September 2019

Measuring rail market power in wheat transportation

An econometric market level analysis

Chi Su and James Nolan
UNIVERSITY OF SASKATCHEWAN, DEPT OF AGRICULTURAL AND RESOURCE ECONOMICS

USDA Supporting Contacts:

Jesse Gastelle, Jesse.Gastelle@usda.gov, ph. 202-690-1144

Peter Caffarelli, PeterA.Caffarelli@usda.gov, ph. 202-690-3244

Adam Sparger, Adam.Sparger@usda.gov, ph. 202-205-8701

Recommended Citation: Su, Chi and James Nolan. Measuring Rail Market Power in Wheat Transportation, September 2019. University of Saskatchewan Dept. of Agricultural and Resource Economics.

Acknowledgements: This research was supported by Cooperative Agreement Number 17-TMTSD-SK-0008, with the Agricultural Marketing Service (AMS) of the U.S. Department of Agriculture (USDA).

Executive Summary

What is the issue?

Railroads are a critical transportation mode for the movement of U.S. agricultural commodities. For wheat, rail is often the only viable mode within the agriculturally productive but landlocked Plains region in the United States. Intermodal transportation competition in moving wheat can be limited because many key production regions are located too far away from an alternative freight transportation mode (e.g. barge transportation). In addition, the distances to end markets combined with large shipment volumes often render truck transportation too costly for wheat shippers to reach these destinations. Thus, many wheat shippers still rely heavily on rail transportation to deliver their product to market. But, while some wheat shippers have access to more than one railway, others remain captive to a single rail carrier.

On the one hand, economic theory offers straightforward predictions of what happens when there are many railroads servicing a given location, as well as what happens when there is only a single railroad. For instance, the consequences for shippers of being served by a monopoly railway is well understood and documented. When exerting monopoly (market) power, railways will typically increase rates and restrict output as compared to a similar but competitive market situation. At the other end of the spectrum, theory also tells us that if multiple railways serve a transportation market, they will compete with each other by increasing output and reducing rates, relative to a monopoly market.

On the other hand, economic theory is not as definitive about the range of in-between cases on the competition spectrum. As an example, where shippers have proximate access to just two major railroads (i.e. a rail duopoly), there is considerable ambiguity about the level of realized competition. If a rail market operates as a duopoly, it is not entirely clear whether railways will compete to the benefit of their shippers or instead collude to their own mutual benefit. When only a few firms serve a market, careful data analysis is crucial to help illuminate the nature and scope of market power.

Many previous studies of rail market power in bulk transportation either focus the analysis at a national level or apply methods to analyze railway market behavior that are not always reliable. While railroads often appear competitive over bulk movements when evaluated on a national level, we offer that any exertion of market or duopoly power by a railway—if present—would be most likely to occur in local or regional markets where there is limited to no intramodal or intermodal competition. In addition, much of the prior research on rail market behavior relies on estimated railroad (marginal) costs, which are themselves unreliable and in turn generate questionable assessments of actual railway market power.

To help shed light on this issue with respect to U.S. wheat transportation, this research evaluates regional-level market structure changes in two separate, high-volume wheat transportation corridors served by a rail duopoly. These are: (1) wheat moving from North Dakota to Minnesota; and (2) wheat moving from Kansas/Oklahoma to Texas. By assessing the nature of duopoly market power in these particular rail markets, the analysis helps support and inform policies designed to improve transportation markets for more captive wheat and grain shippers.

How was the study conducted?

To ensure the reliability of our analysis, we assessed rail market structure with three different statistical models, two of which appear to be novel to the rail economics literature.

Industrial organization is the field of economics that studies firm behavior and market power. In markets with many firms, competition will drive prices down to marginal cost. In contrast, in markets with few firms or even a single firm, prices may include a markup above cost. Deviations between price and marginal cost are therefore a proxy for the degree of competition in any given market. In the empirical industrial organization literature, the level of market power exerted by firms is assessed by estimating market price deviations from firm marginal costs. Our base empirical model uses a multi-equation two-stage least squares (2SLS) specification that is frequently used in market power research. But since marginal costs can be difficult to estimate, we focus our analysis on the estimated slope of the market demand curve as a proxy for how the firms set prices compared to an equivalent competitive market. A 2SLS specification helps us to identify the slope of demand. Subsequently, we calculate our estimated markup and, in turn, the overall market structure.

While this so-called “structural” methodology has been used to estimate market power across many industries (e.g. Chapin and Schmidt, 1999; Wolfram, 1999; Agostini, 2006), some researchers (e.g. Henrickson, 2011) have indicated structural methods may generate inconsistent market power estimates across time. Regardless, the structural estimation method yields an established baseline estimate of firm conduct in each rail market.

Due to these potential shortcomings, we choose to extend the analysis with two additional statistical models. The models are related and fall within a broader class of statistical models called "latent variable models." With a latent variable model, the research objective is to estimate some key variable that is either unobserved or poorly measured. In this case, the latent variable we seek to estimate is the level of market competition. The two different latent variable models derive from two slightly different underlying constructs about what determines firm behavior and the degree of rail competition in each market.

In one construct, we implicitly assume the duopoly firm's choice to cooperate or compete in the market depends on how the other firm makes the same decision. Both firms can do best from their own perspective if they both choose to cooperate (or collude) on rates and quantity. Conversely, the firms do worse if they both choose to compete on rates and quantity. But this also means each firm has an incentive to compete if they know the other is cooperating (colluding) because the competing firm will do better on its own in this situation. When firm choices are made repeatedly over time and firm actions can also account for prior behavior by the other firm using punishment and forgiveness, the long run situation becomes difficult to predict, hence the need for data analysis. Critically, the latter construct about firm behavior predicts that firm behavioral decisions in any give time period will depend on historical choices of both firms.

The first of these latent variable models attempts to account for this time factor and is known as a Hidden Markov Model (HMM). This specification is designed to assess underlying behavioral dimensions generating market structure through time. By way of motivation, we note that a basic Markov model (with no hidden variables) consists of "states" (i.e. collude or compete) as well as given probabilities of transition between the states over time. Under a Markov assumption, the probability of transitioning to a new state (or staying in the same state) in the next time period depends only on the current state. For example, consider two states of weather, "sunny" and "rainy." Suppose it is known that a sunny day might precede another sunny day 85 percent of the time, but a rainy day 15 percent of the time. Alternatively, with a rainy day, another rainy day might follow 50 percent of the time or be sunny the other 50 percent. A standard Markov model with this data allows the forecaster to estimate daily weather probability given the states and the frequencies of transitions actually observed.

In an example germane to this analysis, imagine a hypothetical situation where we somehow knew or could directly observe the state of market structure. That is, imagine we could easily identify the extant state of a (duopoly) market as "competitive" or "collusive." If this was the case, we would estimate the probability of moving to a competitive state from a collusive one, or the probability of staying in a competitive state, or vice versa, by examining the frequencies with which those transitions occurred.

The difficulty faced in the above is that we cannot directly observe market structure. Firms privately decide whether they will compete or collude or do something in between, and we can only observe the outcomes of their actions. For this reason, we use the HMM estimator to identify market structure over each time period in the data. Under this specification, the states themselves are masked or hidden from the researcher, and the model relies on revealed state outcomes (i.e. firm and market data) to infer the actual (hidden) state of market behavior.

As a second construct for comparative purposes, we estimate a finite mixture regression (FMR) specification. Similar to HMM in that we estimate a latent market state transition for each railway, FMR uses observable variables to converge on a parametric (regression) specification that best predicts the unobserved (market state) variable. The multiplicity of covariates that are created with FMR estimation means that instead of market structure being "one sided" and entirely dependent on the behavior and decisions of suppliers (e.g., railroads) as with HMM, data from all market participants (including demanders) is necessarily included in the parameter estimates. Thus as a construct, the FMR specification implicitly assumes a market scenario where the demanders of transportation (i.e. grain companies) in some way also contribute to the determination of transportation (rail) market structure. So, while slightly different in assumptive structure than HMM, in fact we do not actually know how the firms render decisions on this scale, meaning either specification might be the most appropriate model of market level behavior. In this latter behavioral sense, we feel that it is analytically worthwhile to compare and contrast these latent variable specifications where possible. Additional benefits to estimating latent variable models relevant to this analysis are: (1) neither specification requires estimation of the marginal costs of transportation; and (2) real-time changes in market structure are generated as model output.

What did the study find?

The nature of a duopoly market means that a priori, it can be difficult to assert whether a duopoly is acting competitively or monopolistically. This study attempts to shed light on this issue, as applied to wheat transportation by rail in two important markets in the U.S.

First estimating a standard multi-equation structural specification to assess rail market power within each market, we found that over time market structure most frequently fell somewhere between limited competition (i.e. Cournot) and competitive (i.e. Bertrand) in both corridors. Subsequently, under the alternative (single equation, latent variable) specifications to measure market power, both rail corridors were found to be slightly more competitive in comparison to our structural estimates of market power. More specifically, in the North Dakota-Minnesota wheat transportation corridor, we found the two Class I railways serving this market were most likely to remain under restricted (Cournot) competition. For the Kansas/Oklahoma-Texas corridor, while estimated market structure varied considerably throughout the sample period, on average this market tended to remain in a somewhat more competitive state than the North Dakota-Minnesota corridor. Considering these findings and our comparative estimates, we speculate that one explanation for the assessed differences in rail market power was the availability of viable intermodal competition (i.e. river barge) in the Kansas/Oklahoma-Texas corridor.

Table of Contents

List of Figures and Tables

I. Introduction

"The monopolists, by keeping the market constantly understocked, by never fully supplying the effectual demand, sell their commodities much above the natural price, and raise their emoluments, whether they consist in wages or profit, greatly above their natural rate."

--Adam Smith, Wealth of Nations (1776), Ch. 7.

Railroads remain an important mode of freight and agricultural transportation in the United States. In 2012, railroads moved about 11 percent of the total tonnage and 30 percent of total ton-miles (see Freight Analysis Framework; https://faf.ornl.gov/fafweb/Extraction1.aspx). After the Staggers Rail Act of 1980 and subsequent partial deregulation of the rail industry, concentration among the largest U.S. Class I[1] carriers gradually increased. Today, a few very large Class I railroads operate alongside a number of smaller regional and local carriers across the U.S. (Christensen Associates, 2010). The sheer vastness, breadth, and topography of the U.S. rail industry would suggest its market structure at the regional level may vary considerably, potentially moving through a spectrum from relatively more competitive to somewhat less competitive. Where a particular freight transportation market locates on this spectrum depends on several factors, including the number of railroads serving the market as well as the availability of intermodal competition.

Railroads are a relatively unique industry, characterized by large economies of scale and scope.[2] While highly liberalized, Class I railroads are still nominally regulated by the Surface Transportation Board (STB), which supports a policy of contestability in freight rail markets (Tye, 1991).[3] Contestability is the theoretical idea that under certain market conditions (such as free entry and exit by potential competitors), even markets characterized by very few firms will in fact behave as if they were operating competitively (Baumel et al., 1982; Schrager, 2018). Contestability theory also notes that the existence of such markets is sensitive to a number of factors, including the ease of potential entry and exit for a competitive fringe of similar firms. If significant barriers to entry exist in a market (e.g. large entry or setup costs), a market will not actually be contestable but instead behave more monopolistically, with consequences for

---

[1] According to STB definition (https://www.stb.gov/stb/faqs.html) railroads with annual operating revenue greater than $447 million in 2017 were classified as Class I carriers.

[2] Economies of scale means cost per unit output is lower at higher output levels. Economies of scope refer to cost reductions attributable to the production of multiple related outputs.

[3] Formed in 1996, the STB has broad economic regulatory oversight of railroads, including rates, service, mergers and line abandonments.

economic welfare. For our purposes, whether a market duopoly is actually competitive (effectively contestable) or collusive (exerting market power) is ultimately an empirical question.

The theory of industrial organization indicates that two firms operating in a duopoly will find themselves in three potential market power scenarios. These are known as: (1) collusive (not competitive); (2) Cournot (moderate level of competition); or (3) Bertrand (fully competitive). In turn, differences in market structure found within a duopoly are often due to the inherent nature of the product and industry as well as industry cost structure. Market structure alternatives under duopoly are further defined as follows:

1) *Collusion*. Referring to Bishop (1960) in a discussion of a market with two firms, a collusive market structure is one possible duopoly outcome. This comprises a situation where implicit or explicit operational agreements might be made between the two firms, who then "behave in an essentially monopolistic way" (p. 933). Spence (1975) identifies additional problems with collusive agreements by describing how, in a market where market power is exploited, both the quality and quantity relative to the competitive optimum will be undersupplied and accompanied by a comparatively high price. This kind of duopoly outcome compromises economic efficiency.
2) *Cournot*. Cournot competition represents the vast middle ground on the market power spectrum under duopoly. Cournot competition generally prevails when the private costs of the other firm are unknown (Gal-Or, 1986). Cournot competition implies that firms mutually develop profit maximizing reactions to how they believe the other firm will set its share of market output. A firm's reaction to the other firm's profit and output decisions mean that, in a Cournot duopoly market, output is less and market price is greater than the price and quantity that would be observed under perfect competition.
3) *Bertrand*. In contrast to the Cournot duopoly outcome, both firms are instead assumed to have acquired knowledge about costs of the other firm (Gal-Or, 1986). This knowledge means that the firms can expect the other to drop market price to the point of zero economic profitability (i.e. marginal cost) in order to maintain their market share. As both firms decrease market price, this generates additional consumer surplus (Vives, 1984). As a result, the ultimate market outcome in this kind of duopoly will be very similar to that found under a fully competitive market.

In collusive duopoly transportation markets, shippers would face the highest rates along with the poorest service. Conversely, under a Bertrand transportation duopoly, shippers obtain the best possible rates and service. And finally, since a Cournot transportation duopoly falls in the middle of these two market power extremes, it is not as beneficial to shippers as a Bertrand situation, nor as inefficient as the fully collusive outcome.

