Prices, Costs, and Markups for Differentiated Rail Networks

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Abstract

Regulators of the railroad industry are tasked with protecting shippers from excessive rates for shipments in which the railroad is market dominant, defined as an absence of effective competition from intramodal and intermodal competition. This task requires shipment costs at an extremely disaggregate level. The current regulatory accounting approach of allocating costs is heavily criticized and cost functions in the academic literature are generally highly aggregated. In this paper, I develop a method to measure costs and markups that retains their disaggregate properties. I then use these results to explore market dominance, wherein the markup and the presence of competition determine whether shippers may be eligible to contest the reasonableness of the rate. I find that a movement from rail monopoly to duopoly is associated with an average 6.8% decline in rail markups. The results suggest nearby ports decrease the impact of rail competition on rail markups. This approach can be operationalized by regulators and market participants to assess the reasonableness of a rate and to streamline and expedite market dominance inquiry.

***JEL* codes:** D4, K2, L1, L5, L9, R4
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The Surface Transportation Board (STB or Board) proposes a streamlined approach for pleading market dominance in rate reasonableness proceedings. The Board expects that this streamlined approach would reduce burdens on parties, expedite proceedings, and make the Board's rate relief procedures more accessible, especially for complainants with smaller cases.

Market Dominance Streamlined Approach: September 12, 2020

1 Introduction

At the national level the U.S. railroad industry is heavily concentrated, with four companies controlling over 90% of the national rail freight movement. At the more local level, however, rail markets are even more heavily concentrated. Railroads serve a number of unique origins and destinations, carry many commodities, and generally operate independent tracks, which contribute to varying degrees of geographic market concentration, especially on a local level (MacDonald and Cavalluzzo, 1996). Indeed, 95% of origin-destination-commodity defined outputs in this study have but one railroad that provide direct service. Railroads price movements at the origin-destination-commodity-shipment type level and therefore the number of outputs and prices is astronomically large. Railroads are also subject to economic regulation, where regulators are tasked with protecting captive shippers from excessive rates while ensuring rates are sufficient for railroads to remain revenue adequate. Regulators need accurate measures of shipment costs to assess whether the rate is excessive, and if so, determine market dominance, defined as "an absence of effective competition from other rail carriers or modes of transportation for the transportation to which a rate applies" (STB Ex Parte No 756, 2019). However, the current approach to measuring shipment costs, markups, and determining market dominance is heavily criticized, as "methods for assessing rate reasonableness lack a sound economic rationale and are unusable by most shippers; sounder and more economical methods are needed" (National Academies of Sciences, 2015).

In this paper, I examine costs, markups, and market dominance in the railroad industry. In contrast to the academic literature, which is aggregate in nature and estimates the average cost and markup over the network, I develop a method to measure costs and markups in a way that retains their disaggregate properties. I adapt and apply a quadratic cost function theoretically developed by Spady (1986), but to my knowledge has not been empirically implemented. The result yields shipment costs and markups and I use these results to explore market dominance, wherein the markup and the presence of transport competition determine whether shippers may be eligible to contest the reasonableness of the rate. For each shipment, I construct measures of intermodal and intramodal competition and estimate markups as a function of these measures of competition. I find that a movement from rail monopoly to duopoly is associated with an average 6.8% decline in rail markups. The results suggest an interaction between intermodal and intramodal competition, where nearby ports decrease the impact of rail competition on rail markups. While current market dominance analysis relies on testimony from an expert witness, my model provides an empirical analysis of how the presence of transport competition impact shipment markups. This approach can be operationalized by regulators and market participants to assess the reasonableness of a rate and to streamline and expedite market dominance inquiry.

Current rail regulations assess the reasonableness of a rate with an accounting cost allocation procedure, the Uniform Rail Costing System (URCS). URCS is a practical and transparent accounting procedure that provides the cost of a generic shipment; however, this approach has been heavily criticized. Regulators commissioned a study performed by Christensen Associates who found inconsistent revenue to variable cost ratios used for determining the reasonableness of a rate and recommended that "more appropriate measures of captivity should focus on the effects of the transportation market structure on rail rates, and by extension, markups" (Laurits R. Christensen Associates, 2009). More recently, the Transportation Research Board found the URCS cost allocations to be invalid and unrealiable (National Academies of Sciences, 2015). Although URCS provides accounting costs at a disaggregate level, it is "unable to provide a cost measure that a profit-maximizing railroad would use to make operating decisions" and should be abandoned (Wilson and Wolak, 2016). In contrast to the disaggregate accounting approach of URCS, there is a rich and long-lasting academic literature on railroad economic costs and markups. But these studies rely on highly aggregated measure of output and estimate the average cost over the rail network (Keeler, 1983; Chiang and Friedlaender, 1985; Bitzan and Wilson, 2003) or the average markup over the rail network (Ivaldi and McCullough, 2007; Coublucq, 2013; McKenzie and Wilson, 2016). To the best of my knowledge, there are few, if any, published studies that evaluate and consistently estimate the economic relationship between shipment costs, markups, and transport competition at a disaggregate level.

