OCT) \\
& (0.0002) \qquad \qquad (-1.15) \qquad \qquad (1.86) \qquad \qquad (-1.98) \qquad \qquad (2.87) \\
& +0.034 * (NOV) + 0.022 * (DEC)] \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad (57.3) \\
& (2.14) \qquad \qquad (1.23)
\end{aligned}$$

$$n = 500, SSR = 4.577, R^2 = 0.610$$

4.3.1.4. Wheat

Rail rate regression general form:

$$\begin{aligned}
Ln(RRPTM) &= \beta_0 + \beta_d Ln(DIST) + \beta_l \log(LOAD) + \beta_s SHUT + \beta_u UNIT + \beta_t TIME \\
&+ \delta \sum MONTH + \varepsilon \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad (58)
\end{aligned}$$

Rail rate regression estimate (OBEA: 110)

$$\begin{aligned}
(\widehat{RRPTM}) &= Exp[2.972 - 0.431 * Ln(DIST) - 0.740 * Ln(\overline{LOAD}) - 0.189 * (SHUT) \\
& \qquad \qquad \qquad (4.06.) \quad (-45.23) \qquad \qquad (-4.68) \qquad \qquad (-9.77) \\
& -0.151 * (UNIT) + 0.062 * (TIME) - 0.022 * (FEB) + 0.015 * (MAR) + 0.022 * (APR) \\
& (-9.77) \qquad \qquad (21.87) \qquad \qquad (-0.68) \qquad \qquad (0.47) \qquad \qquad (0.71) \\
& +0.008 * (MAY) - 0.002 * (JUN) + 0.024 * (JUL) + 0.056 * (AUG) + 0.051 * (SEP) \\
& (0.22) \qquad \qquad (-0.07) \qquad \qquad (0.75) \qquad \qquad (1.94) \qquad \qquad (1.82) \\
& +0.080 * (OCT) + 0.027 * (NOV) + 0.051 * (DEC) \qquad \qquad \qquad \qquad \qquad \qquad \qquad (58.1) \\
& (2.43) \qquad \qquad (0.83) \qquad \qquad (1.57)
\end{aligned}$$

$$n = 710, SSR = 16.807, R^2 = 0.880$$

Rail rate regression estimate (OBEA: 111)

$$\begin{aligned}
(\widehat{RRPTM}) &= Exp[4.577 - 0.583 * Ln(DIST) - 0.823 * Ln(\overline{LOAD}) - 0.117 * (SHUT) \\
& \qquad \qquad \qquad (6.80) \quad (38.12) \qquad \qquad (-5.79) \qquad \qquad (-6.51) \\
& -0.118 * (UNIT) + 0.038 * (TIME) - 0.003 * (FEB) - 0.041 * (MAR) - 0.016 * (APR) \\
& (-6.51) \qquad \qquad (14.46) \qquad \qquad (-0.08) \qquad \qquad (-1.11) \qquad \qquad (-0.46) \\
& +0.0009 * (MAY) - 0.036 * (JUN) - 0.056 * (JUL) - 0.037 * (AUG) - 0.039 * (SEP) \\
& (0.02) \qquad \qquad (-0.94) \qquad \qquad (-1.54) \qquad \qquad (-1.15) \qquad \qquad (-1.20)
\end{aligned}$$

$$-0.031 * (OCT) - 0.00003 * (NOV) - 0.051 * (DEC)] \quad (58.2)$$

(-0.92) (-0.01) (-1.31)

$$n = 549, SSR = 9.489, R^2 = 0.823$$

Rail rate regression estimate (OBEA: 112)

$$(\widehat{RRPTM}) = Exp[5.607 - 0.541 * In(DIST) - 1.141 * In(\overline{LOAD}) - 0.162 * (SHUT)$$

(9.65) (-34.40) (-9.39) (-8.72)

$$-0.066 * (UNIT) + 0.059 * (TIME) + 0.038 * (FEB) + 0.061 * (MAR) + 0.015 * (APR)$$

(-8.72) (22.14) (1.19) (-1.92) (0.46)

$$+0.048 * (MAY) - 0.002 * (JUN) + 0.006 * (JUL) - 0.001 * (AUG) - 0.009 * (SEP)$$

(1.35) (-0.07) (0.17) (-0.04) (-0.29)

$$+0.027 * (OCT) + 0.050 * (NOV) + 0.061 * (DEC)] \quad (58.3)$$

(0.86) (1.58) (1.81)

$$n = 495, SSR = 7.868, R^2 = 0.868$$

Rail rate regression estimate (OBEA: 113)

$$(\widehat{RRPTM}) = Exp[3.849 - 0.453 * In(DIST) - 0.886 * In(\overline{LOAD}) - 0.216 * (SHUT)$$

(4.02) (-37.48) (-4.29) (-8.67)

$$-0.195 * (UNIT) + 0.071 * (TIME) - 0.00003 * (FEB) - 0.002 * (MAR) - 0.019 * (APR)$$

(-8.67) (18.26) (-0.01) (-0.85) (-0.38)

$$-0.014 * (MAY) - 0.022 * (JUN) - 0.012 * (JUL) - 0.002 * (AUG) - 0.023 * (SEP)$$

(0-.28) (-0.45) (-0.25) (-0.04) (-0.53)

$$+0.029 * (OCT) + 0.077 * (NOV) + 0.018 * (DEC)] \quad (58.4)$$

(0.56) (1.42) (0.37)

$$n = 454, SSR = 12.409, R^2 = 0.880$$

Regression results for all commodities and BEA regions show a good fit as represented by the R-squared. This means that the included explanatory variables account for large portions of variation in rate per ton-mile across commodities and regions. R-squared ranges from $R^2 = 0.904$ for Barley shipments originating from BEA region (110 and 113) to $R^2 = 0.540$ for

soybeans transported from BEA region (110). This means that 90% of the variation in rate per ton-mile can be explained by the included explanatory variables for barley while included variables can explain 50% of rate per ton-mile for soybean shipments emanating from BEA region (110). The high R-squared supports the use of this method to estimate elevator specific rail rates used in the link specific cost function. Most variables have the expected sign, although a few are statistically insignificant. Generally, the natural log of distance and load have a negative relationship with the natural log of rate per ton-mile for all commodities and regions. For example, wheat results for BEA region (110) indicate that a one percent increase in distance will lead to a 0.431 percent decline in rate per ton-mile while a one percent increase in tonnage per car will cause a 0.740 percent reduction in rate per ton-mile. Almost all dummies have (unit train in the corn model for OBEA 110 and 113 the exception). All relationships for shipment type have the expected sign. Shuttle and unit shipments dummy variables show that both types of shipments have comparably lower rates relative to multicar shipment. This is particularly exemplified in the wheat models and the corn estimate for BEA region (111 and 112). In all three soybean models (with two shipment types), unit shipments are shown to have lower rates relative to multicar shipments, which serve as the base. The literature on the seasonality of rail rates suggests that rates are higher in the fourth quarter compared to three quarters of the year following planting and harvesting patterns (e.g. Ndembe 2015). Monthly rail rate estimates vary by commodity and region with no particular discernable pattern.

4.4. Truck Rates

The U.S trucking industry, unlike railroads is very competitive. Competition stems from the less concentrated nature of the industry (there are significant number of firms in the industry). Additionally, the industry is characterized by lower fixed costs compared to railroads,

which need significant investment that is often sunk in way and structures before operations can commence. Starting a trucking firm is relatively easy. All that is needed is for an individual to purchase and register a truck to begin operation. The limited capital requirements and relatively simple structure of the industry also means that operational cost can be fully allocated to specific outputs. Despite this fact, the estimation of truck rates is complicated by the lack of information about the industry. Unlike railroads, which are required to provide operational and financial information to the federal government (Surface Transportation Board), trucking firms are not. This makes it difficult to obtain information on their operational characteristics (proprietary information).

The lack of operational and cost information and the segmentation of the industry as a whole into truckload (TL) and less than truck load (LTL) sectors has led to the development of truck costing models aimed at estimating truck rates. Berwick and Dooley (1997) used an economic engineering truck cost model approach to estimate the trip cost of trucking movements while assuming that truck cost is representative of truck rate paid for specific haulage. Truck costs for individual trips are often modeled as a function of trip distance, operating characteristics (speed, payload, gross vehicle weight), vehicle characteristics or configuration (Rocky Mountain Double, conventional, tandem), and input prices (fuel, insurance, tires). More recently, Dybing (2012) developed a similar approach by making improvements to the (Berwick and Dooley 1997) model. He justified the use of truck cost to approximate rates on an assumption of the trucking industry being perfectly competitive. While truck cost may be reasonable approximation of rates, using the rates themselves is preferred. Since the model in this paper involves estimating a shipper cost function, rates paid are preferred. This study uses average long haul quarterly grain truck rates provided by USDA, Agricultural Marketing

Service, Grain Truck and Ocean Rate Advisory (GTOR). These rates are developed from national and regional surveys of grain elevators indexed by diesel prices. GTOR notes that diesel prices constitute the largest single input in truck operations; hence it constitutes the main determinant for rates paid for trucking services. These rates are provided by U.S regions. This study uses rates for the North Central region, which includes North Dakota among other states. Additionally, the rates are based on trucks with 80,000 pound gross weight (statutory weight limit for commercial trucks on highways) and long haul distances over 200 miles. Based on truck with 80,000 pounds gross weight, the payload (actual commodity weight is 55,000 pounds or 26.6 tons. Truck rates from GTOR represent truck rates per loaded mile. Truck rates per ton-mile are estimated by dividing rates per loaded mile by the payload. This is expressed mathematically as follows:

$$TRTM = \frac{TRLM}{26.6} \quad (59)$$

Where,

TRTM = truck rates per tonmile

TRLM = truck rates per loaded mile

The truck rate per ton-mile is converted to real terms (in 2010 dollars) by dividing by the general Gross Domestic Product price deflator (GDPPD).

$$RTRTM = \frac{TRTM}{GDPPD} \quad (60)$$

Where,

RTRTM = real truck rates per ton – mile

GDPPD = gross domestic product price deflator (2010 base)

CHAPTER 5. RESULTS

5.1. Descriptive Statistics

All data are aggregated by elevator, destination, commodity, and year. Table 2 shows descriptive statistics, including number of observations (yearly elevator to destination movements), mean, and standard deviation by commodity for main variables (in bold) and other related variables used in the link specific shipper transportation cost function estimation. Hard red spring wheat has the highest number of observations followed by barley, corn, durum, and soybeans, respectively.

Table 2: Descriptive Statistics of Variables in Shipper Transportation Cost Function

Variables	Barley	Corn	Soybean	Durum	Hard Red Spring Wheat
	Mean {Std. Dev}	Mean {Std. Dev}	Mean {Std. Dev}	Mean {Std. Dev}	Mean {Std. Dev}
Rail Rates (\$ per ton-miles)	0.0539 {0.0229}	0.0399 {0.0225}	0.0398 {0.0132}	0.0496 {0.0146}	0.0484 {0.0184}
Truck Rates (\$ per ton-miles)	0.0916 {0.0118}	0.0921 {0.0108}	0.0861 {0.0143}	0.0907 {0.0109}	0.0915 {0.0113}
Ton-Mile (000)	2,956 { 7,776}	35,337 { 67,426}	58,526 {91,460}	9,309 {19,624}	18,289 {38,894}
Rail Ton-Mile (000)	2,165 {4,518}	34,259 {67439}	58,184 {91,582}	9,064 {19594}	17,905 {38,960}
Truck Ton-Mile (000)	792 {5,904}	1,077 {5,524}	342 {2,338}	245 {1070}	385 {2,702}
Link Distance (miles)	951 {635}	1,323 {530}	1,217 {538}	862 {593}	945 {624}
Rail Distance (miles)	988 {683}	1,376 {571}	1253 {565}	895 {632}	985 {665}
Truck Distance (miles)	915 {591}	1,270 {496}	1,180 {517}	828 {560}	906 {587}
Observations	952	739	618	637	2002

Rail rates, in general, are lower than those for truck across all commodities. Rail rates range from \$0.0539 per ton-mile for barley to \$0.0398 for soybeans. Truck rates, on the other

hand, range from, \$0.0921 per ton-mile for corn to \$0.0861 per ton-mile for soybeans. Truck rates do not show marked differences between different commodities, whereas noticeable differences are observed with rail rates.

The ton-mile variable (output) represents the sum of total rail and truck ton-miles shipped by a grain elevator for a particular commodity, destination, and year. Ton-miles describe the movement of one ton over a mile. This shows that soybeans have the highest average ton-miles in thousands (58,526) while barley has the lowest ton-miles (2,956). Differences in output originate from variations in total tons shipped from an elevator to a particular destination in a year and distance of the shipment (link distance). A closer look at actual shipments by destination (Table 1) shows that 90% of soybean shipments are destined for the PNW, while more than 75% of barley shipments are destined for Duluth and Minneapolis St Paul, Minnesota. The average volume of soybeans shipped to the PNW is the largest volume in tons transported to any single destination among all five commodities between 2006 and 2013. The volume and distance combination makes soybeans the commodity with the highest ton-miles. Also, it is worthy to observe that rail ton-miles are the biggest contributor to total ton-miles.

Link distance shows that corn (1,323 miles) and soybeans (1,217 miles) are transported the furthest relative to other commodities. This seems reasonable given the fact that approximately 90% of all corn in tons are shipped to Gulf (13%) and PNW (77.7%) destinations (see Table 1). Similarly, for soybeans, an estimated 93% by volume is transported to Gulf (3.4%) and PNW (90%) destinations. Durum (862 miles) and hard red spring wheat (945 miles) have the shortest average link distances. For Durum, looking at Table 1, this is likely the case due to the fact that a combined total of 70% of all volume transported in tons is destined for Duluth and Minneapolis St Paul, markets that are relatively closer compared to the two other major

destinations. In the case of hard red spring wheat, tonnage shipped to both Minnesota destinations and longer distance markets in the Gulf and PNW are almost evenly split. Barley link distance (951) is closer to that for hard red spring wheat. This similarity is reflected in the fact that 75% of barley is shipped to both Minnesota destinations.