The key difference among the possible duopoly market structures lies with the exertion of market power. According to Grant (1999), market power can be determined by the following three factors: barriers to entry, existence of monopoly, and ability to use vertical bargaining power. Railroads are characterized by high fixed costs, making it challenging and costly for new firms to enter the market. With high fixed costs of entry, the level of inter-rail competition in any given transportation market is essentially fixed.

While several high-level market analyses have found that the rail industry appears to be relatively competitive at a macro or national level, at a more micro or regional level there are still significant areas where rail possesses little inter or intra modal competition. This implies there are a number of freight shippers who have access to very limited freight transportation options (Bitzan, 2004). The latter is often the case in rural regions, which tend to be located far from final markets or major transshipment points (e.g. ports), and frequently lack access to other modes of long-distance freight transportation.

From an economic welfare perspective, the effects of monopoly railroads on the freight markets they serve are well understood (i.e., captive shippers), and single-provider rail markets are still subject to regulatory scrutiny by the STB (Bitzan, 2004). But in fact the more difficult regulatory assessment issue arises in those areas and markets where rail could potentially compete intra-modally (i.e., railroad to railroad competition). As we have argued above, under a rail duopoly it is not a priori clear what level of market power railroads might exert. The wide spectrum of potential rail duopoly behavior buttresses the need for empirical assessment of market power exertion in these particular markets.

For this study, we focus on rail transportation serving the major wheat producing regions of Kansas, Oklahoma, and North Dakota. Two of the largest rail duopolies in wheat transportation are explored. These are: (1) the Kansas-Oklahoma (KS-OK) wheat corridor, where both Union Pacific Railroad (UP) and BNSF Railway (BNSF) serve major transshipment points near

Houston, TX; and (2) the region of eastern North Dakota to Minnesota (ND-MN), the "Northwest-Southeast" wheat corridor, served by both the Canadian Pacific Railway (CP) and BNSF. One potential difference between the KS-OK and ND-MN transportation corridors lies in the availability of competing river transportation. While North Dakota wheat moving east to Minnesota does not have any significant intermodal competition (Fuller et al., 1988), river barges are a bulk freight option for wheat shippers in the KS-OK corridor because of the relative proximity of the McCellan-Kerr Arkansas River System. Section II describes the markets in more detail.

Related to prior work of Porter (1983), Ellison (1994), and Winston et al. (2011), we empirically assess market structure for wheat transportation within these two corridors. Building upon standard structural estimates of market power, we also motivate two novel econometric specifications that more parsimoniously generate estimates of dynamic market structure. Further explanations and motivation for these latter models are found in Section III. We start the analysis by estimating a basic structural equation system for each market that measures deviations from competitive (marginal cost) pricing on wheat freight rates. Subsequently, we then re-evaluate market structure using latent variable estimators (Gonzalez et al. 2005), which generate market power measures over time.

In Sections V and VI (results and conclusions, respectively), we offer that the latent variable results, while new to this literature, remain consistent with anecdotal information about the nature of freight rail competition in these duopoly wheat transportation markets. In summary, greater exertion of market power by rail is observed in the North Dakota to Minnesota corridor, where we identify a tendency towards less competitive (between Cournot and collusive behavior) outcomes. In contrast we find that assessed market structure for wheat transportation in the Kansas-Oklahoma corridor is more consistently competitive, mindful that this market also possesses a potentially accessible alternative freight shipping mode. Based on the scope of the analysis, we believe that our findings are insightful since we characterize both the nature and scale of railroad competition in distinct agricultural shipping corridors where railroads operate as duopolists.

II. Market Background - Overview of Wheat Transportation in North Dakota-Minnesota and Kansas-Oklahoma

Kansas, Oklahoma, and North Dakota are important wheat production states. They possess about 40 percent of U.S. planted wheat acres, as shown in Table 1.

Table 1: Planted wheat acres, Kansas, Oklahoma, and North Dakota (2016-2017)

Year	2016			2017		
State	Wheat Planting Acres	% of National Wheat Planting Acres	% of State Crop Planting Acres	Wheat Planting Acres	% of National Wheat Planting Acres	% of State Crop Planting Acres
	(Million Acres)	(%)	(%)	(Million Acres)	(%)	(%)
Kansas	8.50	16.9%	36.4%	7.50	16.4%	31.8%
Oklahoma	5.00	10.0%	49.4%	4.50	9.85%	44.9%
North Dakota	7.59	15.1%	32.0%	6.44	14.1%	27.2%
Total	21.1	42.05%	NA	18.4	40.37%	NA

(Source: USDA Acreage Report, Released June 30, 2017, by the National Agricultural Statistics Service (NASS), Agricultural Statistics Board, United States Department of Agriculture (USDA))

Wheat grown in these states is often transported to other regions for either domestic consumption or for international export (Koo, Tolliver, and Bitzan, 1993; McKamey, 2009; Bessler and Fuller, 2000; and MacDonald, 1989). But the wheat transportation markets selected here differ slightly in this respect. The North Dakota corridor sees wheat moving in an easterly direction, mostly for domestic processing or eventual transhipment by water. In the Oklahoma-Kansas corridor, wheat moves south, with most destined for export through the Gulf of Mexico. In any event, these specific corridors were chosen to represent the most important wheat transportation markets served by a railway duopoly. In addition, there is anecdotal evidence in both markets that some market power is exerted in the movement of wheat.

In North Dakota, rail is by far the primary mode for moving grain. According to Prater et al. (2013) and considering the information contained in Figure 1, the market share of grain transported by railway in North Dakota is consistently above 80 percent (from 2007 to 2010). By comparison, the market share of grain moved by rail is just over 50 percent for Oklahoma and about 35 percent for Kansas (Prater, Sparger and Bahizi, 2013).

Cereal grain transportation volumes transported using various modes in the selected corridors are listed in Table 2. Examining these figures, some degree of intermodal competition for wheat movement via trucking, but especially river barge, seems to apply for the OK market, whereas for North Dakota transportation, rail dominates. In North Dakota, railways remain relatively proximate to many state wheat shippers, but wheat production in the state typically occurs a significant distance from a major waterway.

To get a better sense of the relative size of the chosen transportation markets, Figure 1 shows the average relative market share of rail in cereal grain transportation for the entire U.S., between 2007 and 2010.

Table 2: Volume of cereal grain carried via rail, truck and multiple modes, chosen corridors

Region	Year	2012		2013		2014		2015	
	Mode	Volume (Mil. Ton)	Share (%)	Volume (Mil. Ton)	Share (%)	Volume (Mil. Ton)	Share (%)	Volume (Mil. Ton)	Share (%)
KS&OK-TX	Rail	24.6	72.30%	25.3	74.20%	28.3	73.80%	28.3	73.80%
	Truck	1.71	5.02%	1.53	4.49%	1.77	4.61%	1.71	4.46%
	Multiple Modes	7.72	22.70%	7.28	21.30%	8.28	21.60%	8.34	21.70%
ND-MN	Rail	2.14	89.10%	4.87	95.40%	4.88	95.10%	6.24	94.90%
	Truck	0.18	7.46%	0.24	4.64%	0.25	4.89%	0.33	5.08%
	Multiple modes	0.08	3.41%	0.00	0.00%	0.00	0.00%	0.00	0.00%

(Source: Freight Analysis Framework Version 4; https://faf.ornl.gov/fafweb/Extraction1.aspx)

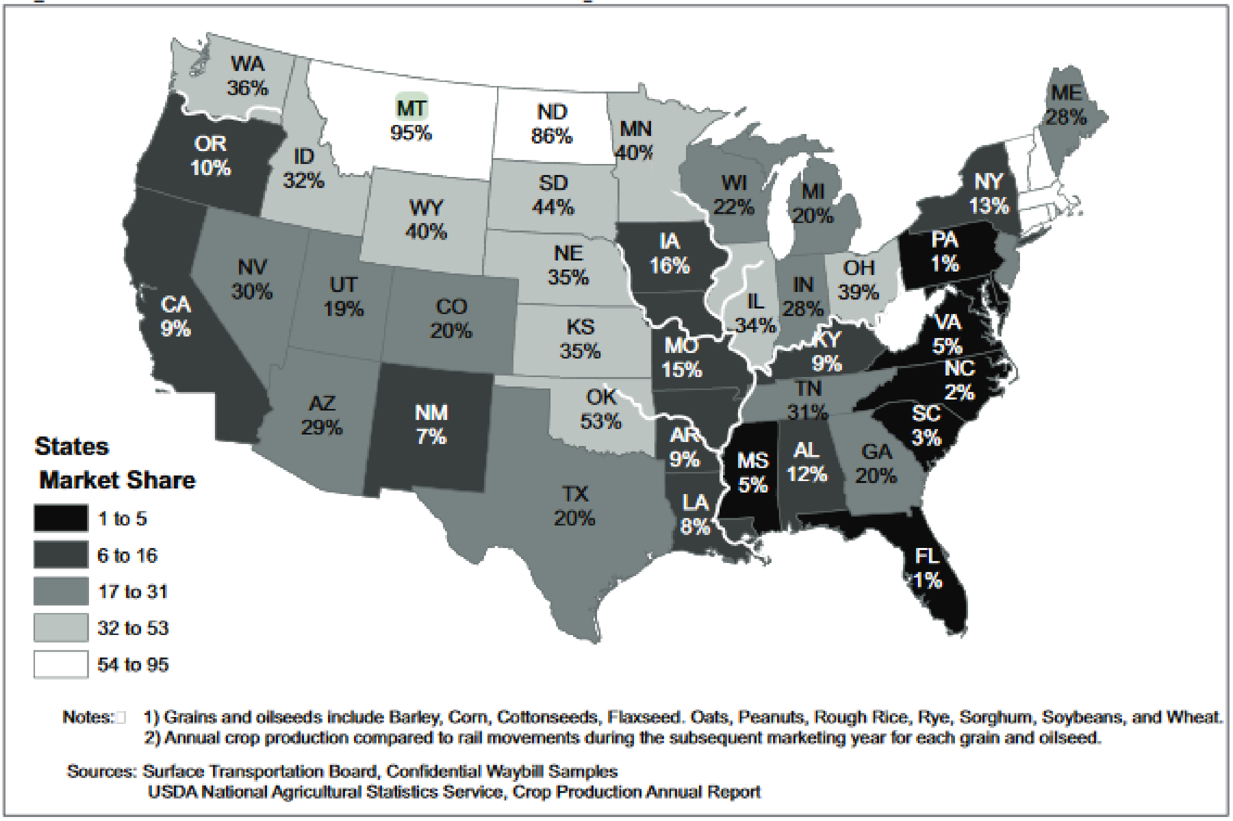

Figure 1: Railroad market share, grain transportation, 2007 to 2010

(Prater, Sparger and Bahizi, 2013, p. 128)

Examining Figure 1, once again intermodal competition for wheat transportation seems to be available in the southern corridor. Further to this point, Catoosa is the port located in northeast Oklahoma near the city of Tulsa. Catoosa also happens to be the first dock of McClellan-Kerr Arkansas River Navigation System and serves both BNSF as well as the South Kansas & Oklahoma Railroad (a Class III carrier). Relevant to this analysis, the port handles varying amounts of wheat traffic. Table 3 shows the amount of wheat transported via Tulsa over selected years, while the column “share of production” shows the amount of wheat transported via Tulsa relative to total wheat production. While traffic volumes moved by barge are typically less than by rail, it is noteworthy that these vary considerably. All tolled, the latter variation would seem to indicate that wheat transportation by barge is a competitive alternative for the southern market. We will expand upon this point later.

Table 3: Wheat transported via port of Catoosa/Tulsa, OK

Year	Wheat Transported from Tulsa	Share of Production for KS and OK	Share of Production for OK
	(Million Tons)	(%)	(%)
2017	1.13	9.60%	42.10%
2016	1.15	6.98%	30.90%
2015	0.56	4.93%	21.00%
2014	1.11	13.80%	85.80%
2013	1.43	12.30%	49.80%
2011	0.68	7.15%	34.20%
2009	0.51	4.12%	24.80%

(Source: Authors' calculations based on the National Agricultural Statistics Service (NASS) and Oklahoma Inland Waterway Fact Sheets)

Next, to compare rail markets in each corridor, relevant freight railroads as well as their track networks within the selected corridors are shown in Figures 2 through Figure 4. A summary of information about relative network size can be found in Table 4.