My research confronts these issues directly by modeling railroad operations with a multiproduct cost function that exploits the aggregation property of the quadratic model. The quadratic approach models economics costs using first and second moments of costs, product, and technological features in a way that retains their disaggregate properties. The results from the quadratic approach suggests shipment economic costs lower relative to URCS costs and disaggregate markups similar to previous studies of aggregate markups. I then use these shipment markups to quantify the relationship between markups and transport competition and find evidence of commodity heterogeneity. My model incorporates intramodal and intermodal competition and can be used in market dominance inquiry to streamline and expedite procedures.

The remainder of the paper proceeds as follows. Section 2 provides a brief overview of the history of the railroad industry and rail regulation in the US. Section 3 reviews the literature on costs and markups, particularly as they apply to modeling the railroad industry. Section 4 provides a theory of costs, markups, and market dominance. In Section 5, I discuss the data sources in greater depth, the process to assemble the data set, and some summary statistics. I present the results of the empirical estimation in Section 6. Finally, Section 7 provides some discussion and concluding remarks.

2 Background

This section provides background of the U.S. railroad industry, its regulation and partial deregulation, and how the industry has responded to these regulatory changes. The first subsection describes the inception of the industry and the impetus for regulation. The second subsection describes rail industry deregulation and the current approach to measuring rail markups. The third subsection describes how rail markups assist regulators in enforcing rail regulations.

2.1 Railroads and Regulation

Transportation is a vital service impacting virtually all economic activities. In the context of railroads, these networks played an important role in the rapid expansion and development of the U.S. economy, as they helped facilitate the growth of other sectors such as agriculture and energy production (Brown, 2013). In the beginning, rail transportation faced little competition, as it was faster, more comfortable, and the only option for traveling long distances in a reasonable amount of time (Brown, 2013). As a result, railroads were successful and the industry flourished.

However, there are features inherent in railroad operations that result in highly concentrated markets. Large fixed factor investments in conjunction with the geographic nature of the railroad industry exacerbate market concentration and result in high degrees of market power. This market power allowed railroads to engage in discriminatory pricing, offering bulk discounts to large corporations and charging high shipping rates to small shippers such as farmers and small businesses (Miller, 1954). Railroads also experience scale economies (Caves et al., 1981; Friedlaender and Spady, 1981; Wilson, 1997), and theory suggests regulators may improve market outcomes in industries with market power and scale economies (Faulhaber, 1975; Baumol et al., 1983; Keeler, 1983). Thus, regulators are tasked with balancing the harm caused by market power with the efficiency gains from natural monopoly

(National Academies of Sciences, 2015; Schmalensee and Wilson, 2016; STB, 2019b).

Federal railroad regulation began with the Interstate Commerce Act (ICA) of 1887, making railroads the first industry subject to federal regulation. The ICA sought to outlaw discriminatory rate-setting and establish a common carrier obligation to service specific rail routes. To accomplish its goal, the ICA established the Interstate Commerce Commission (ICC), an agency charged with regulating the transportation of goods and services between states. The ICC provided regulatory oversight of railroads in terms of minimum and maximum rates, merger activity, and punishment of collusive behavior (Keeler, 1983). Unfortunately for the ICC, determining which rates were discriminatory proved to be outside the the scope of the ICA.

With regulation came the need for more accurate measures of shipment costs. Rail costing became a priority for the ICC. Established in 1939, Rail Form A (RFA) became the workhorse costing methodology for the ICC. RFA takes an accounting-based approach to explain the costs of performing various railroad activities, including track maintenance, freight car repairs, and road train inspection.[1] Although RFA helped establish a consistent approach to allocating rail costs, the declining financial health of the rail industry post World War II along with several high profile railroad bankruptcies of the 1970s exposed the need for more rail rate flexibility. That is, if the industry were to survive and attract the capital necessary to sustain the rail network, then rates would need to be adjusted in order to protect profits.

2.2 Partial Deregulation and Its Effect on the Industry

The financial ruin of several large railroads in the 1970s highlighted the need for more freedom in operational decisions. New competing forms of transportation such as barges, trucks, and airplanes reduced the market power of railroads. As demand for rail transportation

[1]The costs associated with certain activities is then regressed on capacity measures (i.e. track miles) and output measures (i.e. train miles) via Ordinary Least Squares (OLS). Next, regulators determine the amount of output associated with specific shipments (i.e. train miles) and its impact on the various railroad activities. Finally, a measure of accounting costs is estimated based on these relationships.

fell, it became clear that the stability of the industry relied heavily on giving railroads more freedom and removing unneccessary regulations. Railroad deregulation began with the Railroad Revitalization and Regulatory Reform (4-R) Act of 1976, which reduced price regulations and gave firms more control over entry and exit decisions.