5.2. Econometrics Diagnostic Test

The omitted variable version of the Hausman test explained previously is used to test for endogeneity of both rail and truck prices. This might arise if either of the prices is correlated with the error term due to an omitted variable, measurement error, or simultaneity (Wooldridge, 2006). The test determines whether 3SLS (the instrumental variable technique) is a better estimator than SUR. The null hypothesis is to test the joint significance of predicted values for both rail and truck input prices and their interaction with other variables. Calculated F-statistics for each commodity are shown below and Table 3 shows the econometric procedure used based on rejection (3SLS) or failure to reject (SUR) for the joint significance null hypothesis. The null hypothesis of no joint significance is rejected for durum and soybean while we fail to reject it for barley, corn, and hard red spring wheat. Consequently, 3SLS is a better estimator for the former commodities and SUR is for the latter.

$$\text{Barley: } F_{11,920} = \frac{(58.23196 - 57.31162)/11}{57.31162/920} = 1.34$$

$$\text{Corn: } F_{13,707} = \frac{(76.34030 - 75.65220)/13}{75.65220/707} = 0.51$$

$$\text{Durum: } F_{11,605} = \frac{(24.84683 - 23.53997)/11}{23.53997/605} = 3.05^*$$

$$\text{Hard Red Spring Wheat: } F_{13,1970} = \frac{(106.14191 - 105.01945)/13}{105.01945/1970} = 1.31$$

$$\text{Soybean: } F_{11,586} = \frac{(27.61319 - 25.89326)/11}{25.89326/586} = 3.54^*$$

Table 3: Hausman Joint Significance Test

Commodity	Ho: $X_1, X_2, X_3 \dots, X_{11} = 0$	Procedure
Barley	Fail to Reject	Seemingly Unrelated Regression (SUR)
Corn	Fail to Reject	Seemingly Unrelated Regression (SUR)
Durum	Reject	Three Stage Least Squares (3SLS)
Hard Red Spring Wheat	Fail to Reject	Seemingly Unrelated Regression (SUR)
Soybeans	Reject	Three Stage Least Squares (3SLS)

* Significance at the 1%, 15%, 10% level of significance

Concavity in modal rates for cost functions is tested by taking the characteristic roots (Eigen values) of the Hessian matrix for all observations in the sample for each commodity. For barley, corn, soybeans, and hard red spring wheat, the Eigen values are negative for all 952, 739, 618, and 2002 observations, respectively, meaning that the cost functions are strictly concave in factor prices (negative definite). Characteristics roots are positive and negative 50% of the time for the 637 observations for durum (indefinite).

5.3. Econometrics Procedure

The model in equation 13 is estimated using the procedures specified in Table 3. There was also a consideration of including fixed effects. A test of fixed effects was performed for hard red spring wheat without the shuttle dummies. While a joint significant test (F-statistics = 12.4) showed that the elevator-destination fixed effects are jointly significant, the fixed effects exhibited high correlation with the shuttle dummy, making it difficult to isolate shuttle effects (impact of shuttle elevators was one of the major objectives of this study). Consequently, they were dropped from the estimation process for hard red spring wheat and other commodities. With other commodities, an additional concern over degrees of freedom arose due to the large number of fixed effects (e.g. 509 for wheat). Moreover, parameter estimates with and without the

elevator-destination fixed effects for hard red spring wheat were not very different. Seemingly unrelated (SUR) estimates with fixed effects for HRS wheat are shown in Table A1 of the appendix.

To evaluate the potential differences in rail-truck competition for shuttle elevators in comparison to non-shuttle elevators, the shuttle dummy variable was used for the hard red spring wheat and corn estimations (again fixed effects were dropped). These represent the two commodities that use shuttle facilities extensively, based on data from the North Dakota Grain Movement Database. Results for all commodities are shown in Tables 4 through 8. Overall, models for all five commodities indicate that included variables explain much of the variation in the cost of grain transportation. The lowest system weighted R-Squared, $R^2 = 0.9768$ is that for barley,

Since all continuous variables (except time) are divided by their means and are in natural logarithms, estimated coefficients on the first-order terms can be viewed as cost elasticity with respect to particular variable when all variables except time and the shuttle variables are at mean levels. In addition, estimated parameters for input prices (shipping rates) represent each mode's share of total transportation cost according to Shephard's lemma. Estimation results vary by commodity with rail modal share ranging from 0.88 for barley and corn to approximately 0.81 for durum (note, however, that rail shares for corn and wheat are for non-shuttle elevators, only). Rail shares are 0.98 and 0.90 for shuttle elevators shipping wheat and corn, respectively. Truck shares range from 0.19 for durum to 0.12 Truck for barley and corn for non-shuttle elevators. For shuttle elevators, truck shares are 0.02 and 0.10 for wheat and corn.

As expected, increases in truck and rail rates, as well as output (ton-miles) have positive effects on cost for all commodities. Since the parameter estimate on output is close to one for all

commodities, essentially a one percent increase in output leads to a one percent increase in real total transportation cost for all commodities. The output variable is statistically significant at the 1% level in all cases.

Table 4: Barley SUR Parameter Estimates

Parameter	Name	Parameter Estimate	P-Value
α_0	Intercept	12.0280*	0.0001
α_1	In (Rail Rate)	0.8841*	0.0001
α_2	In (Truck Rate)	0.1159*	0.0001
ρ_1	In (Ton-Miles)	0.9750*	0.0001
ρ_2	In (Link Distance)	-0.0083	0.7195
ρ_3	Time	0.0195*	0.0404
τ_{11}	$\frac{1}{2}$ (In Rail Rate) ²	-0.0951***	0.0632
τ_{22}	$\frac{1}{2}$ (In Truck Rate) ²	-0.0951***	0.0632
β_{11}	$\frac{1}{2}$ (In Ton-Miles) ²	-0.0008	0.7843
β_{22}	$\frac{1}{2}$ (In Link Distance) ²	-0.1811*	0.0003
β_{33}	$\frac{1}{2}$ (Time) ²	-0.0041	0.1435
τ_{12}	In (Rail Rate)*In (Truck Rate)	0.0951***	0.0632
χ_{11}	In (Rail Rate)* In (Ton-Miles)	0.0347	0.0001
χ_{12}	In (Rail Rate)*In (Link Distance)	-0.0861**	0.0161
χ_{13}	In (Rail Rate)*Time	-0.0021	0.6612
χ_{21}	In (Truck Rate)*In (Ton-Miles)	-0.0347*	0.0001
χ_{22}	In (Truck Rate)*In (Link Distance)	0.0861**	0.0161
χ_{23}	In (Truck Rate)*Time	0.0021	0.6612
β_{12}	In (Ton-Miles)*In (Link Distance)	-0.0001	0.9867
β_{13}	In (Ton-Miles)*Time	-0.0009	0.6048
β_{23}	In (Link Distance)*Time	0.0017	0.7320

*, **, *** Significance at the 1%, 5% and 10% respectively

Observation = 952

System Weighted R² = 0.9768

System Weighted MSE = 0.9214

Table 5: Corn SUR Parameter Estimates

Parameter	Name	Parameter Estimate	P-Value
α_0	Intercept	14.2230*	0.0001
α_1	In (Rail Rate)	0.8842*	0.0001
α_2	In (Truck Rate)	0.1158*	0.0004
ρ_1	In (Ton-Miles)	0.9094*	0.0001
ρ_2	In (Link Distance)	0.2135*	0.0004
ρ_3	Time	-0.0047	0.7235
ρ_4	Shuttle Dummy	0.0068	0.8702
τ_{11}	$\frac{1}{2}$ (In Rail Rate) ²	-0.0310	0.3569
τ_{22}	$\frac{1}{2}$ (In Truck Rate) ²	-0.0310	0.3569
β_{11}	$\frac{1}{2}$ (In Ton-Miles) ²	0.0048***	0.0801
β_{22}	$\frac{1}{2}$ (In Link Distance) ²	-0.0697	0.3640
β_{33}	$\frac{1}{2}$ (Time) ²	0.0018	0.5426
τ_{12}	In (Rail Rate)*In (Truck Rate)	0.0310	0.3569
χ_{11}	In (Rail Rate)* In (Ton-Miles)	0.1156*	0.0001
χ_{12}	In (Rail Rate)*In (Link Distance)	-0.2758*	0.0001
χ_{13}	In (Rail Rate)*Time	0.0076	0.1294
χ_{14}	In (Rail Rate)*Shuttle Dummy	0.0119	0.6516
χ_{21}	In (Truck Rate)*In (Ton-Miles)	-0.1156*	0.0001
χ_{22}	In (Truck Rate)*In (Link Distance)	0.2758*	0.0001
χ_{23}	In (Truck Rate)*Time	-0.0076	0.1294
χ_{24}	In (Truck Rate)*Shuttle Dummy	-0.0119	0.6516
β_{12}	In (Ton-Miles)*In (Link Distance)	0.0039	0.6212
β_{13}	In (Ton-Miles)*Time	0.0018	0.2259
β_{14}	In (Ton-Miles)*Shuttle Dummy	-0.0090	0.2884
β_{23}	In (Link Distance)*Time	-0.0041	0.4808
β_{24}	In (Link Distance)*Shuttle Dummy	0.0062	0.8325
B_{34}	Time*Shuttle Dummy	-0.0066	0.3505

*, **, *** Significance at the 1%, 5% and 10% respectively

Observation = 739

System Weighted R² = 0.9919

System Weighted MSE = 0.8490

Table 6: Durum 3SLS Parameter Estimates

Parameter	Name	Parameter Estimate	P-Value
α_0	Intercept	12.9752*	0.0001
α_1	In (Rail Rate)	0.8078*	0.0001
α_2	In (Truck Rate)	0.1922*	0.0001
ρ_1	In (Ton-Miles)	0.9689*	0.0001
ρ_2	In (Link Distance)	-0.4556*	0.0001
ρ_3	Time	0.0281*	0.0010
τ_{11}	$\frac{1}{2}$ (In Rail Rate) ²	0.0441	0.7339
τ_{22}	$\frac{1}{2}$ (In Truck Rate) ²	0.0441	0.7339
β_{11}	$\frac{1}{2}$ (In Ton-Miles) ²	0.0084*	0.0008
β_{22}	$\frac{1}{2}$ (In Link Distance) ²	-0.1221***	0.0590
β_{33}	$\frac{1}{2}$ (Time) ²	-0.0049**	0.0486
τ_{12}	In (Rail Rate)*In (Truck Rate)	-0.0441	0.7339
χ_{11}	In (Rail Rate)* In (Ton-Miles)	0.0597*	0.0001
χ_{12}	In (Rail Rate)*In (Link Distance)	-0.0464***	0.0776
χ_{13}	In (Rail Rate)*Time	0.0329*	0.0001
χ_{21}	In (Truck Rate)*In (Ton-Miles)	-0.0597*	0.0001
χ_{22}	In (Truck Rate)*In (Link Distance)	0.0464***	0.0776
χ_{23}	In (Truck Rate)*Time	-0.0329	0.0001
β_{12}	In (Ton-Miles)*In (Link Distance)	-0.0271*	0.0001
β_{13}	In (Ton-Miles)*Time	0.0008	0.5276
β_{23}	In (Link Distance)*Time	0.0083	0.1833

*, **, *** Significance at the 1%, 5% and 10% respectively

Observation = 637

System Weighted R = 0.9932

System Weighted MSE = 0.8418

Table 7: Hard Red Spring Wheat SUR Parameter Estimates

Parameter	Name	Parameter Estimate	P-Value
α_0	Intercept	13.8206*	0.0001
α_1	In (Rail Rate)	0.8479*	0.0001
α_2	In (Truck Rate)	0.1521*	0.0001
ρ_1	In (Ton-Miles)	0.9752*	0.0001
ρ_2	In (Link Distance)	0.0053	0.7260
ρ_3	Time	-0.0047	0.3629
ρ_4	Shuttle Dummy	-0.1136*	0.0001
τ_{11}	$\frac{1}{2}$ (In Rail Rate) ²	-0.0192	0.5581
τ_{22}	$\frac{1}{2}$ (In Truck Rate) ²	-0.0192	0.5581
β_{11}	$\frac{1}{2}$ (In Ton-Miles) ²	0.0041*	0.0033
β_{22}	$\frac{1}{2}$ (In Link Distance) ²	-0.0384	0.1305
β_{33}	$\frac{1}{2}$ (Time) ²	-0.0008	0.5821
τ_{12}	In (Rail Rate)*In (Truck Rate)	0.0192	0.5581
χ_{11}	In (Rail Rate)* In (Ton-Miles)	0.0320*	0.0001
χ_{12}	In (Rail Rate)*In (Link Distance)	-0.0446**	0.0175
χ_{13}	In (Rail Rate)*Time	0.0068**	0.0455
χ_{14}	In (Rail Rate)*Shuttle Dummy	0.1275*	0.0001
χ_{21}	In (Truck Rate)*In (Ton-Miles)	-0.0620*	0.0001
χ_{22}	In (Truck Rate)*In (Link Distance)	0.0446**	0.0175
χ_{23}	In (Truck Rate)*Time	-0.0068**	0.0455
χ_{24}	In (Truck Rate)*Shuttle Dummy	-0.1275*	0.0001
β_{12}	In (Ton-Miles)*In (Link Distance)	-0.0034	0.3327
β_{13}	In (Ton-Miles)*Time	0.0009	0.2408
β_{14}	In (Ton-Miles)*Shuttle Dummy	-0.0057	0.1697
β_{23}	In (Link Distance)*Time	0.0005	0.8472
β_{24}	In (Link Distance)*Shuttle Dummy	-0.0025	0.8427
B_{34}	Time*Shuttle Dummy	0.0060***	0.0562

*, **, *** Significance at the 1%, 5% and 10% respectively

Observation = 2002

System Weighted R² = 0.417

System weighted MSE = 0.9915

Table 8: Soybeans 3SLS Parameter Estimates

Parameter	Name	Parameter Estimate	P-Value
α_0	Intercept	14.4238*	0.0001
α_1	In (Rail Rate)	0.8795*	0.0001
α_2	In (Truck Rate)	0.1205*	0.0015
ρ_1	In (Ton-Miles)	0.9345*	0.0001
ρ_2	In (Link Distance)	-0.2303*	0.0009
ρ_3	Time	0.0840*	0.0001
τ_{11}	$\frac{1}{2}$ (In Rail Rate) ²	-0.2371***	0.0942
τ_{22}	$\frac{1}{2}$ (In Truck Rate) ²	-0.2371***	0.0942
β_{11}	$\frac{1}{2}$ (In Ton-Miles) ²	0.0153*	0.0001
β_{22}	$\frac{1}{2}$ (In Link Distance) ²	0.1880***	0.0647
β_{33}	$\frac{1}{2}$ (Time) ²	-0.0155*	0.0003
τ_{12}	In (Rail Rate)*In (Truck Rate)	0.2371***	0.0942
χ_{11}	In (Rail Rate)* In (Ton-Miles)	0.0734*	0.0001
χ_{12}	In (Rail Rate)*In (Link Distance)	-0.0165	0.6429
χ_{13}	In (Rail Rate)*Time	0.0222*	0.0050
χ_{21}	In (Truck Rate)*In (Ton-Miles)	-0.0734*	0.0001
χ_{22}	In (Truck Rate)*In (Link Distance)	0.0165	0.6429
χ_{23}	In (Truck Rate)*Time	-0.0222*	0.0050
β_{12}	In (Ton-Miles)*In (Link Distance)	-0.0196**	0.0494
β_{13}	In (Ton-Miles)*Time	0.0090*	0.0001
β_{23}	In (Link Distance)*Time	-0.0265*	0.0026

*, **, *** Significance at the 1%, 5% and 10% respectively

Observation = 618

System Weighted R = 0.9886

System Weighted MSE = 0.5986

The link distance variable is expected to have a negative effect on real total transportation cost since the model already controls for ton-miles. The sign for link distance is (unexpected) positively related to cost for corn and hard red spring wheat. The variable is not significant for the hard red spring wheat model, while that for corn is statistically significant at the 1% level. Link distance has the expected negative sign for barley, durum, and soybeans. The negative sign is significant at the 1% level for the durum and soybean models while it is insignificant for barley. The time variable seems to suggest that real transportation cost is increasing over time for barley, durum and soybeans while it seems to be decreasing for corn and hard red spring wheat.