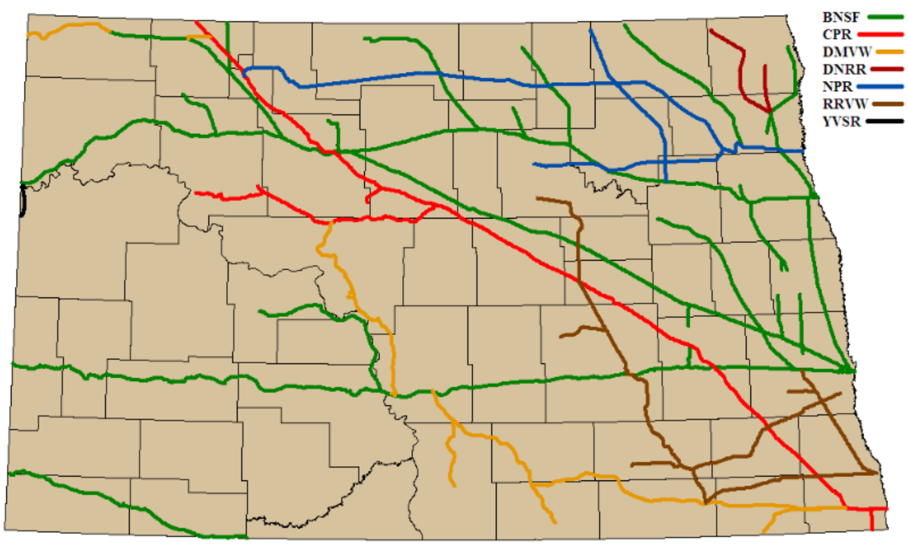

Figure 2: North Dakota railways

(Source: North Dakota State Rail Plan, North Dakota Department of Transportation)

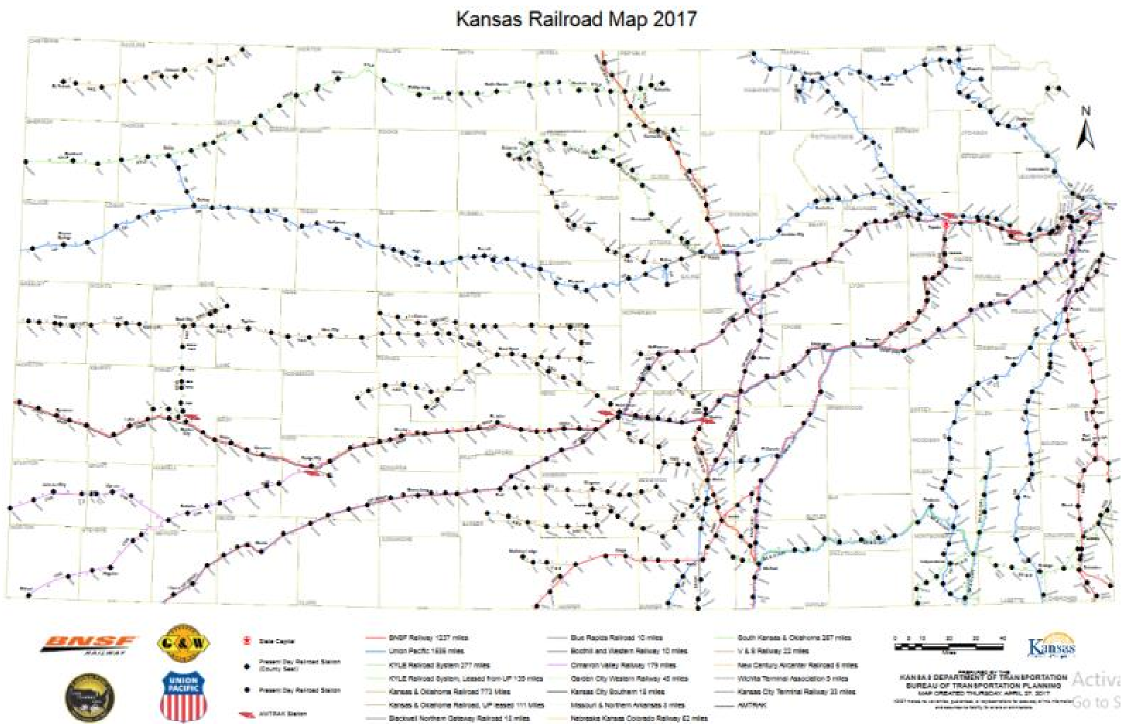

Figure 3: Kansas railways

(Source: Kansas Department of Transportation)

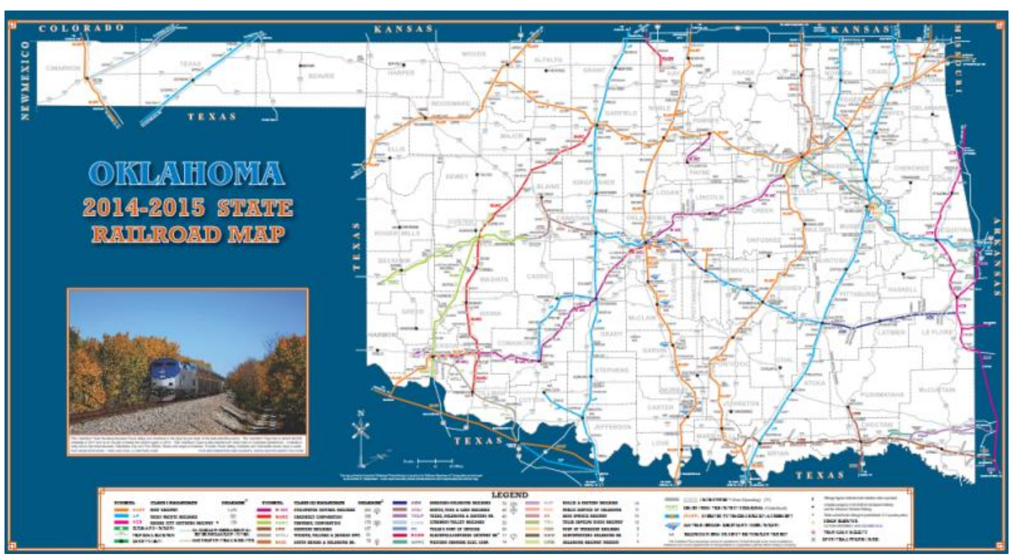

Figure 4: Oklahoma railways

(Source: Oklahoma Department of Transportation)

Table 2: North Dakota, Kansas and Oklahoma railways

State	ND		KS		OK	
Carrier	Rail Track Miles	% of total state track miles	Rail Track Miles	% of total state track miles	Rail Track Miles	% of total state track miles
	(Miles)	(%)	(Miles)	(%)	(Miles)	(%)
BNSF	1,732	45.3%	1,475	39.4%	1,237	26.0%
Union Pacific	NA	NA	NA	NA	1,535	32.3%
Canadian Pacific	482	12.6%	921	24.6%	NA	NA
Other Carriers	1,612	42.1%	971	36.0%	1,986	41.7%

(Source: Authors' calculations)

As shown on the maps, in both corridors a few Class II and Class III[4] short line railroads interconnect with larger Class I trunk railroads. However, each of these railways possess limited networks and trackage, and so they are generally not considered to serve the same wheat transportation market as the Class I railroads.

However, we must note that in the southern corridor, there is an additional Class I railway (Kansas City Southern Railway or KCS) that operates along the eastern border of Kansas and Oklahoma (see Figure 5). KCS is by far the smallest of the U.S. Class I railways and its network is much more limited in geographic scope than the larger Class I's. KCS' state level operations in the region are mostly in and around the city of Kansas City (Besser and Fuller, 2000). From available regional data, we know that KCS originated about 153,000 tons of wheat per year across its entire network between 2015 and 2017, which amounts to a very small volume compared to wheat moved within the corridor by BNSF or UP, and also in comparison with wheat moved along the McClellan-Kerr Arkansas waterway in the corridor (STB, 2016). So while there may exist a very small intra-modal competition effect attributable to the presence of KCS at the margin of the southern corridor, upon further inspection we find that market structure for wheat transportation by rail in the KS-OK corridor is best modeled as a rail duopoly rather than a rail oligopoly (i.e. composed of three railroads).

[4] According to the STB latest definitions (https://www.stb.gov/stb/faqs.html), railroads with annual operating revenues between $35 and $447 million dollars are classified as Class II (mid-size) carriers. Class III (small) railroads possess annual operating revenues less than $35 million.

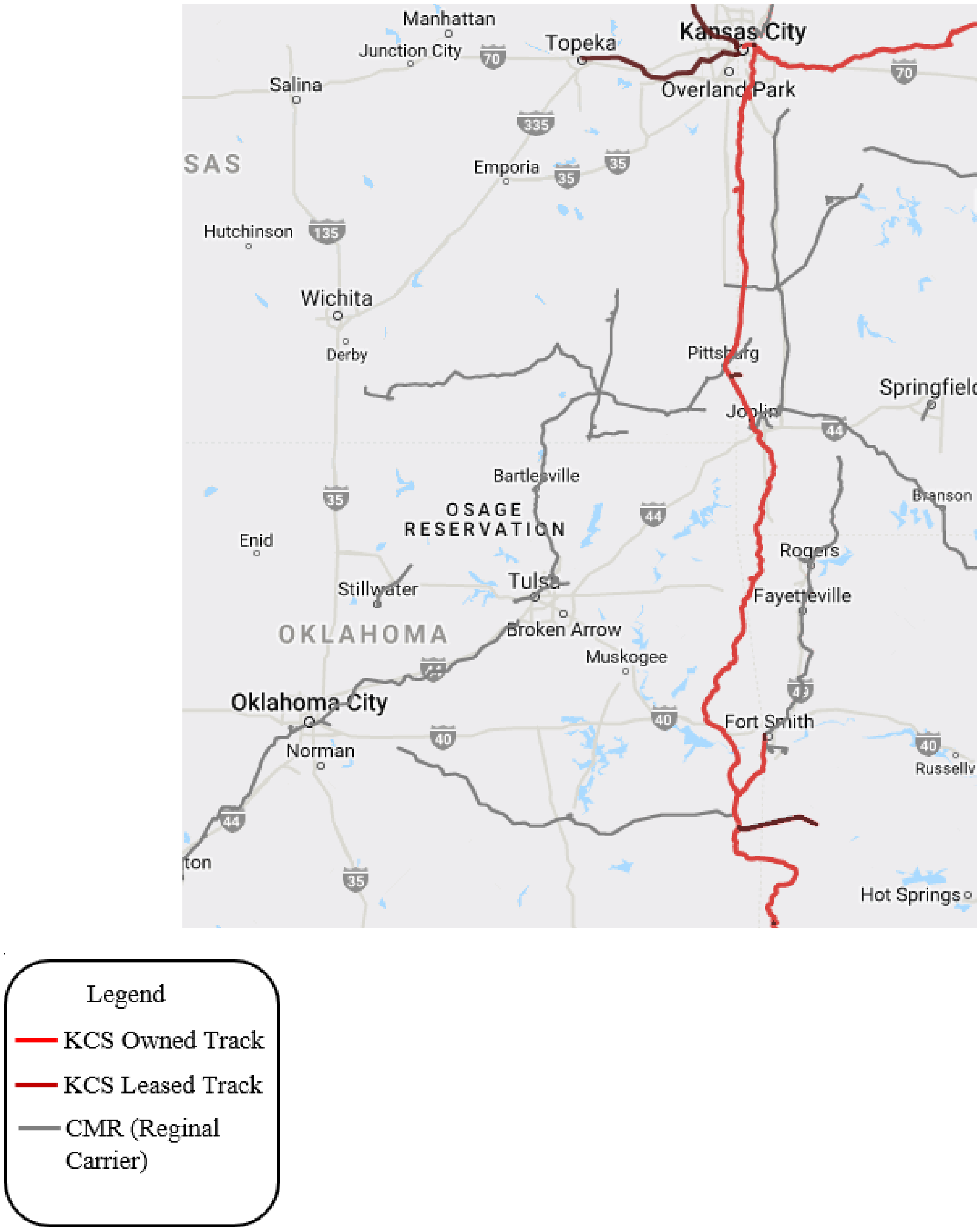

Figure 5: Kansas City Southern Railway map, KS-OK corridor

(Source: Kansas City Southern Railway Official Website, http://www.kcsouthern.com/en-us/why-choose-kcs/our-network/network-map)

In North Dakota, wheat shippers have long been described by researchers as "captive" regarding their rail service (for example, see MacDonald, 1987; Koo, Tolliver and Bitzan, 1993; Vachal, Bitzan and Tolliver, 1996; Johnstone, 2009). Pittman (2010) defines a captive shipper as "a goods shipper lacking economic alternatives, either intramodal competition or intermodal competition from other modes of carriers, to the single railroad serving it" (p. 921). To this end, in much of the North Dakota agricultural commodity sector, farmers and elevators operate a considerable distance from major consumption, processing, or export points. As mentioned, wheat shippers are also far removed from alternative bulk (e.g. water-borne) transportation alternatives (Koo, Tolliver and Bitzan, 1993), while in most of the state rail is still the only proximate bulk freight shipping mode (Johnson, 1981). Finally, all of the short line railways in the state are operationally linked to a regional Class I railroad, so by extension customers of these smaller railways are still captive to a Class 1 carrier (Spychalski and Swan, 2004).

Motivation for the study

A study of duopoly rail markets is of interest because of the theoretical ambiguity over the level of market power exerted under duopoly. Spychalski and Swan (2004), along with Besanko et al. (2009) argue that the possibility of outright cooperation or collusion among railways in duopoly markets must be tempered for several reasons. These include: (1) that many rail freight shipments are lumpy (i.e., typically only available in large volumes) and difficult to control or restrict in size; (2) often there are a limited number of shippers using rail, a situation that can be favorable to countervailing market power by shippers; (3) the inherent volatility of freight demand makes it difficult to plan collusive actions; and (4) there are always practical difficulties associated with sharing detailed shipping information among carriers.

Prior empirical evidence about rail duopolies and their market structure is not definitive. Some duopoly rail markets seem to be relatively competitive, while others much less so. Porter's famous (1983) analysis found that U.S. railroad cartel behavior from 1880 to 1886 in fact constituted an example of Cournot behavior (or limited competition). Building on this research and dataset, Ellison (1994) instead uncovered evidence of dynamic rate collusion by using slightly modified (i.e. less constrained) assumptions about rate setting during that era. More recently, Winston et al. (2011) conducted a study of Class 1 railroads moving coal from the important Powder River Basin production region through the 1980's and 1990's. What is also interesting in this latter case is that this rail market transitioned from monopoly to duopoly during their sample period. Developing a structural econometric model in the spirit of Porter but adding equilibrium assumptions about the entry of the second Class 1 railroad in this market, the authors found that the rail duopoly moving Powder River Basin coal eventually converged over time to a situation approaching Bertrand competition (very competitive).

III. Econometric models of (rail) duopoly

In this section, we begin by motivating an empirical specification based on Porter (1983) as well as Winston et al. (2011). Due to the nature of interactions between supply and demand in these transportation markets, a structural model of wheat transportation demand is developed to generate a baseline set of market power estimates.[5] Initially, by assuming a particular market structure (i.e. collusive, Cournot, or Bertrand) and treating the potential for price discrimination on differentiated shipping rates for wheat as exogenous, a two-stage least squares (2SLS) multi-equation structural market model simultaneously estimates demand and supply for wheat transportation. From these market parameter estimates, we calculate market power parameters. Subsequently we introduce two novel single equation latent variable methods to estimate (dynamic) market power. While relying on slightly different market assumptions, the latter specifications are used to both validate and refine the overall analysis.

2SLS structural market model

A structural approach to estimate wheat transportation demand and supply assumes these transportation markets are in equilibrium (equation 3.1);

$$Demand_{i,t}(Q_{it}^{D}) = Supply_{i,t}(p_{it}^{S}) \quad (3.1)$$

Following Winston et al. (2011) and Porter (1983), we specify a wheat transportation (rail) demand function for the i[th] wheat elevator at time t as:

$$\text{Log}(Q_{it}^{D}) = \alpha_0 + \alpha_1 \log(p_{it}^{D}) + \alpha_2 X_t^{D} + \alpha_3 Quarter + \alpha_4 T + \varepsilon_t^{D} \quad (3.2)$$

[5] Structural models in econometrics are those developed using applicable economic theory. Briefly, relationships between observable endogenous variables are linked by theory to a set of related and observable explanatory variables. In addition, a set of unobservable variables may also be related (theoretically) to the chosen endogenous variables. Depending on the situation and model, the researcher may also have to add assumptions about the joint distributions of the explanatory variables with the unobserved variables. This helps to properly identify the system of structural equations (Reiss and Wolak, 2007). These more advanced modeling techniques are needed due to the problem of simultaneity; that is, as in this case (where demand is set equal to supply), factors jointly determine demand and supply. Therefore, steps must be taken to identify variables (called instruments) that only influence demand and other variables that only influence supply. Simultaneous equations control for both supply and demand changes, leading to unbiased estimators.

Where:

Q_{it}^{D} is the quantity of wheat moving with rail transportation;

p_{it}^{D} is revenue (per ton) for rail transportation;

X_{t}^{D} are exogenous instruments relevant to demand;

Quarter is a quarterly time dummy, following MacDonald (1989);

T is a time trend, following Kwon, Babcock, and Sorenson (1994);

ε_{t}^{D} is the error term.

Exogenous variables (instruments) chosen to estimate demand are based on a shipper's expected gain from the use of transportation, as well as impediments associated with moving wheat (see Table 5). For this analysis, expected wheat export tonnage and expected wheat prices were calculated using a weighted average of historical data.

Similarly, our supply function for the ith railroad is:

$$\text{Log}\left(p_{it}^{S}\right) = \beta_0 + \beta_1 \log\left(Q_{it}^{S}\right) + \beta_2 X_{t}^{S} + \beta_3 PD + \beta_4 Quarter + \beta_5 T + \varepsilon_{t}^{S} \quad (3.3)$$

Where:

p_{it}^{S} is the expanded revenue (per ton) for rail transportation;

Q_{it}^{S} is the quantity of wheat using rail transportation;

X_{t}^{S} are the exogenous instruments (IV's) relevant to supply;

PD is the profit difference between wheat and mining products[6];

Quarter is a quarterly dummy, following MacDonald (1989);

T is the time trend, following Kwon, Babcock and Sorenson (1994);

ε_{t}^{S} is the error term.

As with the demand estimates, (exogenous) instruments are also used to estimate supply and these are all listed in Table 5.

[6] For railways, mining products yield the highest profit margin (i.e. marginal revenue-marginal cost)/marginal cost). This is over 200%, whereas the average profit margin for grain is less than 60 percent (in North Dakota).

Table 3: Wheat transportation - demand and supply variables/instruments

Demand	
Haul Mile	Tracking distance to the destination for the waybill
Quarter Dummy	Dummy Variables to represent the seasons
Wheat Price	Wheat Price in the destination
Wheat Demand	Wheat Export from the destination
Haul Mile	Tracking distance to the destination for the waybill
Supply	
Water Distance	Linear distance to the closest Tulsa, OK
Carrier Distance	Linear distance to the other carrier
Water Distance	Linear distance to the closest water channel
Profit Difference	The profit margin difference between the waybill and the average of carrying the most profitable type of cargo in that year
Carrier Dummy	Dummy variable = 1 for BNSF
Diesel Price	National diesel price
Marginal Cost	Marginal Cost Calculated following *(4)* 's translog function

The logic for our chosen instrument set is based on our need to condition on: (1) potential intermodal competition, and (2) other key market specific factors. To this end, distance from nearest waterway and diesel prices are incorporated to proxy the level of intermodal competition available. Diesel prices and wheat demand were chosen to proxy for economic factors that are outside of the control of the participants. We note as well that the water distance variable is only relevant for the KS-OK market estimates.

Our duopoly market conduct parameter, based on the Lerner index and following Winston et al. (2011), is calculated as follows;

$$\theta_k = -\eta * \frac{p - MC(p)}{p} \tag{3.4}$$

Here, η is the market demand elasticity as computed through the 2SLS demand equation.[7] θ_k is zero in a Bertrand duopoly, one in a collusive duopoly, and essentially approximates a

[7] Given the log-log specification in the supply and demand equations, the coefficients are interpreted as elasticities.

Herfindahl-Hirschman Index (HHI) in the intermediate case of Cournot duopoly (Ellison, 1994). In addition, estimates of the marginal cost of rail transportation in this model use methods developed in Bitzan et al. (1993). However, there is growing evidence that estimating costs for individual rail movements with the kind of rail data at our disposal is biased at best and inapplicable at worst (Wilson and Wolak, 2016). The latter point motivates the search for estimators of market power that do not rely on questionable industry cost estimates.

Latent or hidden variable estimators

In fact, there are other notable limitations associated with structural estimates of market power. Structural estimation also assumes: (1) no changes in demand elasticity over different periods and business cycles; and (2) no changes in market structure over the data series. This means the market conduct parameter in equation 3.4 is computed using a demand function estimated under the assumption of a static duopoly.

Previous authors have recognized aspects of this problem. Henrickson (2011) investigated corn transportation on the Mississippi and Illinois rivers, finding varying demand elasticities among different locks and rivers. Corts (1999) further argued that static structural estimations could be misleading if the duopoly or oligopoly game is inherently dynamic. Given this, we offer that estimation of a market conduct parameter based on the assumption of uniform demand elasticity is likely to be inconsistent. As a result, in the following two sections we describe and introduce two related latent variable maximum likelihood (MLE) estimators, each of which allow us to validate and further refine our individual market power estimates.

Hidden Markov model (HMM)

Most often used currently in computational pattern learning applications, the hidden Markov statistical model (or HMM) is designed to identify hidden or unobserved “states” of nature in a sequence of data. For this research, we define the term “state” as market power in rail transportation that is being exerted in a chosen interval in each corridor. In doing this, we assume market power states fluctuate via a Markov process, a dynamic statistical process where future (conditional) state outcomes are determined based on historical states. Related to applications in economics, HMM has been used to value financial indices and to conduct financial market analysis on pricing (e.g. Hassan and Nath, 2005; Landen, 2000). On an industrial level, it has also been applied to evaluate pricing strategies in energy markets (e.g. Gonzalez and Roque, 2005; Yu and Sheble, 2006). Regarding the latter, Yu and Sheble (2006) assert that an HMM specification is appropriate for the analysis of markets with simultaneous supply and consumption, as well as for limited capacity/storage sectors that rely on networks (such as electricity).

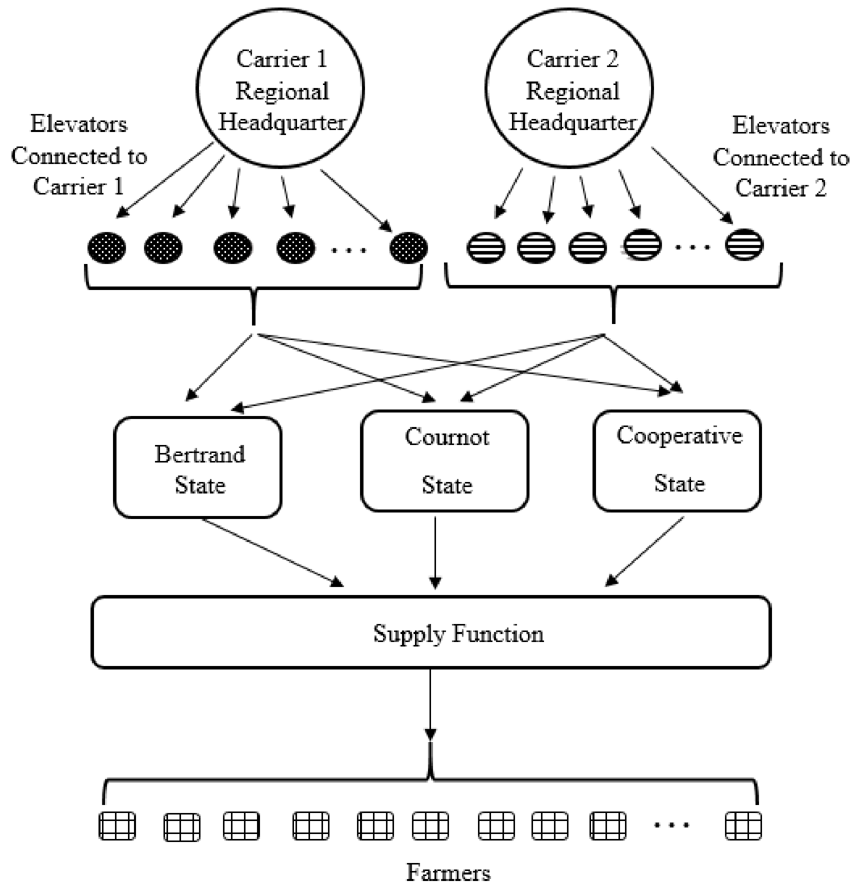

Figure 6: Market behavior for HMM

Building on the latter description, Figure 6 illustrates how HMM assumptions apply for an analysis of market power in wheat transportation. Conceptually, using HMM to evaluate market states implies that railroad management effectively determines market structure in each distinct transportation market, whether that structure is Bertrand (competitive), Cournot (partially competitive), or collusive (uncompetitive). In effect, once a market state "decision" is made by rail management, overall transportation market structure in the region (i.e. in ND-MN or KS-OK) for all users of rail services (i.e. grain elevators) is fixed during that time period.

Due to imbalances within our waybill dataset, some origin (elevator) rate data were only recorded once while others were recorded multiple times in a year. HMM allows us to treat discrete observations from different origins (elevators) as fragments of a broader market structure created by two suppliers (railroads).

Using HMM to estimate transportation market power is structurally relevant to a scenario that assumes a uniform pricing strategy applied by railroads in each market. Other benefits stemming from latent variable estimation are: (1) this model (including FMR) is free from the need to directly estimate the marginal costs (of rail transportation), and (2) real-time changes in market structure are generated in the model output.

In contrast to a structural system model of market power, latent variable models are single equation estimates. And while structural estimates assume market demand elasticity is fixed over time (meaning that the conduct parameter is determined indirectly), under a latent variable specification, market structure (state) can be estimated directly using the following "supply-like" equation (similar to Porter, 1983):

$$\log(Marginal\ Revenue) = \alpha_1 + \beta_1 * \log(Weight) + \Gamma * S + \beta_2 * I + \mu \tag{3.5}$$

where:

Marginal Revenue is the revenue per ton-mile for a single movement;

Weight is the billed weight (i.e. output) of the commodity being transported;

S is a list of variables that can influence market structure;

Γ is the matrix of coefficients for the variables in S;

I is market structure (Porter, 1983), based on calculated state probability as follows:

$$I = \begin{cases} 0\ as\ Bertrand\ with\ Prob.\ of\ \lambda \\ HHI\ as\ Cournot\ (HHI = \ 0.52\ for\ KS-OK\ and\ 0.57\ for\ ND) with\ Prob. of\ \varphi \\ 1\ as\ Collusive\ with\ Prob. 1-\lambda-\varphi \end{cases}$$

and μ is the error term.

Under this specification, determination of the level (or state) of market power relies on the variance of the constant term in the model estimates. Moreover, similar to a supply function, the coefficient on output (β_1) should be positive.

In terms of the matrix S variable list, we include measured distance to the other major carrier (in both markets) as well as the distance to a major waterway (in the KS-OK market) as indicators of inter and intra modal competition, along with diesel price to proxy for input cost pressures on corridor wheat rates. While not commonly used in the market structure literature, there are standard software programs/algorithms available to estimate HMM models. Here, we use the R package called "DepmixS4" (Visser and Speekenbrink, 2010) to estimate the HMM market state specification.

Finite mixture regression model (FMR)

Another latent variable statistical model designed to uncover unknown (to the researcher) participant behavior is the finite mixture regression (FMR) model. This specification is often used to evaluate discrete behavioral choices. According to Deb (2012), a finite mixture regression model accommodates heterogeneity across a finite number of data types or classes through the use of a mixture of statistical distributions. In the empirical economics literature, FMR has been applied to uncover demand-side consumer choices (Draganska and Jain, 2005). Closer to our purposes but on the supply side, Richards and Patterson (2001) utilized an FMR model to examine dynamic oligopsony in the potato processing market in Washington state.

Following Hanson et al (1990) and McDonald and Cavalluzzo (1996), we need to implicitly assume under this specification that larger grain elevators (demanders of transportation) in fact possess some bargaining power with the railroads (suppliers of transportation). Simply put, under FMR one assumes that railways are more likely to deal favorably on pricing/output decisions with individual elevators possessing larger overall capacity. And in order to evaluate potential pricing schemes among the different market participants (i.e. class heterogeneity), FMR is an appropriate estimator. Thematically and in contrast to HMM, instead of assuming railroads make market power decisions over an entire market, in estimating FMR we are assuming that a railroad instead makes independent and dynamic decisions at the elevator level about whether to collude, to act as a Cournot duopoly, or to compete in a specific corridor. This behavioral decision process is illustrated in Figure 7.