However, the parameter estimates for corn and hard red spring wheat are insignificant at widely acceptable levels of statistical significance.

Another parameter of interest is the shuttle dummy for hard red spring wheat and corn. The shuttle dummy variable compares the effect on transportation cost between shuttle and non-shuttle grain elevators. Shuttle elevators are expected to have lower total real transportation costs compared to other grain elevators. The shuttle dummy variable has an unexpected positive sign for the corn model and the expected negative sign for the hard red spring wheat model. However, the sign for the corn model is statistically insignificant, whereas that for hard red spring wheat is significant at the 1% level of significance. This suggests that shuttle elevators have a cost advantage over other elevators for transportation of hard red spring wheat.

5.4. Modal Elasticities Non-Shuttle Elevators

Estimated parameters from the econometric procedures in section 5.1 are used to calculate rail and truck transportation modal demand elasticities (cross-price) for non-shuttle grain elevators (shuttle elevator demand elasticities are presented in the next section). Recall that calculated demand elasticities are from a compensated demand function. They do not take into account the impact of a price change of the commodity on the output (assumes constant outputs). For the two mode case, the cross price elasticity of a given mode with respect to the other mode is equal to the absolute value of the own price elasticity of the first mode: ($\epsilon_{12} = |\epsilon_{11}|$). This is the case because modal compensated demand elasticities sum to zero: ($\epsilon_{11} + \epsilon_{12} = 0$). Table 9 shows modal factor shares and estimated elasticities at the means of all variables for all five commodities involved in this study. ($i = 1, 2$ for rail and truck respectively).

Table 9: Non-Shuttle Elevator Modal Elasticities by Commodity

	Barley	Corn	Soybean	Durum	Hard Red Spring Wheat
Rail Factor share (S_{1l})	0.88	0.88	0.88	0.81	0.85
Truck Factor Share (S_{2l})	0.12	0.12	0.12	0.19	0.15
Elasticity of Substitution σ_{12}	1.93	1.30	3.24	0.72	1.15
Rail price elasticity $\varepsilon_{11} = -\varepsilon_{12}$	-0.23	-0.16	-0.39	-0.14	-0.17
Truck price elasticity $\varepsilon_{22} = -\varepsilon_{21}$	-1.70	-1.14	-2.85	-0.58	-0.98

In examining Table 9, a general observation is that rail factor share is higher than those for truck across all commodities. This indicates that rail accounts for a higher proportion of transportation cost for all commodities transported. The share of transportation cost is highest for barley, corn, and soybeans (0.88) and lowest for durum (0.81). Conversely, truck share of total transportation cost is highest for durum (0.19) and lowest for barley, corn, and soybean (0.12). Rail (0.85) and truck (0.15) shares of transportation cost for hard red spring wheat are the second highest rail share and second lowest truck share respectively among all commodities.

The elasticity of substitution σ_{12} offers an indication about the substitutability (elasticity greater than zero) or complementarity (elasticity less than 0) of two inputs. Results indicate that both rail and truck are “Allen substitutes” across all commodities. That is, an increase in the price of trucking will lead to an increase in rail traffic (more shippers using rail for grain shipment). Rail and truck show the highest level of substitution in soybean transportation, while substitution is lowest for durum. This relationship is similarly observed with the cross-price elasticity of demand.

Modal own-price elasticity is a measure of the responsiveness of quantity demand of a given mode to changes in its price. This can be used to assess different groups of grain shippers’ dependence on a given mode as well as assess the relative usage of different modes over different distances (link-dominance) and over time. As alluded to above, we can deduce cross-

price elasticities from own-price elasticity (i.e., $\varepsilon_{12} = |\varepsilon_{11}|$ and $\varepsilon_{21} = |\varepsilon_{22}|$). In general, the own-price elasticities for rail across all commodities are significantly greater than negative one (inelastic) for rail (consequently cross price elasticity of rail with respect to truck is much less than one across all commodities). This general observation suggests that, rail can increase its price or truck can decrease its price and there won't be a big reduction in rail traffic for all five commodities. On the other hand, own-price elasticity for truck is much less than negative one for all commodities except wheat (about negative one) and durum (-0.58) (consequently, cross-price elasticity of truck with respect to rail is much greater than 1 for most commodities). This indicates that any increase in truck prices or decrease in rail prices will lead to a big reduction in truck traffic for four out of five commodities (excluding durum).

Own-price elasticity for rail ε_{11} ranges from a high of approximately -0.14 for durum, to a low of -0.39 for soybeans. Results for the rail price elasticities means that a one percent increase in rail prices will lead to a less than proportionate reduction in the quantity demanded of rail transportation. This reduction in rail traffic is lowest for durum and is highest for soybeans.

Rail results indicate a high dependence on rail for all commodities, though more so for, wheat and corn shippers. The dominance of rail is also illustrated by considering cross-price elasticity with respect to truck. The relatively low cross price elasticity of rail with respect to truck rate ε_{12} suggests that a reduction in truck rate will have very little effect on rail traffic (rail is the dominant mode either way). For example a one percent decrease in truck price will only decrease rail traffic by 0.39 percent for soybeans, which has the highest cross-price elasticity of rail with respect to truck price.

Own-price elasticity for truck ε_{22} ranges from a low of approximately -0.58 for durum to a high of -2.85 for soybeans. As opposed to the own-price elasticity for rail ε_{11} , the own-price

elasticity of truck ε_{22} varies widely among different commodities. For example, results show that truck own-price elasticity ε_{22} for durum (-0.58) is inelastic while for hard red spring wheat it is statistically not different from -1, and for the other three commodities it is elastic (less than -1). This means that for most commodities, a one percent increase in truck rate will lead to a more than proportionate decrease in truck traffic. The cross price elasticity of truck with respect to rail rates ε_{21} indicates that reductions in rail rates are likely to have noticeable impacts on truck transportation for four out of the five commodities (excluding durum which shows very little impact). For example, a one percent decrease in rail rates will decrease truck traffic by 2.58 percent for soybeans. This decrease in truck traffic from a reduction in rail rates is almost 7 times (in percentage points) higher than that observed from the effect of a reduction in truck rates on rail traffic ε_{12} (cross price elasticity of rail with respect to truck rates). Calculated elasticities in Table 8 show that rail dominates most of the traffic for all but one commodity (durum).

Rail dominance can be explained by the small size of the cross-price elasticity of rail with respect to truck rates (ε_{12}) and the comparatively large cross-price elasticity of truck with respect to rail rates ε_{21} . The low ε_{12} implies that shippers who ship by rail do not view truck as a good substitute for rail for all five commodities. On the other hand, the relatively high ε_{21} for all commodities but durum suggests that barley, corn, hard red spring wheat, and soybean shippers who shipper by truck view rail as a good substitute for truck. These can be explained mathematically as well using the elasticity of substitution σ_{12} .

The elasticity of substitution $\sigma_{12} = \left(\frac{\tau_{12}}{S_1 S_2} \right) + 1$ gets bigger as absolute deviation between rail and truck share $|S_{1l} - S_{l2}|$ increases. This is shown for durum and soybeans as σ_{12} increases from (0.72) to (3.24) with corresponding rise in the difference between rail and truck share from 0.62 to 0.76 for durum and soybeans respectively. Rail share is larger than truck share, $S_{1l} > S_{l2}$

for all commodities. Thus, since $\varepsilon_{21} = |\varepsilon_{22}| = \sigma_{12}S_1$ as such own price elasticity for trucking is high (elastic) for at least three out of five commodities. High own price elasticity for trucking means a high cross price elasticity of demand for trucking with respect to rail rate as well. The next section provides results on modal dominance by link distance (elevator-destination).

5.5. Rail-Truck Link Dominance Non-Shuttle Elevators

Initial results based on modal own-price elasticities in general indicate that the demand for rail is inelastic (price insensitive) across all commodities and that for truck is elastic (price sensitive) except in the case of durum. Since shippers who ship by rail do not view truck as a good substitute for rail for all five commodities and those who ship by truck view rail as a good substitute for truck, rail dominates (i.e., more will be shipped by rail compared to truck for most of the links).

This fact can be explained mathematically using the elasticity of substitution. Rail is shown to dominate most of the traffic given that the deviation between rail and truck share $|S_1 - S_2|$ is large and $S_{1l} > S_{l2}$. Not only is rail dominant for North Dakota grains, this dominance is likely to vary by distance shipped. Recall Koo et al (1993) have shown that rail tends to dominate truck at longer distances due to higher terminal costs, but lower line haul costs. However, previous studies have used various rules of thumb to determine distances at which rail dominates. By examining modal elasticities at different distances, we can determine dominance based on shipper behavior. In this section, we make determination about modal dominance for specific links, by examining the relationship between link distances and modal own and cross price elasticities. Recall the rule of thumb for link dominance. A link is described as truck dominant if the absolute value of the own price elasticity of rail is greater than one and twice that of the own price elasticity of truck given as $|\varepsilon_{11}| > 1$ and $|\varepsilon_{11}| > 2|\varepsilon_{22}|$. A link is rail

dominant if the absolute value of the own price elasticity of truck is greater than one and twice the absolute value of the own price elasticity of rail $|\varepsilon_{22}| > 1$ and $|\varepsilon_{22}| > 2|\varepsilon_{11}|$.

The literature on intermodal (rail-truck) competition, (e.g. Koo et al. 1993) suggests that due to comparatively lower fixed and terminal cost components, which compensates for a higher line haul component (e.g., fuel, labor, tire wear) trucking has a comparative advantage at shorter distances. Railroads on the other hand have a very high fixed cost and realize economies of haul as distance increases (specifically because fixed terminal cost can be spread over greater mileage). It is expected that rail will dominate long distances. Consequently, we expect own-price elasticity for truck to increase (in absolute value) and that for rail to decrease as distance increases. We provide results for four commodities and exclude corn. The calculated elasticities for corn become unrealistic due to a large positive interaction term between truck rate and distance. Table 10 shows rail and truck own-price elasticities for barley at different distances. Results in Table 10 for selected links show that rail is the dominant mode for barley transportation. The own-price elasticity for truck (in absolute value) $|\varepsilon_{22}|$ is greater than 1 and twice that for rail ($|\varepsilon_{22}| > 2|\varepsilon_{11}|$) for all links from the smallest to the largest and for all other link distances in between.

Table 10: Barley Modal Elasticities Selected Links

City (Elevator)-Destination	Link Distance	Rail $ \varepsilon_{11} $	Truck $ \varepsilon_{22} $
Fairmount - Minneapolis St Paul, MN	192	0.12	4.81
Leeds - Duluth, MN	400	0.16	2.46
Crosby - Portland, OR	1250	0.23	1.66
Williston - New Orleans, LA	2087	0.26	1.50

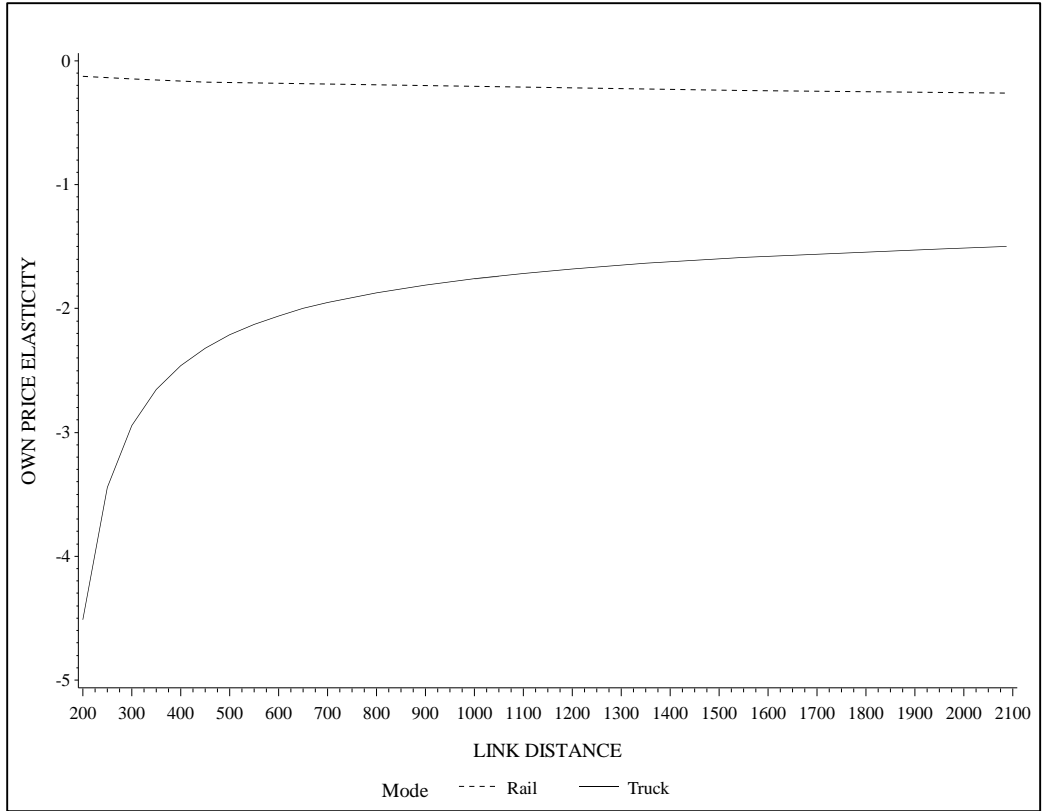


Figure 11: Barley Modal Elasticities by Link Distance

Despite rail being inelastic and truck elastic for the entire range of link distances, it can also be observed that the elasticity for rail increases with distance and that for truck decreases with link distance, which is counter intuitive. This observation is illustrated in Figure 11 which traces changes in modal own-price elasticities in 50 mile increments for all link distances associated with barley shipments. This unexpected result suggests that truck is a stronger competitor with rail for longer distances for barley shipments from North Dakota. Results for durum are presented in Table 11 and Figure 12 below. Link and corresponding modal elasticities for durum indicate that the condition for modal dominance is not met for any link distances.