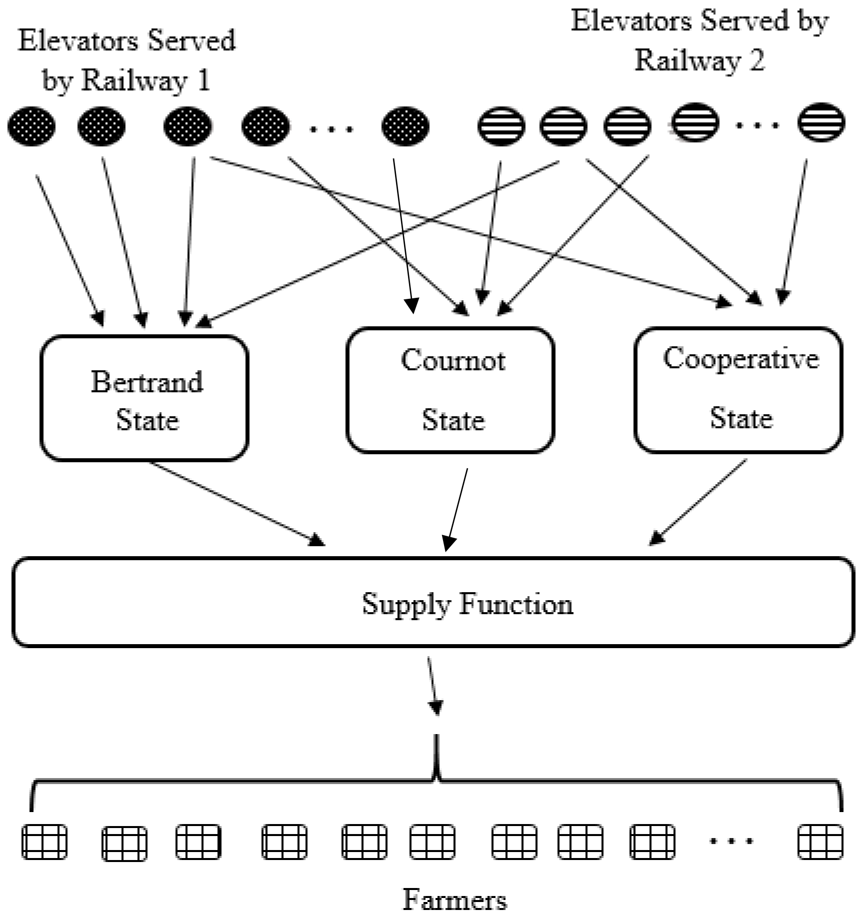

Figure 7: Illustration of market behavior under FMR

Due to imbalances within the dataset (as mentioned previously), observations need to be treated independently in order to operationalize FMR. Once again software is available to estimate this model, and we use the R package known as "Flexmix" by Leisch (2004) to conduct the analysis.

IV. Data

We employ the Surface Transportation Board's confidential carload waybill sample (from 2005 to 2015) in this analysis. These two major duopoly wheat transportation corridors were chosen because (in both instances) BNSF and another Class I carrier (Canadian Pacific in North Dakota and Union Pacific in Kansas-Oklahoma) are the primary providers of freight transportation for wheat grown in the region moving to the same destinations.

To begin, we assumed the origins of the waybills were located within the origin zip code as obtained from the U.S. Census. All other relevant distances were calculated relative to the zip code using GIS software. To focus on active rail duopolies at an origin, only those originating waybills whose measured distances to both railroads were under 50 miles were included in the sample. Using recent data on the trucking of grain (UGPTI, 2015), a radius of 50 miles was chosen as the modal distance over which a farmer or elevator might truck their wheat to take advantage of any competitive rail transportation conditions.

Figures 8 and 9 show the approximate locations of the chosen waybills in each origin area. Due to the lack of precise location information, the latitude and longitude of the counties for the originating waybills is applied as a spatial or locational substitute.

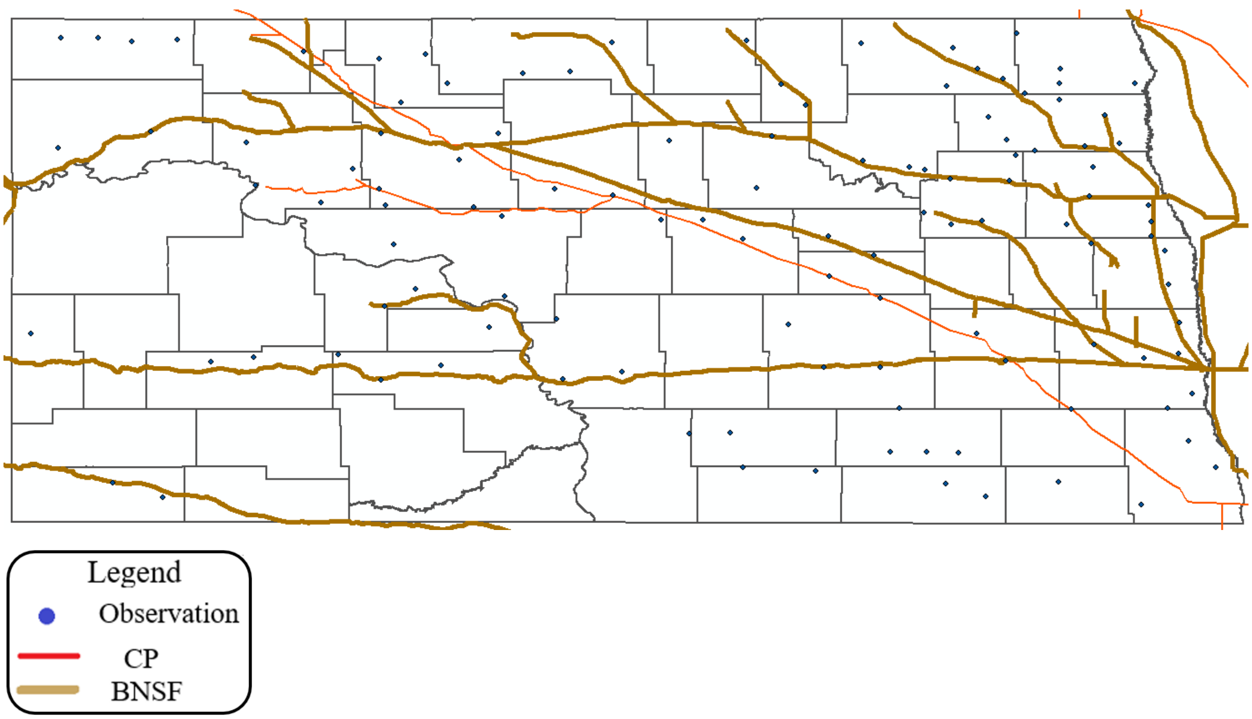

Figure 8: Data points, ND-MN waybills

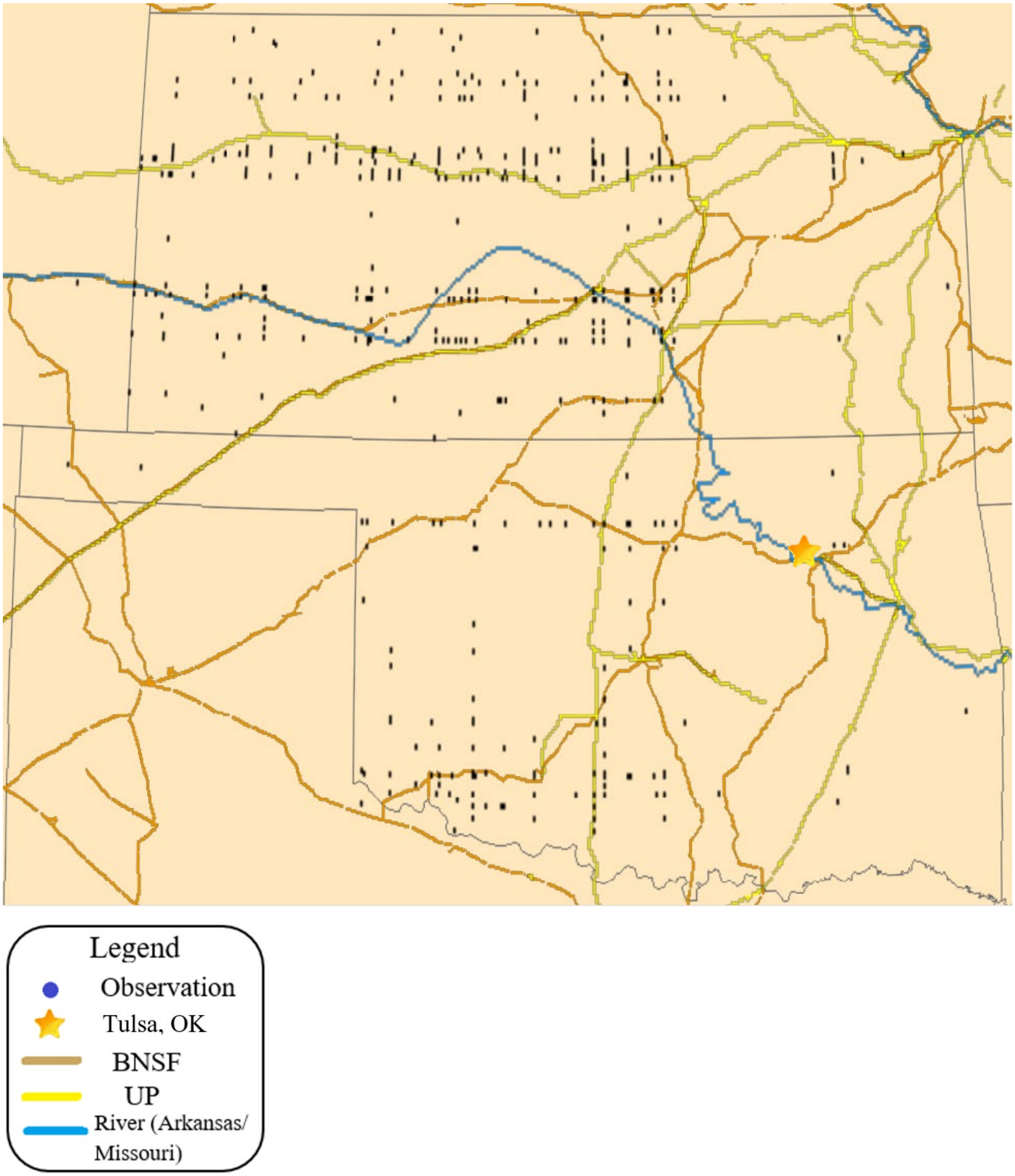

Figure 9: Data points, KS-OK waybills

Tables 6 and 7 contain descriptive statistics for both ND-MN and KS-OK sub-samples. As mentioned, most of the variables used in this analysis are consistent with other related studies of rail pricing and competition. Further, Table 6 also shows the logged data as used in the estimations. However, one variable included here— *profit difference* —is somewhat novel. The profit difference variable is included in the ND wheat market power estimates in order to condition on the relative profitability of wheat movements versus other bulk movements (i.e. coal or oil) in the region.[8]

Table 4: Descriptive statistics, untransformed data, ND-MN and KS-OK sample

North Dakota												
Indicator	Revenue/1000	Weight/1000	Revenue/Ton-Mile	Cost/Ton-Mile	Haul Mile	Wheat Demand	Wheat Price	Diesel Price	Distance River	Distance Carrier	Profit Margin	Profit Difference
	($)	(1000 Ton)	($/Ton-Mile)	($/Ton-Mile)	(1000 Miles)	(1 Mil. Ton)	($/Bushel)	($/Gallon)	(Mile)	(Mile)	(%)	($/Ton-Mile)
Mean	5.53	1.69	0.05	0.02	0.48	0.60	7.81	3.15	NA	32.87	0.56	1.51
Variance	0.84	2.10	0.01	0.00	0.01	0.04	8.08	0.44	NA	138.11	0.02	0.90
Maximum	6.86	12.6	0.54	0.19	0.73	1.20	19.00	4.68	NA	49.59	0.87	2.85
Minimum	4.23	0.09	0.01	0.00	0.16	0.24	4.13	1.96	NA	1.43	0.11	-0.32
Obs.	448	448	448	448	448	448	448	448	NA	448	448	448
Kansas-Oklahoma												
Indicator	Revenue/1000	Weight/1000	Revenue/Ton-Mile	Cost/Ton-Mile	Haul Mile	Wheat Demand	Wheat Price	Diesel Price	Distance Tulsa	Distance Carrier	Profit Margin	Profit Difference
	($)	(1000 Ton)	($/Ton-Mile)	($/Ton-Mile)	(1000 Miles)	(1 Mil. Ton)	($/Bushel)	($/Gallon)	(Mile)	(Mile)	(%)	($/Ton-Mile)
Mean	7.83	9.23	0.05	0.02	0.73	0.62	6.90	3.34	218.57	15.20	0.59	NA
Variance	0.55	15.4	0.00	0.00	0.04	0.20	4.58	0.46	5648.11	512.00	0.01	NA
Maximum	10.70	13.1	0.33	0.04	1.50	4.17	12.30	4.70	398.85	154.20	-0.04	NA
Minimum	6.37	0.08	0.02	0.01	0.00	-1.35	0.50	1.96	2.67	0.14	0.82	NA
Obs.	968	968	968	968	968	968	968	968	968.00	968	968	968

Notes:

1. Revenue, weight and miles hauled come directly from the waybill data, while cost per mile is calculated using the work of Bitzan (2003).
2. Source of wheat demand: USDA, World Agricultural Outlook Board, World Agricultural Total Supply and Demand Estimates and supporting materials; source of wheat price: Wheat Data: Yearbook Tables of USDA Economic Research Service; source of diesel price: U.S. Energy Information Administration, https://www.eia.gov/petroleum/gasdiesel.

[8] Profit Difference = $\frac{Profit\ Margin\ of\ the\ most\ profitiable\ commodity - Profit\ Margin\ of\ the\ waybill}{Profit\ Margin\ of\ the\ waybill} * 100\%$.

Where:

Profit margin of the most profitable commodity: the monthly average of the margin of the waybill carrying the most profitable commodity, which at the time was usually coal.

Finally, we want to illustrate for the reader the viability of waterborne wheat transportation for the KS-OK corridor. To this end, Table 7 shows the distribution of distances to the Mississippi river at Tulsa, OK as derived from the delivery points within our sample.

Table 7: Distribution of line distance to Tulsa, KS-OK

Distance (Miles)	Observation (Number)	Prob. (%)
>50	2	0.21%
50-100	27	2.79%
100-150	166	17.1%
150-200	216	22.3%
200-250	262	27.1%
250-300	143	14.8%
300-350	93	9.61%
350-400	59	6.10%

Although a (linear) distance measure could be misleading due to the topography of the transportation system in the region, the table gives a sense of the proximate distance to a (water-based) bulk transportation alternative in this corridor. The vast majority of wheat locations we use are somewhere between 100 and 250 miles from the river (i.e. within trucking distance).

V. Market power results

We begin our assessment of market power with a description of our structural (multi-equation) results. Table 8 lists the 2SLS coefficient estimates relevant to both the North Dakota and Kansas-Oklahoma wheat transportation markets. The estimated signs of most coefficients agree with our prior expectations. For example, using weight as a proxy for output as our dependent variable in the demand equation, under 2SLS we obtain expected negative signs on Revenue/Ton-Mile in both markets. The similarities between these estimated demand elasticities across the two regions (significant at the 1 percent level) is noteworthy. It is strongly indicative that our choice of comparable wheat transportation markets is defensible and that in many key respects, the two markets are broadly similar, all else equal.

Looking over our demand equation estimates, the only result that seems somewhat unintuitive is that distance (haul mile) is significantly positive for ND-MN and negative for KS-OK. But the estimated difference may be attributable both to distance and train length differences between the two wheat transportation corridors. The average distance hauled for wheat shipments in KS-OK is twice as far as in the ND-MN market, while as well the average car count is 90.9 for KS-OK but just 15.6 for ND. In effect, the distance variable appears to be controlling for market differences in economies of scale.

On the supply side, distance to the nearest (other) carrier coefficients are small and insignificant in both markets, implying that revenues are not affected by proximity to the other carrier. We also note that distance to Tulsa coefficient (included in the KS-OK supply estimate only) is significantly negative. This is likely attributable to the availability of intermodal (water) competition in the southern corridor. Coefficients on marginal costs for both supply estimates are positive and significant, which accords with our expectations for output ranges in these mid-sized rail markets. In terms of seasonal effects on revenue, supply dummies in the KS-OK market are all positive, which is probably due to the more consistent agronomic and weather conditions associated with wheat production in this more southerly corridor, as well as the limited availability of water-based competition in winter.

With respect to railroads' effect on revenue per ton (rate), a dummy variable included for BNSF generates a positive coefficient for the ND-MN market, but a negative coefficient for the KS-OK market. This shows there is a "BNSF" (i.e. a large, regionally dominant carrier) effect in what is arguably the more captive wheat transportation market (ND-MN). Further, we note the estimated effect of BNSF in the KS-OK market is statistically but not economically significant, a finding expected for a relatively more competitive wheat transportation market. Finally, with respect to considerations of revenues over time, seasonal effects on supply are not significant (either economically or statistically) in either corridor.

Table 8: 2SLS results for North Dakota-Minnesota and Kansas-Oklahoma (N=448, N=966)

	North Dakota		Kansas-Oklahoma	
Variable	Demand	Supply	Demand	Supply
Revenue/Ton-Mile	-0.65***	Dep.	-1.03***	Dep.
	(0.009)		(0.03)	
Weight	Dep.	0.87***	Dep.	-0.72***
		(0.06)		(0.02)
Haul Mile	0.23***	--	-0.39***	--
	(0.07)		(0.05)	
Wheat Price	0.01	--	0.12***	--
	(0.06)		(0.05)	
Wheat Demand	-0.01	--	-0.003	--
	(0.05)		(0.03)	
Distance Carrier	--	0.02	--	0.01*
		(0.03)		(0.01)
Distance Tulsa	--	--	--	-0.09***
				(0.02)
Profit Difference	--	0.001	--	--
		(0.02)		
Marginal Cost	--	1.53***	--	0.72***
		(0.04)		(-0.03)
Diesel Price	--	-0.15**	--	0.13***
		(0.07)		(0.05)
Carrier (BNSF=1)	--	-0.06	--	-0.16***
		(0.07)		(0.02)
Quarter 1	-0.01	0.03	0.01	0.05**
	(0.06)	(0.04)	(0.03)	(0.02)
Quarter 2	-0.05	0.02	-0.06***	0.03
	(0.06)	(0.04)	(0.03)	(0.02)
Quarter 4	-0.07	-0.0009	0.01	0.06**
	(0.05)	(0.04)	(0.03)	(0.02)
Month Trend	0.0008	0.0009***	0.005	0.005***
	(0.0005)	-0.0003	(0.0004)	(0.0003)
Constant	-4.261***	3.79***	1.76***	1.91***
	(0.87)	(0.25)	(0.51)	(0.15)
Adj. R-Square	90.5%	97.9%	60.2%	71.7%
F-Statistics	465***	1892***	181***	243***

Note: *** indicates 1% significance; ** indicates 5% significance and * indicates 10% significance.

From equation 3.3 as applied using our 2SLS parameter estimates, annual market conduct parameter estimates and their 95% confidence intervals are listed in Table 9.

Table 9: Market conduct parameters, 2SLS (0% is competition, 100% is collusion)

Year	North Dakota				Kansas-Oklahoma			
	Mean	Lower 5%	Upper 5%	HHI	Mean	Lower 5%	Upper 5%	HHI
2005	35.5%	34.4%	36.7%	50.0%	56.3%	54.5%	58.0%	74.5%
2006	36.4%	35.2%	37.5%	57.6%	58.5%	56.7%	60.3%	71.8%
2007	35.6%	34.5%	36.7%	50.3%	54.5%	52.8%	56.1%	55.6%
2008	35.6%	34.5%	36.7%	59.1%	52.6%	51.0%	54.2%	54.4%
2009	34.9%	33.8%	36.0%	51.4%	62.7%	60.7%	64.6%	52.5%
2010	34.2%	33.2%	35.3%	51.3%	62.8%	60.9%	64.7%	63.8%
2011	33.5%	32.5%	34.6%	61.6%	62.2%	60.3%	64.1%	51.6%
2012	37.5%	36.3%	38.6%	54.9%	63.6%	61.7%	65.6%	52.8%
2013	35.9%	34.8%	37.0%	56.4%	63.8%	61.9%	65.8%	58.7%
2014	40.1%	38.8%	41.3%	63.0%	66.3%	64.2%	68.3%	55.5%
2015	38.8%	37.6%	40.0%	56.0%	62.7%	60.7%	64.6%	53.6%
Average	36.2%	35.0%	37.3%	55.6%	60.5%	58.7%	62.4%	57.2%

Looking at the table, we note broad similarities between the estimated conduct parameters in both ND-MN and KS-OK markets. While we acknowledge that these wheat transportation markets in fact differ in some ways, the system 2SLS estimates indicate that conduct parameters estimated for both markets most frequently fall between weakly competitive (30%) or Cournot (around 60%). The structural model estimates indicate that the Class 1 railroads have exerted some market power over wheat shippers in both corridors.

HMM market power estimates

While considerable prior empirical research in industrial organization uses structural modelling to help estimate market power, there is evidence that results can be misleading. Referring again to Corts (1999), who argued that an estimated conduct parameter is "fully determined by 'equilibrium variation', the extent to which equilibrium quantities respond to perturbations of demand" (p. 233), we now turn to a set of alternative estimators of market power that are founded on slightly different firm and market behavioral assumptions.

Based on these concerns along with seasonal characteristics of these markets, we believe a more dynamic estimator of market power in these markets is required. Next, we provide an overview of the results of HMM estimates of market power as a latent or hidden variable. Tables 10 and 11 as well as Figures 10 and 11 highlight HMM output applicable to both rail corridors.

Since some of the wheat waybills used were reported on the same day and because HMM effectively assumes a dynamic rate setting process by the railroad, it may be misleading to rely on market power state estimates generated from (in some cases) multiple observations in the same time period. To account for this, only a single observation for any sampled day possessing multiple observations was randomly chosen for inclusion in this sample. This left a sample size for the North Dakota-Minnesota and Kansas-Oklahoma corridors of 398 and 654 observations, respectively.

Table 10: HMM equation results, North Dakota-Minnesota, Kansas-Oklahoma

Region	Structure	Intercept	Weight	Distance to the other Railway	Distance to Tulsa	Profit Difference	Diesel Price	S.D.
North Dakota	Bertrand	-8.15	-1.41	-0.14	NA	-0.19	3.93	0.14
	Cournot	-5.45	-1.42	0.01	NA	0.07	0.54	0.23
	Collusive	-4.19	-1.36	0.16	NA	-0.19	-0.38	0.60
Kansas-Oklahoma	Bertrand	-3.70	-0.02	-0.002	-0.09	NA	0.86	0.20
	Cournot	-3.28	-0.018	0.001	0.035	NA	-0.08	0.19
	Collusive	-2.08	-0.002	-0.018	0.009	NA	0.38	0.13

Looking at Table 11 and referring to the basic model specification (equation 3.5), a greater intercept value in the equation indicates reduced competitiveness in a given market. Note as well that the standard deviation is for the dependent variable in each state. The other listed coefficients, except for diesel price, share the same signs as our 2SLS estimates and seem to be stable under all specifications.

The only major difference between these model estimates and those of our structural model is the elasticity of diesel price. In ND-MN where more collusive rail behavior is believed to dominate, under a Bertrand (or more competitive) market state, diesel price as an input cost contributes negatively to price. But we also observe higher coefficients for diesel prices under a more collusive market state. In this case, the coefficient may also be indicating some shifting of "future costs" (i.e. forecast fuel prices) on current rail rates. This also supports the supposition that when operating in a Bertrand or more competitive market state, carriers are more sensitive to input prices since rising input prices will cause a loss in profit margins. We also find that in the KS-OK corridor, when the market state is Cournot and collusive, the coefficient of the distance to port is positive. This gives us some reference point as to how and when effective water-based competition operates in this market. As measured here, it seems the limited level of rail collusion in the KS-OK corridor implies that barges have been a relatively ineffective modal alternative for wheat shippers.

Table 5: Transition matrix for HMM, North Dakota and Kansas-Oklahoma

		To Bertrand	To Cournot	To Collusive
North Dakota	From Bertrand	21.0%	79.0%	0.00%
	From Cournot	18.4%	37.8%	43.8%
	From Collusive	0.00%	41.4%	58.6%
		To Bertrand	To Cournot	To Collusive
Kansas-Oklahoma	From Bertrand	98.6%	0.30%	1.10%
	From Cournot	0.00%	92.9%	7.1%
	From Collusive	20.6%	74.90%	4.5%