Table 11: Durum Modal Elasticities Selected Links

City (Elevator)-Destination	Link Distance	Rail $ \epsilon_{11} $	Truck $ \epsilon_{22} $
Prosper - Minneapolis St Paul, MN	248	0.16	0.57
Harlow - Duluth, MN	500	0.15	0.58
Scranton - Portland, OR	1250	0.14	0.58
Williston - New Orleans, LA	2087	0.13	0.58

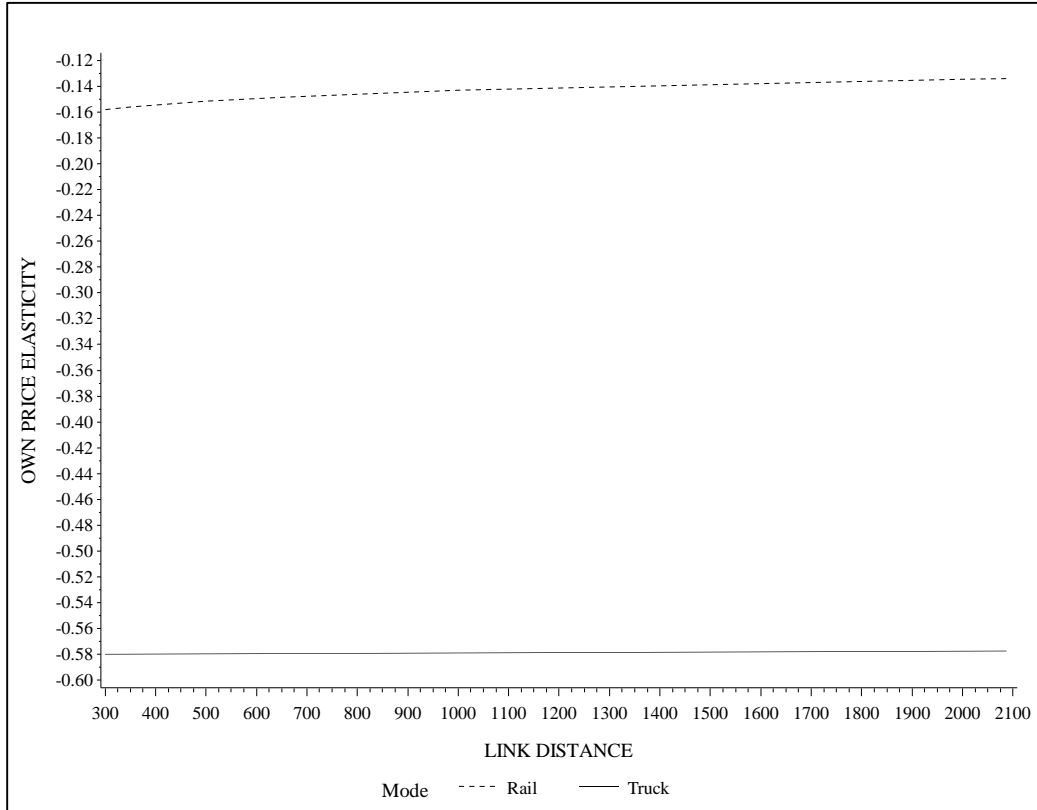


Figure 12: Durum Modal Elasticities by Link Distance

Although the absolute value of own-price elasticity for truck $|\epsilon_{22}|$ is greater than twice that for rail ($|\epsilon_{22}| > 2|\epsilon_{11}|$), the absolute value for truck elasticity is less than one ($|\epsilon_{22}| < 1$) for all links. Both rail and truck are inelastic for all distances. Rail own-price elasticity becomes smaller in absolute value as link distance increases. Trucking own-price elasticity increase slightly from the minimum observable link distance and remains constant. Hard red spring results are shown in Table 12 and Figure 13 below.

Table 12: Hard Red Spring Wheat Modal Elasticities Selected Links

City (Elevator)-Destination	Link Distance	Rail $ \varepsilon_{11} $	Truck $ \varepsilon_{22} $
Fairmount - Minneapolis St Paul, MN	192	0.21	0.92
Jamestown - Duluth, MN	400	0.20	0.94
Berthold - Portland, OR	1300	0.17	0.97
Williston - New Orleans, LA	2087	0.17	0.99

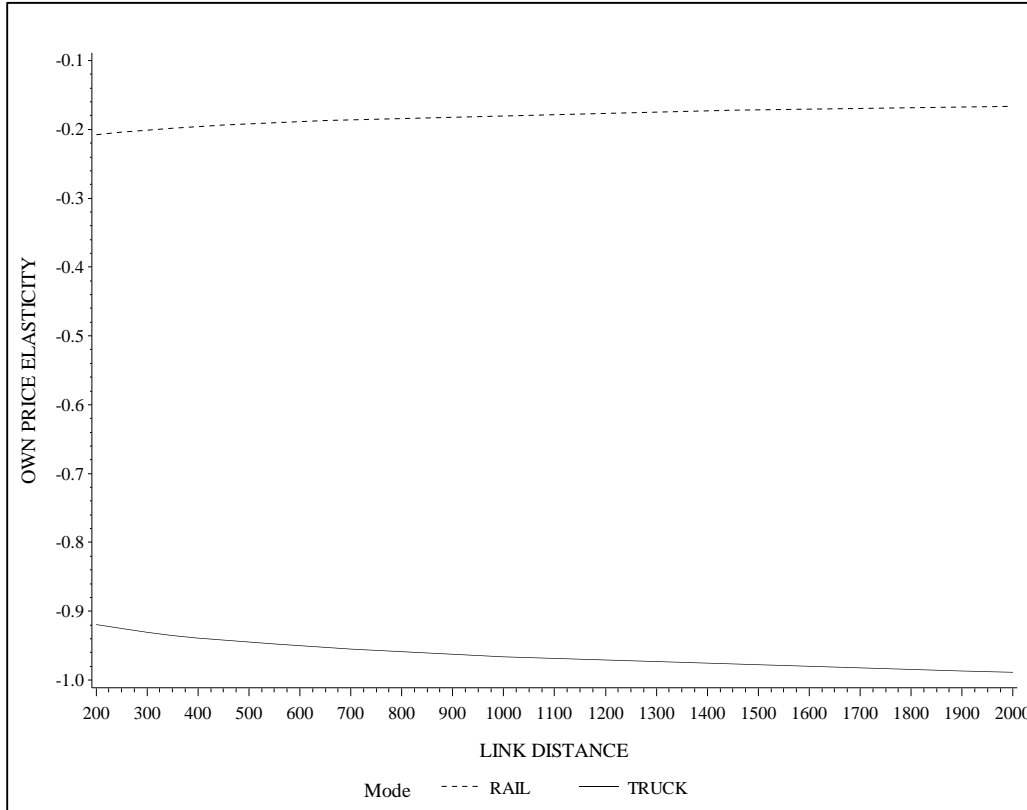


Figure 13: Hard Red Spring Wheat Modal Elasticities by Link Distance

Rail dominance is not met for all link distances for hard red spring wheat despite the fact that own-price elasticity for truck $|\varepsilon_{22}|$ is greater than twice that for rail ($|\varepsilon_{22}| > 2|\varepsilon_{11}|$) for all links. Rail increasingly becomes more inelastic while truck become less inelastic and becomes unit elastic for the longest link distance (see Table12 and Figure 13). Soybeans results are shown in Table 13 and Figure 14.

Table 13: Soybeans Modal Elasticities Selected Links

City (Elevator)-Destination	Link Distance	Rail $ \varepsilon_{11} $	Truck $ \varepsilon_{22} $
Fairmount - Minneapolis St Paul, MN	192	0.55	1.75
Max - Duluth, MN	500	0.48	2.10
Hamberg - Portland, OR	1400	0.40	2.76
Ray - New Orleans, LA	2041	0.37	3.16

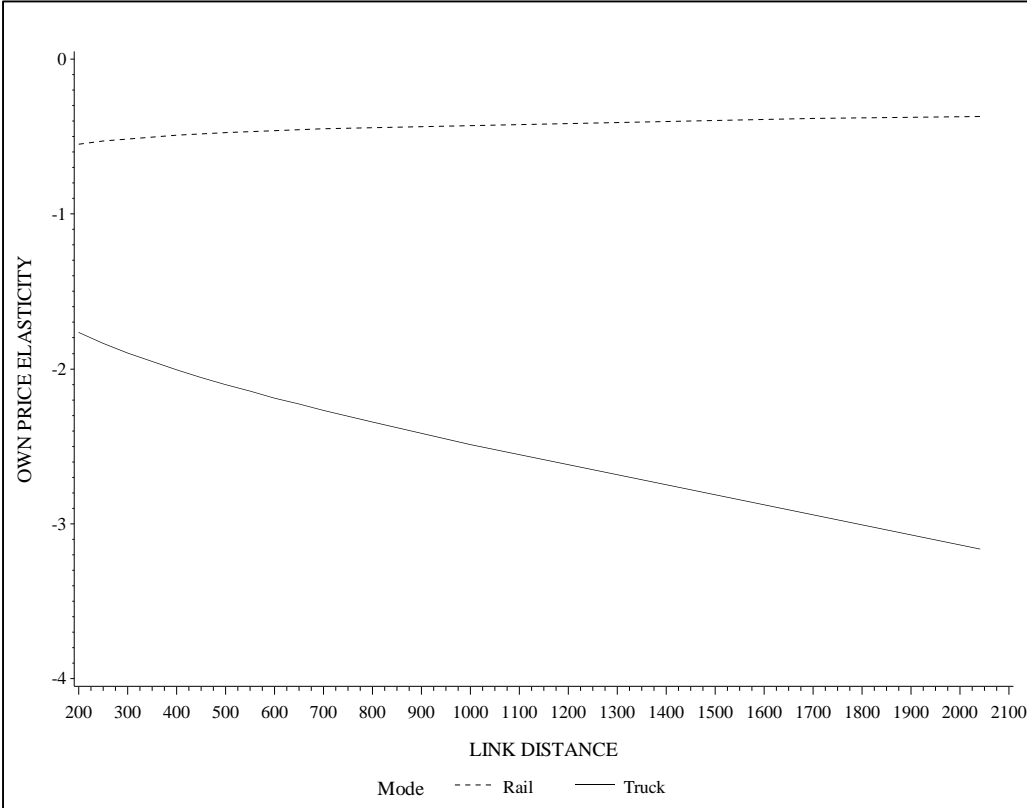


Figure 14: Soybeans Modal Elasticities by Link Distance

The condition for rail dominance is met for all links for soybeans. The absolute value of the own-price elasticity of truck $|\varepsilon_{22}|$ is greater than 1 and twice that for rail ($|\varepsilon_{22}| > 2|\varepsilon_{11}|$) for all links. Rail becomes more inelastic as link distance increases (see Table 13 and Figure 14). Truck is markedly elastic as link distances increases. This is demonstrated by the noticeable increasing truck own-price elasticity. Own-price elasticity for truck is the steepest among other commodities as link distance increases. This suggest that soybeans are the most rail dependent commodity for long distance shipment among non-shuttle elevators.

5.6. Modal Elasticities over Time Non-Shuttle Elevators

In addition to evaluating rail-truck competition for different distances for non-shuttle elevators, another important consideration is to evaluate how potential competition between both modes and relative usage has changed over time by commodity. Table 14 and Figure 15 shows average rail and truck own-price elasticities for barley between 2006 and 2013. Results in general show that rail is inelastic while truck is elastic between 2006 and 2013. However, the trend within this time period indicates that rail becomes relatively less inelastic between 2006 and 2013. Rail average own-price elasticity in absolute value $|\varepsilon_{11}|$ becomes bigger. Truck on the other hand becomes less elastic from 2006 to 2013. This is shown by the relative decrease in the average absolute value of the own-price elasticity for truck $|\varepsilon_{22}|$.