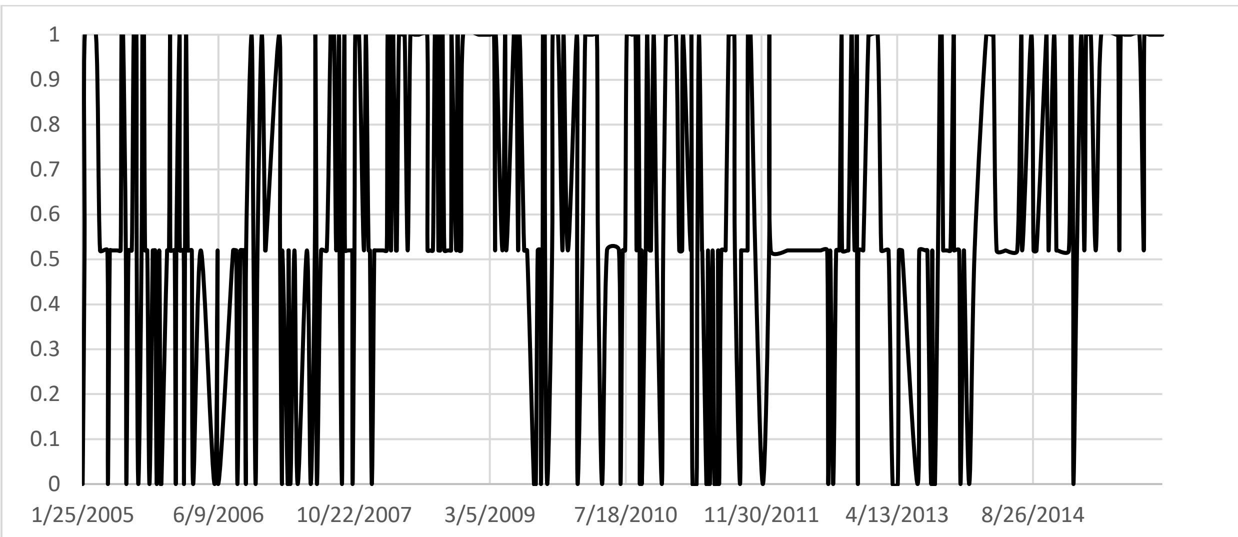

Figure 10: HMM estimated market structure parameters, ND-MN

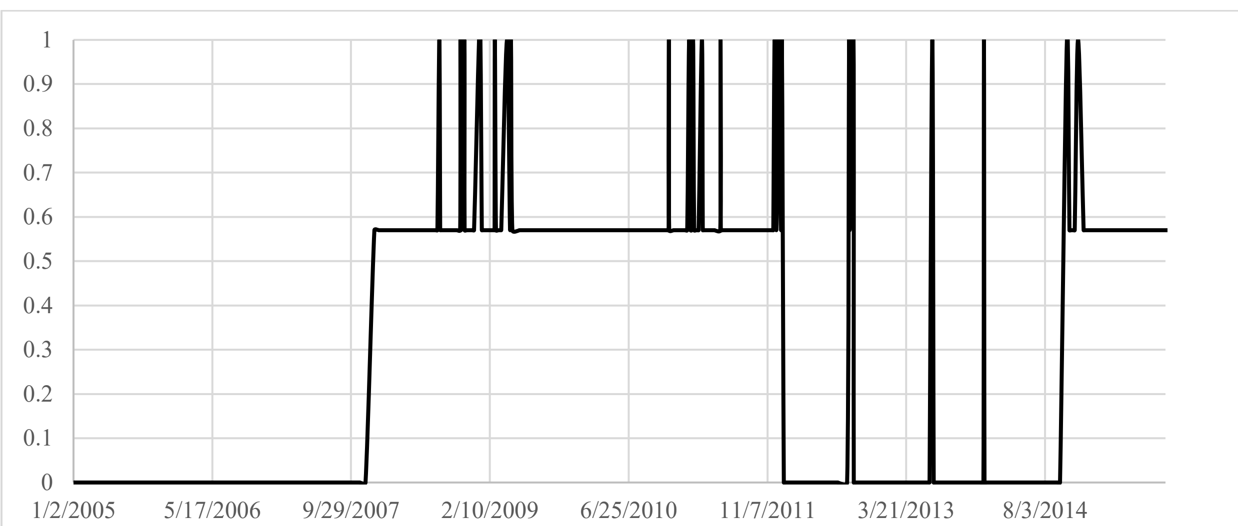

Figure 11: HMM - estimated market structure parameters, Kansas-Oklahoma

From Table 11, HMM estimates indicate that for the KS-OK market, there is some market state inertia. To this end, we find the probability of the market structure/state remaining in its previous state is greater than 90 percent for both Bertrand and Cournot. Overall, the estimated probability of the KS-OK rail market remaining in a relatively more competitive state is considerably greater than the probability of being in a more collusive state. Our estimates also show that once entered into either Bertrand and Cournot (more competitive) states, market structure in KS-OK remains unchanged with a greater than 90 percent probability. Conversely, when the ND-MN market enters into a collusive state, the probability of the market remaining in this state is about 58 percent, with a 42 percent chance of moving into a more competitive (Cournot) state and a 0 percent chance of moving to a competitive (Bertrand) state. To this end, we found the ND-MN market was most likely to be in either a Cournot or collusive (but not Bertrand) state.

Figures 10 and 11 illustrate and compare the degree of market state variation in the two corridors over time. To summarize, for the ND-MN market, we see more variation across the sample period, but most of the observations are in either a Cournot or collusive state. Alternatively, we find throughout the sample that no matter what the current market state for the KS-OK market, KS-OK almost always tends to transition towards a Bertrand or Cournot (more competitive) state.

FMR market power estimates

Here we describe our comparative findings based on the alternate latent variable specification (FMR). One major difference with the HMM model is that due to the implicit assumption of bilateral bargaining power between shipper and carrier, additional data on origin (elevator) locations is necessary. But available data on elevator capacity in many cases lacks spatial information to help identify FMR estimates. As a result of this limitation, the ND-MN corridor sample did not contain sufficient data to compute an acceptable FMR estimate.

For KS-OK we identified enough data for unique elevator locations to generate a viable sub-sample. In effect, only waybill observations from locations where only one or two wheat elevators operate are included in this sub-sample. For those locations where two elevators are co-located, we randomly selected one for inclusion into our sub-sample. The total number of observations in the FMR sub-sample was 424, as compared to 654 for HMM and 2SLS estimates. Table 12 and Figure 12 illustrate the FMR estimates of market power in the KS-OK corridor, noting that elevator capacity was included in these estimates (transformed using natural logarithms).

Table 12: FMR estimates, KS-OK

Region	Structure	Intercept	Weight	Distance to the other Railway	Distance to Tulsa	Diesel Price	Elevator Capacity	S.D.
Kansas-Oklahoma	Bertrand	-3.95	-0.06	0.00	-0.03	-0.18	0.64	0.20
	Cournot	-3.52	-0.23	0.01	-0.03	1.58	-0.49	0.10
	Collusive	-2.11	-0.98	-0.04	0.14	0.78	-0.19	0.17

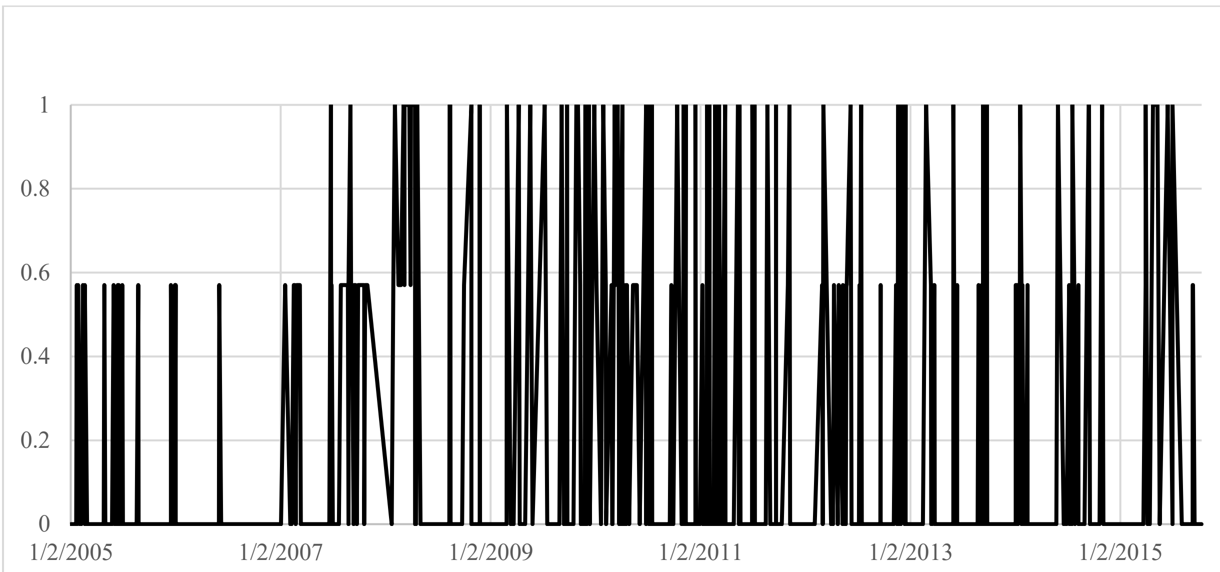

Figure 12: FMR - estimated market structure parameters, KS-OK

The most notable estimate in Table 12 is the small and negative sign of elevator capacity when the market is in a Cournot state. We speculate that this might be attributable to difficulty on the part of one of the carriers in the corridor in predicting the output of the competing railway, especially in relation to the operations of the largest shippers (elevators). Compared to the previous model estimates, FMR generates greater coefficients on output (by weight) but smaller coefficients on the distance to other railways, as well as to water. Under FMR, we find that the behavior of transportation providers outside of the market (i.e. not one of the rail duopolists) matters very little for rates. This finding is consistent with our prior HMM findings that the KS-OK duopoly rail corridor is inherently quite competitive.

Under this specification, we also find that as a railroad's market power decreases, changes in diesel (input) prices seem to be reflected in the rates charged to wheat shippers. This in turn implies that when carriers in this market exercise more power, rates deviate more from costs. In addition, we find that when the market structure is in a collusive or Cournot state, there is a negative correlation between elevator capacity and the freight rate. As we discovered using HMM estimation in the ND-MN market (under different circumstances), this suggests when this wheat transportation market is inherently more collusive, there are scale economies, meaning the railways charge reduced rates on higher volume movements. This finding accords with the prior results of Hanson et al. (1990) as well as McDonald and Cavalluzzo (1996) regarding behavioral linkages between grain transportation costs and elevator capacity.

Table 13: Average market conduct parameters, by model (0% is competition, 100% is collusion)

Method	2SLS		HMM		FMR
Year	ND	KS-OK	ND	KS-OK	KS-OK
2005	35.5%	51.4%	54.5%	0.0%	7.3%
2006	36.4%	58.5%	45.2%	0.0%	2.6%
2007	35.6%	54.5%	51.0%	0.9%	29.8%
2008	35.6%	52.6%	75.5%	59.2%	22.9%
2009	34.9%	62.7%	65.9%	61.7%	23.3%
2010	34.2%	62.8%	64.3%	57.7%	23.4%
2011	33.5%	62.2%	51.0%	62.7%	21.4%
2012	37.5%	63.6%	54.7%	6.1%	20.5%
2013	35.9%	63.8%	48.5%	2.1%	9.6%
2014	40.1%	66.3%	68.6%	10.6%	17.2%
2015	38.8%	62.7%	86.8%	57.0%	21.6%
Average	36.2%	60.1%	60.5%	28.9%	18.1%

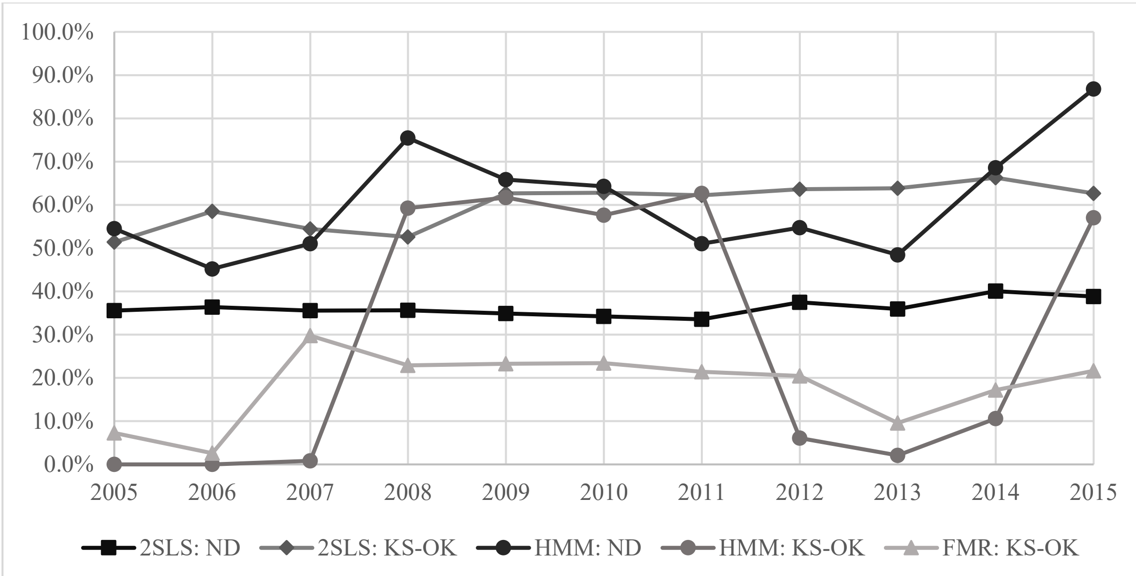

Figure 13: Average conduct parameter estimates, 2005-2015

Table 13 and Figure 13 summarize market structure findings of this analysis. Although structural 2SLS estimates of the market conduct parameter for both corridors are between 36 and 60 percent (indicating both markets tend towards Cournot states), in fact we did uncover subtle differences between the ND-MN and KS-OK corridors using the latent variable estimators. According to our HMM estimates, the ND-MN rail market operated somewhere between a collusive or Cournot market state during the sample period. What was noteworthy from the perspective of the use of structural modeling in this regard was how much less competitive the ND-MN market was found to be under HMM as compared to the initial structural estimates.

Regarding market power exertion in the KS-OK corridor, while market power was found to be relatively stable over time, the HMM model did identify a peak in rail market power between 2008 and 2011, and also in 2015. In these years, we note that the overall wheat handling capacity of Tulsa was reduced as shown in Table 3. Overall, while we estimated the FMR model just on the KS-OK corridor because of data limitations, as with the HMM estimates we found that market power levels were relatively stable over time, with relatively little market power exerted through the entire sample. Both the HMM and FMR estimates regarding the KS-OK market were very similar and yielded the same basic trends but stood in contrast to the structural estimates, which indicated this market was subject to more rail market power than ND-MN. However, the consistency of the latent variable estimates supports the credibility of these estimators as alternative single equation methods to estimate market power (states) when the correct type of data is available.