Table 14: Barley Modal Elasticities by Year

Year	Rail $ \varepsilon_{11} $	Truck $ \varepsilon_{22} $
2006	0.223	1.705
2007	0.225	1.688
2008	0.228	1.672
2009	0.231	1.656
2010	0.233	1.641
2011	0.235	1.626
2012	0.238	1.612
2013	0.240	1.600

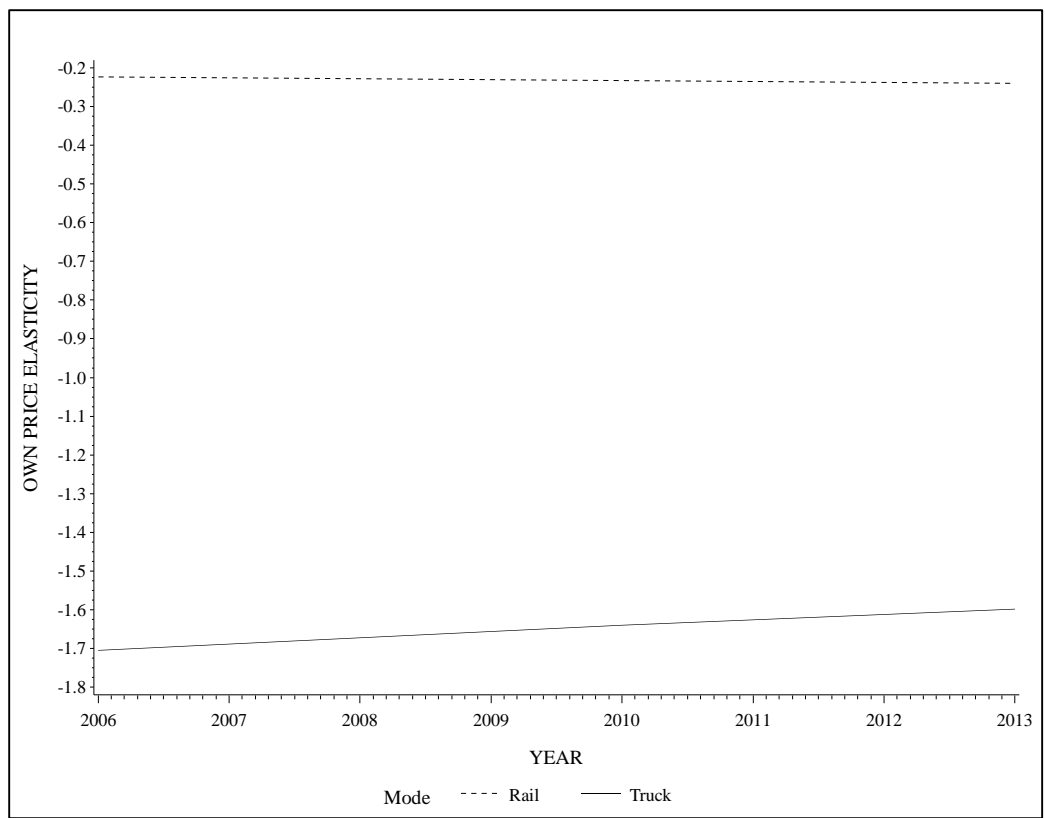


Figure 15: Barley Modal Elasticities over Time

The average rail and truck own-price elasticities for corn by year between 2006 and 2013 shown in Table 15 and Figure 16 show that rail is increasingly becoming inelastic while truck increasingly gets elastic over time. For rail, this is exhibited by decreasing average own-price elasticity in absolute value $|\varepsilon_{11}|$ (see Table 15). For truck, this is demonstrated by increasing average own-price elasticity in absolute value $|\varepsilon_{22}|$ (see Table 15). This trend suggest that rail use is increasing while truck usage is decreasing over time in corn transportation (Figure 15).

Table 15: Corn Modal Elasticities by Year

Year	Rail $ \epsilon_{11} $	Truck $ \epsilon_{22} $
2006	0.150	1.152
2007	0.143	1.178
2008	0.135	1.207
2009	0.127	1.240
2010	0.119	1.277
2011	0.112	1.319
2012	0.104	1.370
2013	0.096	1.431

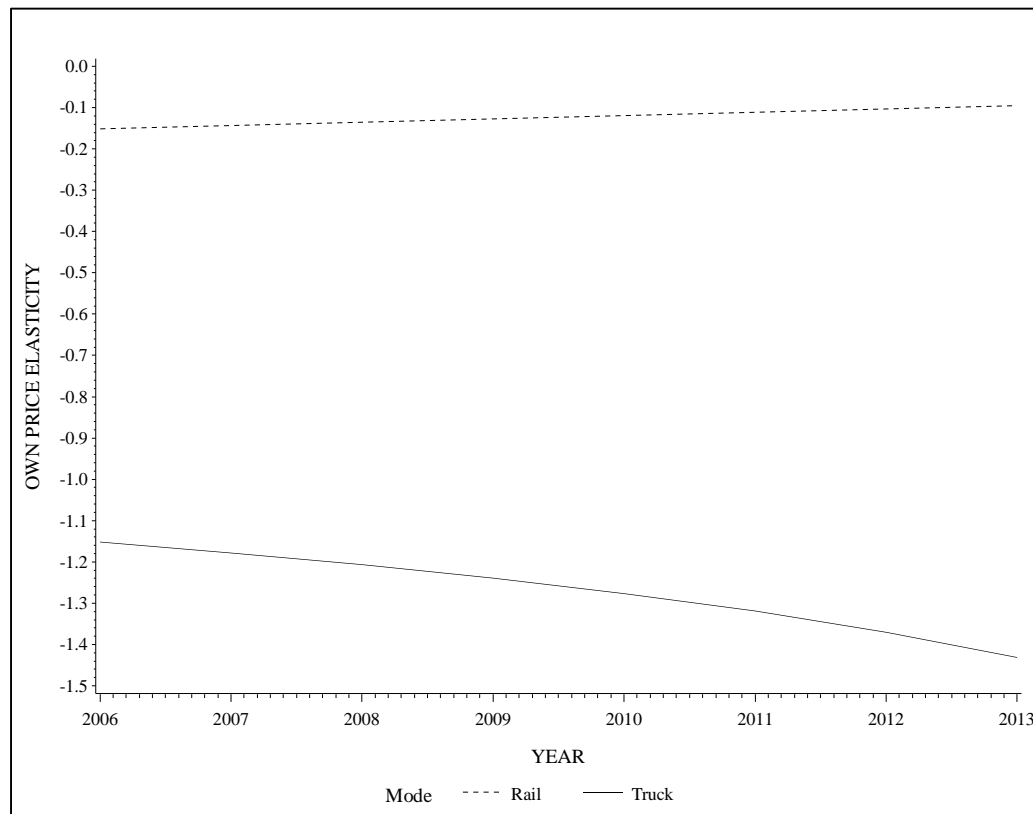


Figure 16: Corn Modal Elasticities over Time

The rail and truck own-price elasticities for durum and soybeans are not presented over time due to a large rail rate time interaction term in both models, rail and truck quickly revert to unreasonable levels. Truck share becomes negative in both models. Consequently, examining

elasticities over time for either commodity would be very misleading. The trend in elasticity for hard red spring wheat is presented in Table 16 and Figure 17.

Table 16: Hard Red Spring Wheat Modal Elasticities by Year

Year	Rail $ \epsilon_{11} $	Truck $ \epsilon_{22} $
2006	0.175	0.974
2007	0.168	0.987
2008	0.161	1.000
2009	0.154	1.014
2010	0.147	1.028
2011	0.140	1.044
2012	0.133	1.061
2013	0.126	1.079

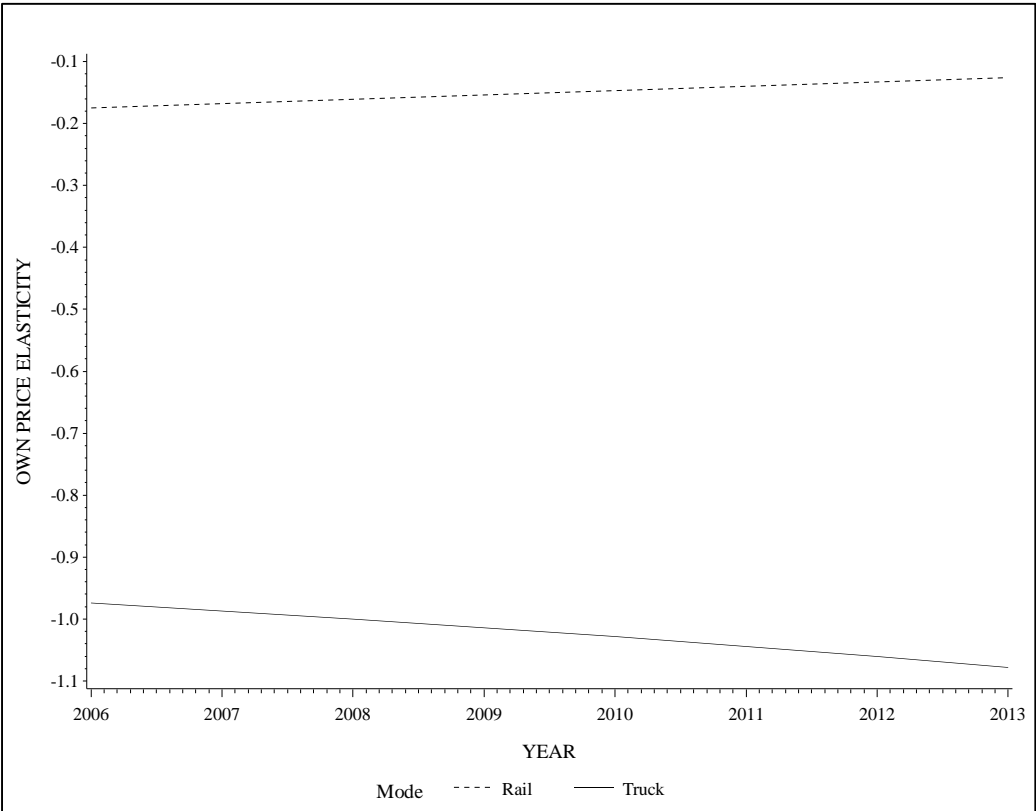


Figure 17: Hard Red Spring Wheat Modal Elasticities over Time

Results for modal elasticities over time for hard red spring wheat indicate that the demand for rail is becoming more inelastic as reflected by the reduction in the own-price elasticity for rail $|\epsilon_{11}|$ in absolute value (see Table 16 and Figure 18). Truck own-price elasticity

(absolute value) on the other hand ε_{22} is shown to be increasing over time (becoming unit elastic in 2010 then fairly elastic after that period). The pattern exhibited by hard red spring wheat is closely related to that for corn, the other commodity that uses and has potentially been affected by shuttle grain elevators. This raises an interesting question about the likely differences between shuttle and non-shuttle elevators. Likely differences will be analyzed in the next section. Results presented so far have not explicitly evaluated the impact of shuttle grain elevators which have likely played a role in corn and hard red spring wheat transportation. Our next interest is to assess the role and likely differences between shuttle and non-shuttle grain elevators.

5.7. Modal Elasticities Shuttle Elevators

The model in equation (13) estimated with shuttle elevator dummies (those capable of shipping 100 railcars and above) and their interactions was used for hard red spring wheat and corn to assess whether the nature of rail-truck competition is different for shuttle elevators than for non-shuttle elevators. Specifically, this provides insight into the potential impact of shuttle services in the North Dakota grain supply chain. As alluded to previously, both corn and hard red spring wheat are two the commodities affected by shuttle elevators, based on data from the North Dakota Grain Movement database. Parameter estimates in Table 4 (corn) and Table 6 (hard red spring wheat) are used to calculate modal price elasticities for shuttle elevators and compared with the non-shuttle estimates obtained previously for both corn and hard red spring wheat. Results are shown in Table 17 below.

Table 17: Shuttle and Non-Shuttle Corn and Hard Red Spring Wheat Modal Elasticities

	Hard Red Spring Wheat		Corn	
	Shuttle	Other	Shuttle	Other
Rail Factor share (S_{1l})	0.98	0.85	0.90	0.88
Truck Factor Share (S_{2l})	0.02	0.15	0.10	0.12
Elasticity of Substitution σ_{12}	1.79	1.15	1.33	1.30
Rail price elasticity $\varepsilon_{11} = -\varepsilon_{12}$	-0.04	-0.17	-0.13	-0.16
Truck price elasticity $\varepsilon_{22} = -\varepsilon_{21}$	-1.75	-0.98	-1.19	-1.14

The calculated rail and truck shares for shuttle elevators are used to estimate modal price elasticities. Both rail and truck share for shuttles are obtained by summing the estimated modal rate parameter and that for the interaction between modal rate and the shuttle dummy variable. That for rail is given as: $\alpha_1 + \hat{X}_{14} * (shut)$ while that for truck is given as: $\alpha_2 + \hat{X}_{24} * (shut)$. Shuttle rail share for hard red spring wheat, $S_{1l} = 0.8479 + 0.1275$ while the corresponding truck share is given as: $S_{2l} = 0.1521 - 0.1275$. Similarly, calculated modal shares for rail and truck are: $S_{1l} = 0.8842 + 0.0119$ and $S_{2l} = 0.1158 - 0.0119$ respectively for corn.

A general observation is that the rail factor share for shuttle elevators gets bigger (truck share gets smaller) compared to non-shuttle (previous estimate) for both commodities. This increase in rail share is more noticeable for hard red spring wheat, which increases by close to 15% from 0.85 for non-shuttle to 0.98 for shuttle elevators. This increase in rail share represents a 14 percentage point increase for hard red spring wheat. Corn rail share on the other hand only increases by approximately 2 percentage points from 0.88 for other elevators to 0.90 for shuttle elevators. These share differences suggest that shuttle elevators are more rail intensive than non-shuttle elevators. This points to likely differences between shuttle and non-shuttle elevators. Estimates for non-shuttle elevators for hard red spring wheat and corn obtained previously are compared to those for shuttle elevators in this section to evaluate these potential differences.

The cross price elasticity of demand for truck with respect to rail rates ε_{21} indicates that reductions in rail rates for shuttle elevators are likely to have an even bigger impact in reducing truck traffic compared to non-shuttle elevators for both hard red spring wheat and corn. A one percent decrease in rail rates for shuttle elevators will decrease truck traffic more for hard red spring wheat (1.75 %) than for corn (1.19%). The relatively high ε_{21} for shuttle elevators means that truck corn and hard red spring wheat shippers consider rail as an even better substitute for truck for shuttle compared to non-shuttle elevators. This view (or rail dominance) is strikingly bigger for hard red spring wheat compared to corn.

On the other hand, the relatively low cross price elasticity of rail with respect to truck rate ε_{12} for shuttle elevators is an indication that reduction in truck rate will have an even smaller effect on rail traffic for shuttle elevators compared to that for non-shuttle elevators. This effect is even more so smaller for hard red spring wheat compared to corn. A one percent decrease in truck rate only decreases hard red spring wheat rail traffic for shuttle elevators by 0.04 percent. Related decreases for corn shuttle elevator rail traffic (0.13) is three times higher than that for hard red spring wheat. The relatively lower ε_{12} for shuttle elevators compared to non-shuttle elevators for corn and hard red spring wheat traffic means that shippers who ship by rail from shuttle elevators view truck as an even lesser substitute for rail. This assessment of truck is even lower for hard red spring wheat shuttle shippers. Overall based on ε_{12} and ε_{21} rail is dominant for shuttle elevators, particularly for hard red spring wheat. We next undertake an in-depth comparison between shuttle and non-shuttle elevators beginning with hard red spring wheat.

5.8. Modal Elasticities Shuttle and Non-Shuttle Elevators

Shuttle elevators have made significant investments in their facilities in order to take advantage of lower shuttle rail rates. While shuttle rail service provides lower rail rates for

shuttle elevators, it also has been shown to offer other advantages; for example better service quality (e.g. shorter delays in delivery). Consequently, it is likely that the nature of competition between rail and truck is different for shuttle and non-shuttle elevators. Shuttle and other elevator rail price elasticities, and the trend by selected link distance for hard red spring wheat are shown in Table 18 and Figure 18 respectively. These results show that rail for shuttle elevators is more inelastic than that for non-shuttle elevators.

Table 18: Shuttle and Non-Shuttle Rail Elasticities Hard Red Spring Wheat

Link Distance	Shuttle Elevator Rail $ \epsilon_{11-shut} $	Non-Shuttle Elevator Rail $ \epsilon_{11-non_shut} $
250	0.073	0.204
500	0.061	0.192
1000	0.049	0.179
2000	0.036	0.167

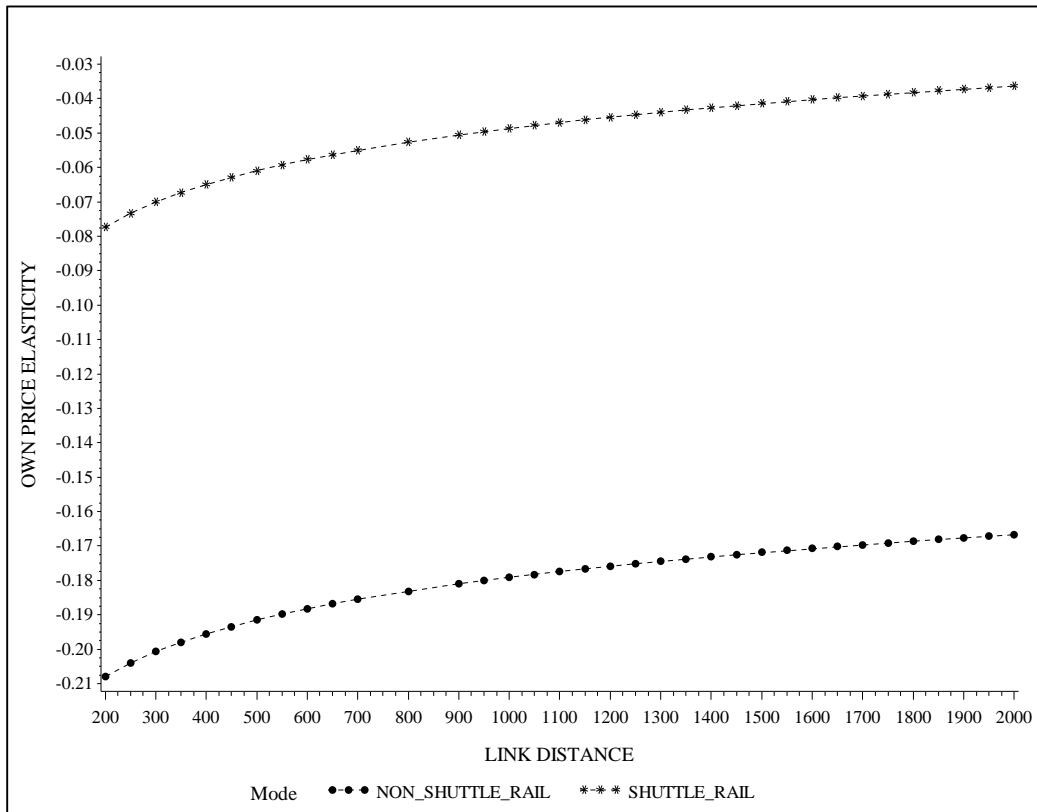


Figure 18: Shuttle and Non-Shuttle Hard Red Spring Wheat Rail Elasticities

This means increases in rail rates will lead to lower traffic loss for shuttle elevators compared to non-shuttles. The advantage of shuttle and significant investment in shuttle facilities lead to more rail dominance for shuttle in comparison to non-shuttle elevators. This rail dominance for shuttle elevators is also shown with truck elasticities (Table 19 and Figure 19). These truck own-price elasticities for shuttle and non-shuttle elevators for selected link distances indicate that the demand for truck is fairly elastic for shuttle elevators and inelastic for other elevators.

Table 19: Shuttle and Non-Shuttle Truck Elasticities Hard Red Spring Wheat

Link Distance	Shuttle Elevator Truck $ \epsilon_{22-shut} $	Non-Shuttle Elevator Truck $ \epsilon_{22-non_shut} $
192	1.27	0.92
200	1.28	0.92
400	1.38	0.94
1300	1.76	0.97
2087	2.17	0.99

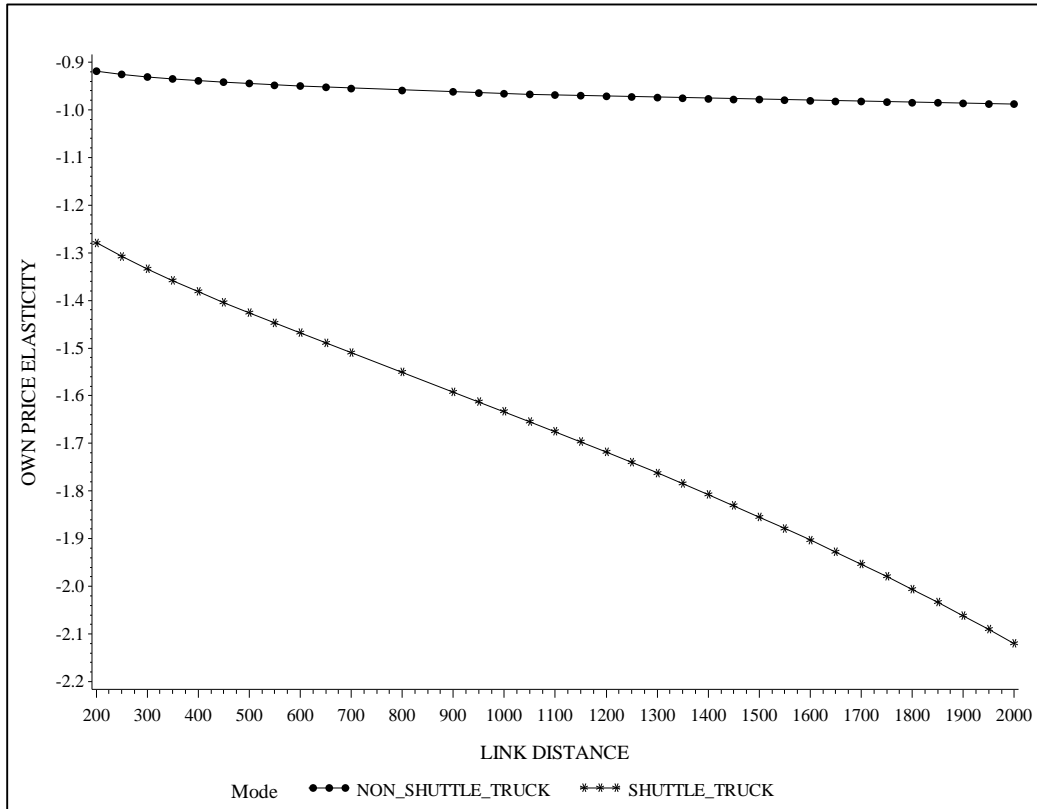


Figure 19: Shuttle and Non-Shuttle Hard Red Spring Wheat Truck Elasticities

These results are plausible. If investment in shuttle facilities lead to more rail dominance for shuttle elevators, then we would expect truck own-price elasticity for shuttle to be more elastic than for non-shuttle elevators (shuttle elevators use relatively more rail than truck compared to non-shuttle elevators). Results presented above highlight the distinguishing characteristics of shuttle grain elevators. It is necessary to assess rail-truck competition for shuttle elevators as well. These are illustrated in Table 20 and Figure 20.

Table 20: Shuttle Modal Elasticities Hard Red Spring Wheat

Link Distance	Shuttle Elevator Rail $ \varepsilon_{11-shut} $	Shuttle Elevator Truck $ \varepsilon_{22-shut_truck} $
192	0.078	1.274
200	0.077	1.279
250	0.073	1.308
300	0.070	1.334
2000	0.036	2.120

Shuttle elevator absolute own-price elasticity for rail $|\varepsilon_{11-shut}|$ becomes smaller (more inelastic) as distance increases whereas that for truck $|\varepsilon_{22-shut_truck}|$ increasingly becomes bigger with increasing distance (see Table 20 and Figure 20). The fairly elastic truck own-price elasticity and fairly inelastic own-price elasticity for rail for shuttle elevators supports earlier findings that shuttle elevators are more rail intensive.

A similar assessment done for corn to make comparisons between shuttle and non-shuttle elevators provided unexpected results. A large positive interaction term between distance and truck rates resulted in unrealistic rail and truck shares. Results to compare shuttle and non-shuttle elevators for corn were consequently not presented. However, overall results for hard red spring wheat from the previous section tend to suggest that rail dominates for longer distances and its use has been increasing over time for most of the five commodities under evaluation in this study. Specifically, there is an increasing commitment to rail for shuttle elevators, which

distinguishes them from other elevators. These factors together provide impetus to assess North Dakota shippers' mode choice decisions in more detail. That will answer the question whether increase use of rail reflect potentially improved quality of service from shuttle elevators.

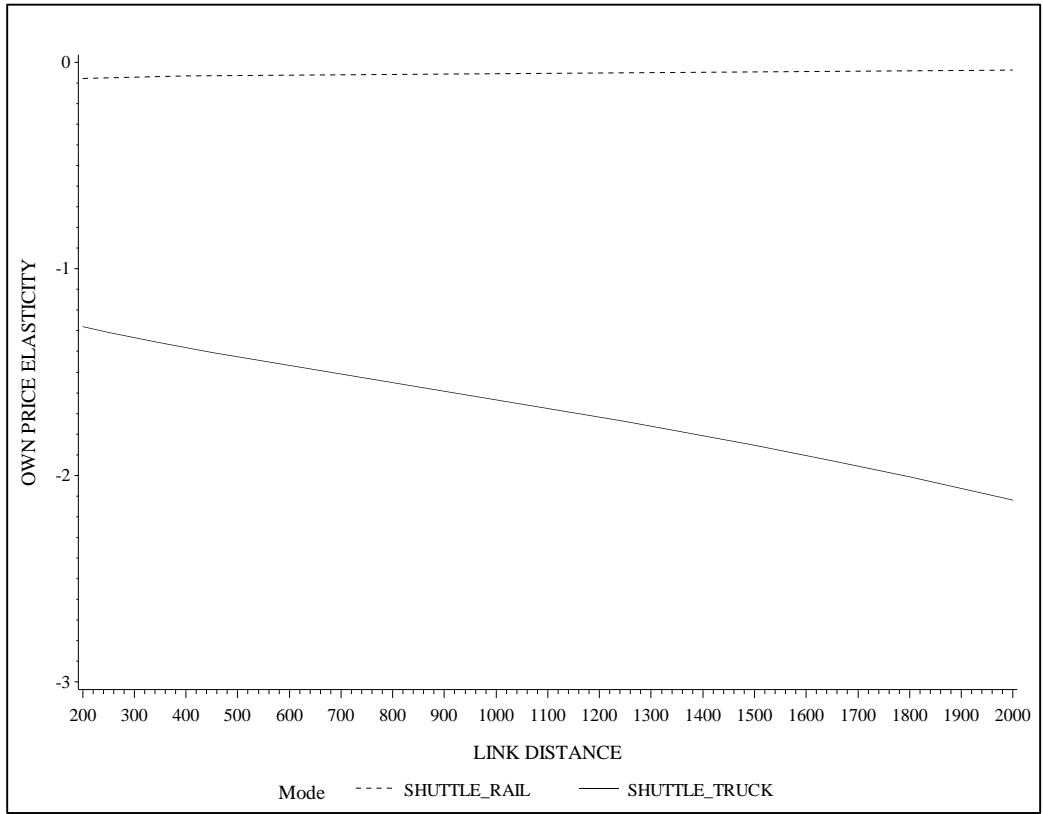


Figure 20 Shuttle Modal Elasticities Hard Red Spring Wheat

5.9. Mode Choice and Allocative Efficiency

The likely increasing use of rail over time identified in section (5.3.1) and distinguishing characteristics of shuttles for hard red spring wheat in section (5.4 and 5.4.1) raises an interesting question about North Dakota hard red spring and other grain shippers' mode choice decisions. Our analyses, so far, has assumed that shippers minimize the cost of transportation based on market rates. However, if there are capacity limitations, service problems, or other differences in service quality, it is likely that shippers' might deviate from transportation cost minimization. An

important way to check for this deviation is to evaluate whether shippers' mode choice decisions reflect cost minimization based on transportation rates. This will shed light on the relative usage of rail and truck. By examining shipper mode choices in this way, this study allows an assessment of service quality that does not rely on shipper survey that may or may not provide accurate assessment of service quality.

Non-linear Seemingly Unrelated Regression results to test for cost minimization by commodity are shown in Tables 21 to Table 25. Similar to the previous estimation, all continuous explanatory variables are divided by their means and are in natural logarithms. Thus, estimated parameters for first order terms represent cost elasticity for the particular variable when all variables except time are at their means. Additionally, estimated parameters for input prices (shipping rates) represent each mode's shadow share of total transportation cost. Most parameters have their expected signs and are significant at conventional levels. As expected, increases in both modal input prices and ton-miles (output) lead to increase in total transportation cost for all commodities.

Truck rate is not statistically significant for durum and soybeans, while rail rate is significant for all commodities. Ton-miles are slightly greater than one or approximately equal to one and statistically significant at the 1% level of significance for all commodities. Again this indicates that a one percent increase in output leads to a one percent increase in real total transportation cost for all commodities. Link distance only has the expected negative sign for hard red spring wheat and soybeans. The sign for hard red spring wheat is statistically insignificant. The positive sign for link distance for barley and durum are statistically insignificant, whereas that for corn is significant. The time trend parameter for all other commodities except barley seem to suggest that transportation cost in real terms is decreasing

over time. This likely decrease is not significant for each of four commodities; however, the positive sign for barley is statistically significant at the 5% level. Overall results for all five commodities show that included variables explain most of the variation in total transportation cost across commodities as shown by high adjusted R-square for the cost functions. Adjusted R-square ranges from 0.9730 for barley to 0.9926 for soybeans.