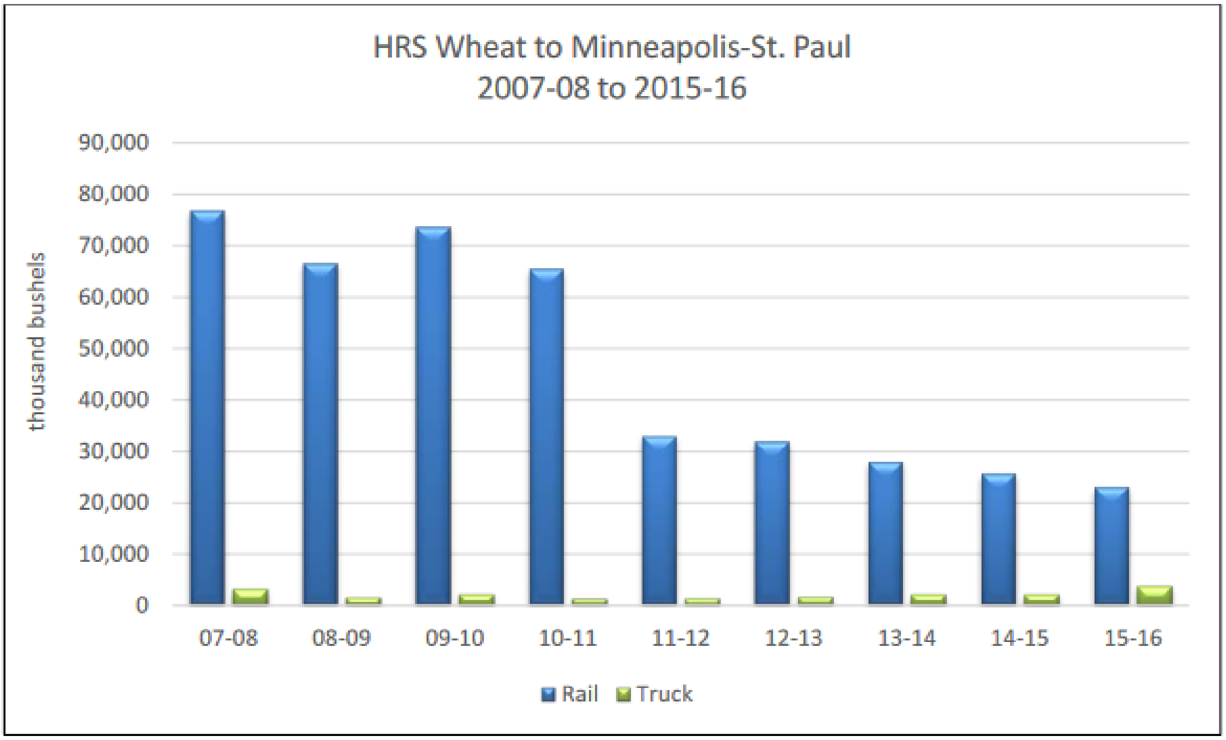

Figure 14: HRS Wheat to Minneapolis-St. Paul, 2007 to 2016

(Source: Vachal and Benson (2016), p.22, https://www.ugpti.org/resources/reports/downloads/dp-291.pdf)

As a final note on these markets and changes within them and potential effects on market power, we examined wheat output data in a bit more detail. In fact, there was more than 100 percent growth in wheat transportation volumes originating from the KS-OK corridor from 2007 to 2012. While this shift is at least partially linked to increased ethanol production and its effects on farming decisions across the U.S., it could also be attributable to changes in wheat demand from export destinations served through the Gulf of Mexico. Rotemberg and Saloner (1986) as well as Cowan (2004) note that greater demand tends to inhibit incentives for firms to collude, and vice versa. Considering these factors, we believe this study also shows that when demand for wheat transportation fell in the ND-MN corridor (see Figure 14), that rail duopoly tended to exploit their market power more, whereas the expanding wheat market situation in the KS-OK corridor appears to have helped shift rail market power in the opposite direction.

In summary and referring again to Table 13 and Figure 13, it is clear that market power measures produced by each latent variable estimation technique in each corridor are all broadly consistent, affirming that the wheat transportation market operating in Eastern North Dakota is inherently less competitive than the one serving the Kansas-Oklahoma corridor. In fact, these markets were chosen to represent a limited statistical "control" situation since both share duopoly rail provision while moving a very similar commodity. Accounting for possible shortfalls in the data (such as aforementioned demand shifts) as well as potential pitfalls in our econometric analysis, we offer that one key difference between the assessed market conduct in the two duopoly rail markets was the presence of accessible inter-modal (barge) competition in the KS-OK market.

While novel to the literature because the analysis was conducted at a corridor level, our findings buttress theoretical suppositions about the nature of competition in duopoly markets. Duopoly (transportation) markets necessarily lead to ambiguous and conditional levels of market power exertion. Given the diverse and varied nature of our findings, ultimately we hope we have shown that a complete understanding of duopolist behaviour over time and space needs to be based upon empirically defensible methods for measuring market power.

VI. Conclusions

Building upon established empirical models of market structure, this study uses detailed U.S. rail waybill data coupled with elevator location data to estimate market power in two major wheat transportation markets. While monopoly and captivity continue to be issues germane to agricultural shippers, what makes this analysis novel is that we specifically compared two ostensibly similar duopoly rail markets, controlling for the same major commodity being transported. However, the two corridors are somewhat distinct a priori in that one of the markets is perceived to be highly captive to rail, while the other market possesses what appear to be viable inter-modal transportation alternatives to move wheat.

After reviewing problems with standard static structural methods often used to measure market power, we then motivate and implement two novel maximum likelihood estimators to conduct market power analysis. Based on the latter estimates, we speculate that the availability of an inter-modal transportation alternative seems to render one of the duopoly transportation markets (KS-OK) relatively more competitive throughout the sample. Alternatively, the market (ND-

MN) perceived to be captive to rail transportation consistently generates parameter estimates indicating a less competitive duopoly situation.

Market level differences necessarily get buried within the more commonly attempted country- or state-wide analyses of market power in the rail sector. This suggests some form of aggregation bias distorts a more refined understanding of the market power conditions facing many resource and agricultural shippers. While our major findings contrast somewhat to those of Winston et al. (2011) regarding rail duopoly behavior in coal transportation, the transportation markets for coal and wheat are in fact quite different. In the coal market, there are likely additional forms of spatial competition (such as source competition) that in turn help generate the more competitive duopoly market structure identified in their major coal corridor.[9]

This research is novel in that it offers unique insight into rail market behavior at the regional or route level. As inferred by economists writing about multi-product firms and associated discriminatory pricing schemes (see Shy, 2008), we appear to have identified corridor level evidence that railroads: (1) are very knowledgeable about route level demand parameters; and (2) constantly adjust corresponding rates and volumes based on their assessment of what levels each of these routes and markets can bear.

Considering the theoretical ambiguity associated with duopolies, this research contributes to our knowledge of these unique industrial organizations. From a transportation policy perspective, this research also represents a preliminary step in developing a better understanding of how freight railways behave at the corridor or route level. Future research will similarly analyze other major rail duopoly routes/markets that serve other major agricultural commodities, including soybeans and corn. Knowing that corn and soybean supply chains are somewhat distinct from wheat will help us identify the drivers that contribute to the similarities or differences in railway behavior within other concentrated agricultural transportation markets.

[9] We also offer that the econometric behavioral model used in the Winston et al. paper may not be appropriate. While the paper has considerable merit in the context of our analysis, we note that it has never been published.

References

1. Bessler, D. and S. Fuller (2000). Railroad wheat transportation markets in the central plains: modeling with error correction and directed graphs. Transportation Research Part E: Logistics and Transportation Review, 36: 21-39.

2. Besanko, D., Dranove, D., Shanley, M., and S. Schaefer (2009). Economics of strategy. John Wiley & Sons.

3. Bishop, R. L. (1960). Duopoly: Collusion or Warfare? The American Economic Review, 50(5), 933-961.

4. Bitzan, J. (2003). Railroad costs and competition: The implications of introducing competition to railroad networks. Journal of Transport Economics and Policy, 37: 201-225.

5. Christensen Associates (2010). An Update to the Study of Competition in the U.S. Freight Railroad Industry. Final Report for the Surface Transportation Board, L.R. Christensen Associates, Inc., Madison, WI.

6. Corts, K. (1999). Conduct parameters and the measurement of market power. Journal of Econometrics, 88: 227-250.

7. Cowan, S. (2004). Demand shifts and imperfect competition. Discussion Paper No. 188, Oxford University.

8. Deb, P. (2012). FMM: Stata module to estimate finite mixture models. Statistical Software Components, Boston College Dept. of Economics (last modified 2012).

9. Draganska, M. and D. Jain (2005). Product‐Line Length as a Competitive Tool. Journal of Economics & Management Strategy, 14: 1-28.

10. Ellison, G. (1994). Theories of cartel stability and the joint executive committee. The Rand Journal of Economics, 25: 37-57.

11. Fuller, S., J. MacDonald, D. Bessler, and M. Wohlgenant (1998). Effect of Railroad Deregulation on Export-Grain Transportation Rate Structures. Texas FARMER Coalition.

12. Gal-Or, E. (1986). Information transmission—Cournot and Bertrand equilibria. The Review of Economic Studies, 53(1), 85-92.

13. González, A., A. Roque, and J. García-González (2005). Modeling and forecasting electricity prices with input/output hidden Markov models. IEEE Transactions on Power Systems, 20: 13-24.

14. Grant, D. (1999). Recycling and market power: A more general model and re-evaluation of the evidence. International Journal of Industrial Organization, 17: 59-80.

15. Hanson, S., S. Baumhover, and P. Baumel (1990). Characteristics of grain elevators that contract with railroads. American Journal of Agricultural Economics, 72: 1041-1046.

16. Hassan, M. and B. Nath (2005). Stock market forecasting using a hidden Markov model: a new approach. In Intelligent Systems Design and Applications (ISDA'05) proceedings, 5th International Conference, 192-196.

17. Henrickson, K. and W. Wilson (2010). Railroad Pricing, Market Power and Competitive Alternatives over Space. Working Paper, Dept. of Economics, Oregon State University.

18. Henrickson, K (2011). Spatial competition and geographic grain transportation demand on the Mississippi and Illinois rivers. Applied Economics, 43:1257-1269.

19. Johnson, M. (1981). Impacts on Agriculture of Deregulating the Transportation System. American Journal of Agricultural Economics (Proceedings), 63: 913-920.

20. Johnstone, A. (2009). Captive regulators, captive shippers: The legacy of McCarty Farms. Mont. L. Rev., 70: 239-272.

21. Koo, W., D. Tolliver, and J. Bitzan (1993). Railroad pricing in captive markets: an empirical study of North Dakota grain rates. The Logistics and Transportation Review, 29: 123-137.

22. Kwon, Y., M. Babcock, and L. Sorenson (1994). Railroad differential pricing in unregulated transportation markets-A Kansas case study. Logistics and Transportation Review, 30: 223-244.

23. Landen, C. (2000). Bond pricing in a hidden Markov model of the short rate. Finance and Stochastics, 4:371-389.

24. Leisch, F. (2004). Flexmix: A general framework for finite mixture models and latent class regression in R. Journal of Statistical Software, 11: 1-18.

25. MacDonald, J. and L. Cavalluzzo (1996). Railroad deregulation: Pricing reforms, shipper responses, and the effect on labor. Industrial and Labor Relations Review, 50: 80-91.

26. MacDonald, J. (1987). Competition and rail rates for the shipment of corn, soybeans, and wheat. The RAND Journal of Economics, 18: 151-163.

27. MacDonald, J. (1989). Effects of railroad deregulation on grain transportation. United States Dept. of Agriculture, Economic Research Service Report 1759.

28. McKamey, M. (2009). Analysis of rail rates for wheat rail transportation in Montana; comparing rates in a captive market to one with more intramodal competition. Doctoral dissertation, Kansas State University, Dept. of Agricultural Economics, Manhattan, KS.

29. Pittman, R. (2010). The Economics of Railroad "Captive Shipper" Legislation. Administrative Law Review, 62: 919-936.

30. Porter, R. (1983). A study of cartel stability: The Joint Executive Committee, 1880-1886. The Bell Journal of Economics, 14: 301-314.

31. Prater, M., A. Sparger, P. Bahizi, and D. O'Neil (2013). Rail market share of grain and oilseed transportation. Journal of the Transportation Research Forum, 52: 127-150.

32. Reiss, P. and F. Wolak (2007). Structural econometric modeling: Rationales and examples from industrial organization. Ch. 64 in Handbook of Econometrics (V6A), Elsevier, New York.

33. Richards, T., P. Patterson, and R. Acharya (2001). Price behavior in a dynamic oligopsony: Washington processing potatoes. American Journal of Agricultural Economics, 83: 259-271.

34. Rotemberg, J. J., and G. Saloner (1986). A supergame-theoretic model of price wars during booms. The American Economic Review, 76(3), 390-407.

35. Schrager, A. (2018). "A Nobel-winning economists guide to taming tech monopolies" (interview with J. Tirole), Quartz Magazine (online); https://qz.com/1310266/nobel-winning-economist-jean-tirole-on-how-to-regulate-tech-monopolies/, June 26.

36. Shy, O. (2008). How to Price: A guide to pricing techniques and yield management. Cambridge University Press, Cambridge, MA.

37. Spence, A. M. (1975). Monopoly, quality, and regulation. The Bell Journal of Economics, 417-429.

38. Spychalski, J. and P. Swan (2004). US rail freight performance under downsized regulation. Utilities Policy, 12: 165-179.

39. Tye, W. (1990). The Theory of Contestable Markets: Applications to Regulatory and Antitrust Problems in the Rail Industry. Contributions in Economics and Economic History, (N106).

40. Upper Great Plains Transportation Institute (2015). North Dakota Elevators Transportation Activities and Service, 2015 Survey. UGPTI, North Dakota State University, Fargo, ND.

41. Vachal, K., and L. Benson (2009). North Dakota Grain and Oilseed Transportation Statistics. Upper Great Plains Transportation Institute.

42. Vachal, K., J. Bitzan, and D. Tolliver (1996). Transportation as an Input to the North Dakota Agricultural Marketing Process (No. MPC Rept. No. 96-54). Upper Great Plains Transportation Institute, North Dakota State University.

43. Visser, I., and M. Speekenbrink (2010). DepmixS4: An R package for hidden Markov models. Journal of Statistical Software, 36: 1-21.

44. Vives, X. (1984). Duopoly information equilibrium: Cournot and Bertrand. Journal of Economic Theory, 34, 71-94.

45. Wilson, W. and F. Wolak (2016). Freight Rail Costing and Regulation: The Uniform Rail Costing System. Review of Industrial Organization, 49, 229-261.

45. Winston, C., S. Dennis, and V. Maheshri (2004). Duopoly equilibrium over time in the railroad industry. Working paper, Brookings Institution, Washington, DC.

46. Yu, W., and G. Sheblé (2006). Modeling electricity markets with hidden Markov model. Electric Power Systems Research, 76: 445-451.