Table 21: Barley Nonlinear SUR Parameter Estimates

Parameter	Name	Parameter Estimate	P-Value
α_0	Intercept	11.8656*	0.0001
α_1	In (k_1 Rail Rate)	0.8783*	0.0001
α_2	In (k_2 Truck Rate)	0.1218*	0.0314
ρ_1	In (Ton-Miles)	1.0302*	0.0001
ρ_2	In (Link Distance)	0.0390	0.4519
ρ_3	Time	0.0207**	0.0482
τ_{11}	$\frac{1}{2}$ (In k_1 Rail Rate) ²	0.1342*	0.0001
τ_{22}	$\frac{1}{2}$ (In k_2 Truck Rate) ²	0.1342*	0.0001
β_{11}	$\frac{1}{2}$ (In Ton-Miles) ²	0.0180*	0.4397
β_{22}	$\frac{1}{2}$ (In Link Distance) ²	0.0435	0.3101
β_{33}	$\frac{1}{2}$ (Time) ²	-0.0029	0.0001
τ_{12}	In (k_1 Rail Rate)*In (k_2 Truck Rate)	-0.1342*	0.0001
χ_{11}	In (k_1 Rail Rate)* In (Ton-Miles)	0.0606*	0.4927
χ_{12}	In (k_1 Rail Rate)*In (Link Distance)	0.1586*	0.0001
χ_{13}	In (k_1 Rail Rate)*Time	0.0047	0.4927
χ_{21}	In (k_2 Truck Rate)*In (Ton-Miles)	-0.0606*	0.0001
χ_{22}	In (k_2 Truck Rate)*In (Link Distance)	-0.1586*	0.0001
χ_{23}	In (k_2 Truck Rate)*Time	-0.0047	0.4927
β_{12}	In (Ton-Miles)*In (Link Distance)	0.0358*	0.0001
β_{13}	In (Ton-Miles)*Time	0.0014	0.5613
β_{23}	In (Link Distance)*Time	0.0060	0.4214
k_2	Truck Factor of Proportionality	1	Normalized
k_1	Rail Factor of Proportionality	0.1227*	0.0001

*, **, *** Significance at the 1%, 5% and 10% respectively

Observation = 952

Adjusted R²: Cost = 0.9730

Table 22: Corn Nonlinear SUR Parameter Estimates

Parameter	Name	Parameter Estimate	P-Value
α_0	Intercept	14.2166*	0.0001
α_1	In (k_1 Rail Rate)	0.8889*	0.0001
α_2	In (k_2 Truck Rate)	0.1114*	0.0001
ρ_1	In (Ton-Miles)	0.9239*	0.0001
ρ_2	In (Link Distance)	0.1766*	0.0006
ρ_3	Time	-0.0114	0.2579
τ_{11}	$\frac{1}{2}$ (In k_1 Rail Rate) ²	0.0183	0.5018
τ_{22}	$\frac{1}{2}$ (In k_2 Truck Rate) ²	0.0183	0.5018
β_{11}	$\frac{1}{2}$ (In Ton-Miles) ²	0.0109*	0.0086
β_{22}	$\frac{1}{2}$ (In Link Distance) ²	-0.0421	0.5342
β_{33}	$\frac{1}{2}$ (Time) ²	0.0025	0.3303
τ_{12}	In (k_1 Rail Rate)*In (k_2 Truck Rate)	-0.0183	0.5018
χ_{11}	In (k_1 Rail Rate)* In (Ton-Miles)	0.1261	0.0001
χ_{12}	In (k_1 Rail Rate)*In (Link Distance)	-0.2709	0.0001
χ_{13}	In (k_1 Rail Rate)*Time	0.0071	0.1590
χ_{21}	In (k_2 Truck Rate)*In (Ton-Miles)	-0.1261*	0.0001
χ_{22}	In (k_2 Truck Rate)*In (Link Distance)	0.2709*	0.0001
χ_{23}	In (k_2 Truck Rate)*Time	-0.0071	0.1590
β_{12}	In (Ton-Miles)*In (Link Distance)	-0.0067	0.4585
β_{13}	In (Ton-Miles)*Time	0.0011	0.3261
β_{23}	In (Link Distance)*Time	-0.0044	0.3640
k_2	Truck Factor of Proportionality	1	Normalized
k_1	Rail Factor of Proportionality	0.7351*	0.0001

*, **, *** Significance at the 1%, 5% and 10% respectively

Observation =739

Adjusted R²: Cost = 0.9780

Table 23: Durum Nonlinear SUR Parameter Estimates

Parameter	Name	Parameter Estimate	P-Value
α_0	Intercept	13.0874*	0.0001
α_1	In (k_1 Rail Rate)	0.9403*	0.0001
α_2	In (k_2 Truck Rate)	0.0599	0.1761
ρ_1	In (Ton-Miles)	1.0200*	0.0001
ρ_2	In (Link Distance)	0.0280	0.3367
ρ_3	Time	-0.0054	0.4499
τ_{11}	$\frac{1}{2}$ (In k_1 Rail Rate) ²	0.1429*	0.0001
τ_{22}	$\frac{1}{2}$ (In k_2 Truck Rate) ²	0.1429*	0.0001
β_{11}	$\frac{1}{2}$ (In Ton-Miles) ²	0.0292*	0.0001
β_{22}	$\frac{1}{2}$ (In Link Distance) ²	0.0962***	0.0695
β_{33}	$\frac{1}{2}$ (Time) ²	0.0020	0.2867
τ_{12}	In (k_1 Rail Rate)*In (k_2 Truck Rate)	-0.1429*	0.0001
χ_{11}	In (k_1 Rail Rate)* In (Ton-Miles)	0.1029	0.0001
χ_{12}	In (k_1 Rail Rate)*In (Link Distance)	0.0699**	0.0295
χ_{13}	In (k_1 Rail Rate)*Time	0.0197*	0.0106
χ_{21}	In (k_2 Truck Rate)*In (Ton-Miles)	-0.1029*	0.0001
χ_{22}	In (k_2 Truck Rate)*In (Link Distance)	-0.0699**	0.0295
χ_{23}	In (k_2 Truck Rate)*Time	-0.0197*	0.0106
β_{12}	In (Ton-Miles)*In (Link Distance)	-0.0023	0.7346
β_{13}	In (Ton-Miles)*Time	0.0036**	0.0292
β_{23}	In (Link Distance)*Time	-0.007	0.8915
k_2	Truck Factor of Proportionality	1	Normalized
k_1	Rail Factor of Proportionality	0.3321*	0.0001

*, **, *** Significance at the 1%, 5% and 10% respectively

Observation =637

Adjusted R²: Cost = 0.9891

Table 24: Hard Red Spring Wheat Nonlinear SUR Parameter Estimates

Parameter	Name	Parameter Estimate	P-Value
α_0	Intercept	13.7342*	0.0001
α_1	In (k_1 Rail Rate)	0.9188*	0.0001
α_2	In (k_2 Truck Rate)	0.0812*	0.0008
ρ_1	In (Ton-Miles)	0.9805*	0.0001
ρ_2	In (Link Distance)	-0.0077	0.6074
ρ_3	Time	-0.0004	0.9422
τ_{11}	$\frac{1}{2}$ (In k_1 Rail Rate) ²	0.0211	0.4623
τ_{22}	$\frac{1}{2}$ (In k_2 Truck Rate) ²	0.0211	0.4623
β_{11}	$\frac{1}{2}$ (In Ton-Miles) ²	0.0089*	0.0002
β_{22}	$\frac{1}{2}$ (In Link Distance) ²	-0.0407	0.1107
β_{33}	$\frac{1}{2}$ (Time) ²	-0.0006	0.6543
τ_{12}	In (k_1 Rail Rate)*In (k_2 Truck Rate)	-0.0211	0.4623
χ_{11}	In (k_1 Rail Rate)* In (Ton-Miles)	0.0979*	0.0001
χ_{12}	In (k_1 Rail Rate)*In (Link Distance)	-0.0285	0.1325
χ_{13}	In (k_1 Rail Rate)*Time	0.0118*	0.0037
χ_{21}	In (k_2 Truck Rate)*In (Ton-Miles)	-0.0979*	0.0001
χ_{22}	In (k_2 Truck Rate)*In (Link Distance)	0.0285	0.1325
χ_{23}	In (k_2 Truck Rate)*Time	-0.0118*	0.0037
β_{12}	In (Ton-Miles)*In (Link Distance)	0.0042	0.2002
β_{13}	In (Ton-Miles)*Time	0.0011	0.1755
β_{23}	In (Link Distance)*Time	0.0014	0.6234
k_2	Truck Factor of Proportionality	1	Normalized
k_1	Rail Factor of Proportionality	0.6103*	0.0001

*, **, *** Significance at the 1%, 5% and 10% respectively

Observation = 2002

Adjusted R²: Cost = 0.9852

Table 25: Soybeans Nonlinear SUR Parameter Estimates

Parameter	Name	Parameter Estimate	P-Value
α_0	Intercept	146939*	0.0001
α_1	In (k_1 Rail Rate)	0.9928*	0.0001
α_2	In (k_2 Truck Rate)	0.0072	0.8335
ρ_1	In (Ton-Miles)	1.0036*	0.0001
ρ_2	In (Link Distance)	-0.0728**	0.0316
ρ_3	Time	-0.0024	0.7549
τ_{11}	$\frac{1}{2}$ (In k_1 Rail Rate) ²	0.0322	0.2374
τ_{22}	$\frac{1}{2}$ (In k_2 Truck Rate) ²	0.0322	0.2374
β_{11}	$\frac{1}{2}$ (In Ton-Miles) ²	0.0206	0.0001
β_{22}	$\frac{1}{2}$ (In Link Distance) ²	-0.0271	0.5775
β_{33}	$\frac{1}{2}$ (Time) ²	0.0008	0.6741
τ_{12}	In (k_1 Rail Rate)*In (k_2 Truck Rate)	-0.0322	0.2374
χ_{11}	In (k_1 Rail Rate)* In (Ton-Miles)	0.1123	0.0001
χ_{12}	In (k_1 Rail Rate)*In (Link Distance)	0.0016	0.9495
χ_{13}	In (k_1 Rail Rate)*Time	0.0069	0.2601
χ_{21}	In (k_2 Truck Rate)*In (Ton-Miles)	-0.1123	0.0001
χ_{22}	In (k_2 Truck Rate)*In (Link Distance)	-0.0016	0.9495
χ_{23}	In (k_2 Truck Rate)*Time	-0.0069	0.2601
β_{12}	In (Ton-Miles)*In (Link Distance)	-0.0055	0.2928
β_{13}	In (Ton-Miles)*Time	0.0030**	0.0142
β_{23}	In (Link Distance)*Time	-0.0015	0.7237
k_2	Truck Factor of Proportionality	1	Normalized
k_1	Rail Factor of Proportionality	0.4444	0.0001

*, **, *** Significance at the 1%, 5% and 10% respectively

Observation = 618

Adjusted R²: Cost = 0.9926

As expected, increases in both truck and rail rates have positive effects on total transportation cost for all commodities. These are statistically significant at conventional levels except truck rates for durum and soybeans that are not significant. These modal shares as well as factors of proportionality by commodity are the main parameters of interest in this section. They will enable assessment of cost minimization and grain shippers' relative utilization of different modes. Summary results showing factor of proportionality, shadow share as well as actual share for all five commodities are shown in Table 26. Calculated actual cost shares are shown for

comparison. Shadow cost share range from 0.99 for soybeans to 0.88 for barley. All factors of proportionality are significant at the 1% level of significance.

Table 26: Cost Shares and Factors of Proportionality by Commodity

Commodity	Input	Shadow Share	Actual Share [#]	Factor of Proportionality	T-Test $H_0: k_1 = 1$
Barley	Rail	0.88	0.98	0.1227	-40.1*
	Truck	0.12	0.02	1	
Corn	Rail	0.89	0.92	0.7351	-3.6*
	Truck	0.11	0.08	1	
Durum	Rail	0.94	0.98	0.3321	-27.1*
	Truck	0.06	0.02	1	
Hard Red Spring Wheat	Rail	0.92	0.95	0.6103	-5.9*
	Truck	0.08	0.05	1	
Soybean	Rail	0.99	0.997	0.4444	-13.10*
	Truck	0.01	0.003	1	

*significantly different from 1,

[#]Actual share $S_i^A = \frac{s_i^s}{k_i} / \sum_i \left(\frac{s_i^s}{k_i} \right)$

As pointed to earlier, actual cost are homogeneous of degree zero in (k_{i_s}) . Hence, the absolute value of all k_{i_s} cannot be estimated. Consequently, that for truck (k_2) is normalized to one and that for rail (k_1) measured relative to the factor of proportionality for truck. Column five shows estimated factor of proportionality for rail and the normalized truck factor. As these results show, the factor of proportionality for rail is less than one for all commodities. Moreover, a t-test (column 6) shows that these factors of proportionality are statistically significantly different than one. This is an indication that North Dakota grain shippers do not employ an allocatively efficient mix of both rail and truck given market prices. The lower than 1 factor of proportionality for rail suggests that the shadow price of rail relative to its market price is low in comparison to truck. Hence there is an over utilization of rail compared to truck. This may reflect capacity limitations, poor service quality or unpredictable service quality for trucks. On the other hand, it could represent exemplary rail service. In any event, rail over utilization is a reflection of

the fact that there is a real or perceived advantage in using rail that is not reflected in market rates.

An interesting observation from the results in Table 26 is the relatively larger rail factor of proportionality for corn and hard red spring wheat (closer to one than other commodities). This suggests that there is less rail over utilization for both of these commodities in comparison to the other three. Additionally, both corn and hard red spring wheat are two of the commodities that use shuttle elevators extensively for grain transportation. This may suggest that the divergence of the shadow price from market price results from poor quality of truck service, rather than from exemplary quality of rail service. Shuttle elevators are likely to receive at least as high of a quality of rail service as non-shuttle elevators. The smaller divergence from allocative efficiency for these elevators may suggest that they also receive better truck service than non-shuttle elevators. In essence, truckers may feel more pressure to provide better service to shuttle elevators. The factor of proportionality closer to one for wheat and corn suggest the non-attainment of allocative efficiency observed for all groups of grain shippers will have a higher impact on transportation cost for barley, durum and soybean shippers compared to corn and hard red spring wheat shippers. Total transportation cost for the former three shippers will be comparatively higher compared to the latter two. Better quality of service provided to shuttle elevators by both modes in addition to relatively lower transportation cost may give corn and hard red spring wheat shippers a comparative advantage over barley, durum, and soybean shippers who lack access to shuttles.

Table 26 also shows variation between shadow and actual cost shares. In all cases, the higher shadow truck share than actual truck share reflects the higher shadow price paid for truck in comparison to its market price. For barley, there is a noticeable difference between shadow

and actual cost shares. Shadow share for truck soybeans is almost zero. Shadow and actual cost share for corn, durum and hard red spring wheat show moderate differences.

Allocative efficiency findings in this study are in contrast to those by Satar and Peoples (2010). They found that coal shippers with access to truck and rail use too much truck transportation in comparison to an allocatively efficient mix if mode choice is based on rates. They attributed observed price distortions to poor and unpredictable rail service, which cause an over use of truck. Grain shippers in North Dakota, on the other hand, use too much rail than an allocatively efficient mix. A potential reason for this observation is that rail provides a better quality of service compared to truck. Additionally, it could be that recent observations about congestion and dilapidating highway infrastructure has made shippers view trucking as a less viable alternative compared to rail. In fact, for reasons described previously, poor trucking service is the more likely reason. Another potential reason for increasing use of rail might be related to increased volume of production. Genetic engineering and improvements in science has given grain producers the ability to grow a variety of crops in large volumes for a very short period of time. To haul these commodities to market is easily done by rail without increasing crew size due to economies of size and shipping distance. Economies of size are difficult to attain with trucks due to the need to use a proportionate number of drivers and trucks for 80, 000 pounds (federal weight limit for trucks on highways) increments in volume of grain. This makes rail a more viable option as well.

CHAPTER 6. SUMMARY, CONCLUSIONS AND IMPLICATIONS

The demand for grain transportation is derived from the demand for grains and related activities. Agricultural transportation demand evaluations are necessary for transportation policy analysis and carriers' business operation decisions. Specifically, elasticities obtained from grain transportation demand studies can help regulators assess the nature of competition and help carriers in pricing decisions. The Class I railroad industry moved from a cost-based structure in the regulatory era to market-oriented differential pricing in the deregulatory environment, making intermodal competition (e.g. rail-truck) an important factor (Bitzan et al. 2003). Differential pricing is based on the idea that shippers with inelastic demand (lack of alternative) pay a higher rate for goods transportation. Grain shippers in North Dakota may lack an alternative competitive mode to rail, making knowledge about demand elasticities even more important. Carriers and shippers need to know the nature of transportation demand for their investment decisions. Carriers also use information on modal elasticities in pricing decisions.

Estimation of a link-specific cost function facilitated comparative analysis of calculated modal demand elasticities and testing the cost minimization hypothesis for shippers of five different commodities. Demand elasticities enable examination of rail-truck competition over distance, time, as well as by elevator type (shuttle and non-shuttle elevators). A cost minimization test assessed whether shippers' mode choice decisions were based on market rates ("allocatively efficient"). The links in the link-specific cost function involved individual grain elevator origins within the state and four principal destinations for North Dakota grains, including two Minnesota destinations (Minneapolis and Duluth), U.S Pacific North West, and Gulf. Two cities in the latter two regions were used as destinations (Portland, OR and New Orleans, LA respectively). Using specific elevators (disaggregate data) is a better reflection of

grain shippers' choices. The choice of mode is made at the elevator level rather than at the regional level as used in previous other related studies (aggregate data). Inclusion of all four destinations for North Dakota grains enhances the accuracy of calculated elasticities (previous related studies only include two at most).

A pricing model used to estimate elevator-destination specific rail rates indicated that included variables accounted for most of the variation in rail rates indicated by high R-squared values. These factors included distance, volume, shipment type (e.g. shuttle, unit, and multicar), year, and month of shipment. Truck rates were USDA Agricultural Marketing Services Grain Truck and Ocean Rate Advisory. As opposed to rail rates, the trucking industry is close to a perfectly competitive industry. As such, truck rates are viewed widely competitive (uniform). Both input price (rail and truck rates) were adjusted using the gross domestic price deflator. All other explanatory variables used in cost functions, including, link distance, output, elevator dummies, and time were generated from individual elevator shipment characteristics.

Econometric diagnostic testing was undertaken to validate econometric procedures and curvature of the total transportation cost function. Endogeneity test results from an omitted variable version of the Hausman test showed that SUR was the preferred procedure for barley, corn, and hard red spring wheat while 3SLS was used for durum and soybeans models. Concavity testing also revealed that all cost functions except that for durum (indefinite) are strictly concave in factor prices.

Estimation of cost models with either SUR or 3SLS indicated that variables included in equations explained much of the variability in grain shippers' total transportation costs for all commodities. Estimated own-price elasticities for non-shuttle elevators showed a high rail dependence across commodities. This dependence was highest for soybeans. Grain shippers for

all five commodities who shipped by rail did not view truck as a good substitute as reflected by the low cross-price elasticity of rail with respect to truck. On the other hand, shippers who shipped by truck except durum shippers viewed rail as a good substitute for truck shown by a high cross price elasticity of truck with respect to rail.

Calculated elasticities for shuttle elevators for hard red spring wheat and corn, two of the commodities affected by shuttle elevators, point to differences between shuttle and non-shuttle elevators. Dependence on rail increases with shuttle elevators for both commodities; even more so with hard red spring wheat. Shippers who ship by rail from shuttle elevators view truck as a lesser substitute compared to non-shuttle elevators. On the other hand, shippers who ship by truck see rail as an even better substitute. Shuttle elevators are more rail intensive than non-shuttle elevators. Additional investments were made to upgrade existing elevators to shuttle capacity or to construct new shuttle facilities to enable shippers to benefit from economies of shipping size (lower rates) associated with large rail shipments. So higher rail intensity for shuttle elevators is reasonable.

The Cost minimization test indicates that North Dakota grain shippers do not minimize total cost of transportation if their mode choice decisions are based on market rates. Something causes the shadow price of trucking to increase relative to that for rail (e.g. poor trucking service) or decreases the shadow price of rail (e.g. good rail service). In addition to providing better rail service, smaller divergence from allocative efficiency specifically observed with corn and hard red spring wheat (both commodities affected by shuttle elevators) point to better quality of trucking service compared to that offered to non-shuttle elevators. This is an important finding suggesting that investment in shuttle facilities may have benefits beyond those obtained from the ability to ship shuttle trains.

Results obtained herein have widespread implications. Structural changes observed in the U.S transportation industry and in the grain supply chain in production and handling have had some effects on the demand for grain transportation in North Dakota. One of the main rationales behind deregulation of the transportation industries was to increase operational efficiency. The environment provided by deregulation enabled the transportation industries to undertake cost reducing strategies and to innovate (Gallamore 1999). In rail grain transportation, for example, there has been increasing emphasis and use of shuttle trains. In the trucking domain, operational flexibility from elimination of route restrictions gave truck carriers the ability to reduce empty backhauls and reduce the cost of operation (Keeler, 1986). This likely increased the potential for trucks to compete with rail for longer distances, in addition to likely dominance of shorter distance hauls.

Results here indicate that rail dominates the traffic for grain shipments out of North Dakota to all four principal destinations for North Dakota grains. Shuttle elevators were also shown to have played a role in corn and hard red spring wheat transportation. Grain elevators with shuttle capacity were shown to be more rail intensive than non-shuttle elevators based on calculated elasticities. Shippers' view of truck as a lesser substitute for rail for shuttle elevators serves as likely incentive for carriers to expand track related investment to increase the use of shuttle elevators in grain. This study points to the fact that despite shippers in the state being highly dependent on rail for grain shipments, the impact of shuttle elevators needs to be considered when making assessments about possible linkages between dependency and captivity. Increasing use of shuttle elevators has led to less over utilization of rail based on market rates suggesting that shuttle elevators may receive better trucking service in addition to the obvious benefits of better rail service. Other research has noted the impact of shuttle elevators on local

road degradation and increasing repair costs. Whether the benefits to shippers for increasing use of shuttle elevators outweigh related impacts to local communities is a question for further analysis.

Results presented in this study are based on sound empirical and theoretical foundation. However, estimation procedures to calculate elasticities come with potential limitations. It is essential to discuss some of these limitations. First, analyses are based on estimated rather than actual rates. This has the implications that calculated elasticities may not be reflective of what shippers are facing. Also, using calculated rates to evaluate divergence between shadow and market rates (actual) paid by grain shippers involved in allocative efficiency assessment raises some concerns if observed rates or market rates are not reflective of what shippers pay.

A Second limitation is the use of compensated demand elasticities (Hicksian) and the partial equilibrium nature of analysis. Compensated demand elasticities do not consider the effects of price change on total output shipped (ton-miles). However, using compensated demand elasticities is the most practical option given that to estimate Marshallian (uncompensated) demand elasticities will require knowledge about the demand elasticity for transported commodity. To our knowledge, no recent commodity specific studies exist. Additionally, using a hypothetical number such as one as the own-price elasticity of consumer demand for the transported commodity is arbitrary and can be misleading.

The third limitation is the lack origin-destination data on local, relatively shorter distance movement of commodities. One of the principal objectives of this study was to identify the distance at which truck and rail compete. As illustrated previously, it is likely that trucks dominate shorter distance movements and rail relatively longer distances. Results here show that rail dominates most of the traffic possibly stemming from the fact that grain movements used in

this study are for out of state grain haulage representing relatively longer distance movements. Hence the cutoff point where each mode dominates is not observed in analysis. This presents an opportunity an opportunity for future research. This will entail assigning local elevator originating grain movements to local processing facilities. In the case of corn and hard red spring wheat for example, it could be assigning these movements to local ethanol plants and wheat mills. That way, the data could be representative of both local (relatively shorter distances) and out of state (relatively longer distance) grain haulage. This will improve the potential of observing cutoff dominance distances.

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APPENDIX

Table A1: Hard Red Spring Wheat SUR Parameter Estimates with Fixed Effects¹

Parameter	Name	Parameter Estimate	P-Value
α_0	Intercept	13.8875*	0.0001
α_1	In (Rail Rate)	0.9022*	0.0001
α_2	In (Truck Rate)	0.0978*	0.0001
ρ_1	In (Ton-Miles)	0.9839*	0.0001
ρ_2	In (Link Distance)	0.5320*	0.0001
ρ_3	Time	-0.0085***	0.0585
τ_{11}	$\frac{1}{2}$ (In Rail Rate) ²	-0.0898**	0.0648
τ_{22}	$\frac{1}{2}$ (In Truck Rate) ²	-0.0898**	0.0648
β_{11}	$\frac{1}{2}$ (In Ton-Miles) ²	0.0077*	0.0001
β_{22}	$\frac{1}{2}$ (In Link Distance) ²	0.3765**	0.0601
β_{33}	$\frac{1}{2}$ (Time) ²	0.0025**	0.0433
τ_{12}	In (Rail Rate)*In (Truck Rate)	0.0898***	0.0648
χ_{11}	In (Rail Rate)* In (Ton-Miles)	0.0728*	0.0001
χ_{12}	In (Rail Rate)*In (Link Distance)	-0.0817*	0.0012
χ_{13}	In (Rail Rate)*Time	0.0125*	0.0012
χ_{21}	In (Truck Rate)*In (Ton-Miles)	-0.0728*	0.0001
χ_{22}	In (Truck Rate)*In (Link Distance)	0.0817*	0.0012
χ_{23}	In (Truck Rate)*Time	-0.0125*	0.012
β_{12}	In (Ton-Miles)*In (Link Distance)	0.0049	0.2956
β_{13}	In (Ton-Miles)*Time	0.0020*	0.0098
β_{23}	In (Link Distance)*Time	0.9834*	0.0001

*, **, *** Significance at the 1%, 5% and 10% respectively

Observation = 2002

System Weighted R² = 0.9947

System Weighted MSE = 0.94.76

¹ elevator-destination Fixed Effects not shown

Table A2: Hard Red Spring Wheat SUR Parameter Estimates with No-Fixed Effects²

Parameter	Name	Parameter Estimate	P-Value
α_0	Intercept	13.7449*	0.0001
α_1	ln (Rail Rate)	0.9193*	0.0001
α_2	ln (Truck Rate)	0.0807	0.0001
ρ_1	ln (Ton-Miles)	0.9561	0.0001
ρ_2	ln (Link Distance)	0.0046	0.7175
ρ_3	Time	-0.0021	0.6715
τ_{11}	1/2 (ln Rail Rate) ²	-0.0563***	0.0778
τ_{22}	1/2(ln Truck Rate) ²	-0.0563***	0.0778
β_{11}	1/2 ln (Ton-Miles) ²	0.0025**	0.0411
β_{22}	1/2(ln Link Distance) ²	-0.0578**	0.0222
β_{33}	1/2(Time) ²	-0.0005	0.7062
τ_{12}	ln (Rail Rate)*ln (Truck Rate)	0.0563***	0.0778
χ_{11}	ln (Rail Rate)*ln (Ton-Miles)	-0.0759	0.0001
χ_{12}	ln (Rail Rate)*ln (Link Distance)	-0.0652*	0.0004
χ_{13}	ln (Rail Rate)*Time	0.0100**	0.0032
χ_{21}	ln (Truck Rate)*ln (Ton-Miles)	-0.07586*	0.0001
χ_{22}	ln (Truck Rate)* ln (Link Distance)	0.0652*	0.0004
χ_{23}	ln (Truck Rate)*Time	-0.0100*	0.0032
β_{12}	ln (Ton-Miles)*ln (Link Distance)	-0.0039	0.2300
β_{13}	ln (Ton-Miles)*Time	0.0014**	0.0502
β_{23}	ln (Link Distance)*Time	0.0007	0.8041

*, **, *** Significance at the 1%, 5% and 10% respectively

Observation = 2002

System Weighted R² = 0.9913

System Weighted MSE = 0.9515

² elevator-destination fixed effects not used