The Staggers Rail Act of 1980 relaxed constraints on the rates railroads can charge, the lines over which they can operate, on merger activity, as well as a wide array of other activities. Staggers substantially reduced the level of inefficiency in the market, increased productivity, and led to substantial declines in railroad costs and prices (Wilson and Burton, 1994; Bitzan, 2003). As a direct response to the high profile railroad failures of the 1970s, Staggers requires an annual revenue adequacy check to ensure the railroads, "achieve a rate of return sufficient to attract the capital necessary for long-term financial viability" (National Academies of Sciences, 2015). Some regulations remained in place, however, such as protecting rail shippers from excessive rates and from loss of service in markets that lacked alternative transportation options.

Current rail regulation relies on the Uniform Rail Costing System (URCS) to estimate the cost of a shipment.[2] Designed to "protect shippers from excessively high rates, to ensure revenue adequecy of the railroads, as well as the long-term financial viability of the industry" (STB, 2016), URCS takes an accounting based approach to estimating the "variable cost" of a generic type of shipment.[3] However, for contracting and regulatory purposes, rail rates are based on the origin-destination-commodity of the shipment. Defining a market at the origin-destination-commodity level results in an overwhelmingly large number of markets, as there exists over ten thousand rail stations and over one thousand different commodities at the STCC5 level. The "variable cost" generated by URCS is too generic for regulatory purposes, as railroad market concentration and operational expenses exhibit spatial heterogeneity, in

[2]URCS documentation can be found at the following website
`https://www.stb.gov/stb/docs/URCS/URCS%20User%20Manual.pdf`

[3]Note that the Interstate Commerce Commission measure of "variable cost" is a weighted average of total costs from individual railroad cost categories, whereas the economic definition of variable cost is a cost that varies with the level of output. See the Appendix for documentation.

part due to the massively multiproduct nature of the railroad industry. As a result, URCS has been heavily criticized. Regulators commissioned a report of the rail industry and found inconsistent revenue to variable cost ratios used for determining the reasonableness of a rate and recommended that "more appropriate measures of captivity should focus on the effects of the transportation market structure on rail rates, and by extension, markups" (Laurits R. Christensen Associates, 2009). Indeed, the Transportation Research Board found the URCS cost allocations to be invalid and unrealiable (National Academies of Sciences, 2015). Although URCS provides accounting costs at a disaggregate level, it is "unable to provide a cost measure that a profit-maximizing railroad would use to make operating decisions" and should be abandoned (Wilson and Wolak, 2016). Nevertheless, this congressionally mandated accounting based approach serves as the current regulatory tool for screening excessive rates.

2.3 Markups and Market Dominance

For regulatory purposes, rail shipments are classified into three rate categories. These include: 1. Exempt; 2. Contract; 3. Tariff rates. The first category contains shipments where the railroad faces adequate competition for the rail service from trucks. These shipments are automatically exempt from rate relief. The second category contains shipments that are negotiated contract rates, and these shipments are also automatically exempt from rate relief. The third category contains shipments that are transported under posted tariff rates and are confidential. If these goods cannot be competitively moved by truck, then they are eligible to be challenged and may be eligible for rate relief. To assess rate relief eligibility for category three shipments, regulations require that the revenue to URCS variable cost ratio exceed 180 percent.[4] Given that revenue to variable cost exceed 180 percent, the STB must also find that the railroad is market dominant over the movement, defined as "an absence of effective competition from other rail carriers or modes of transportation for the trans-

[4]Shipments with markups less than the threshold are automatically reasonable and cannot be challenged.

portation to which a rate applies" (STB Ex Parte No 756, 2019). With the burden of proof for showing market dominance is on the shipper, rate relief is inaccessible to many market participants.

Given the rate is excessive and the railroad is found to be market dominant, shippers can use three different methodologies to contest the reasonableness of a rate. However, contesting the reasonableness of a rate is expensive and time-consuming (National Academies of Sciences, 2015). The Stand-Alone Cost (SAC) test establishes the cost of facilitating the movement to an individual consumer, as if a separate hypothetical railroad were built for just that traffic. This approach is inaccessible to small shippers and has been heavily criticized (Tye, 1986; Pittman, 2010; National Academies of Sciences, 2015).[5] In an attempt to make rate relief more accessible to smaller shippers, the STB created the Simplified-SAC test (STB Ex Parte No 646, 2007). Unfortunately, the "simplified procedures have not overcome these deficiencies and in some respects have made matters worse" by offering even less predictible decision criteria (National Academies of Sciences, 2015). The STB also allows shippers to contest the reasonableness of a rate through the Three-Benchmark test "for which even a Simplified-SAC presentation would be too costly, given the value of the case" (STB Ex Parte No 646, 2007). Although this approach is relatively straight-forward to implement, it relies heavily on URCS to provide a realistic estimate of cost.

From 1996 to 2019, there have been only 51 rate cases filed with the STB, with only 12 resulting in an unreasonable rate.[6] In order to "reduce burdens on parties, expedite proceedings, and make the Board's rate relief procedures more accessible, especially for complainants with smaller cases", the STB recently approved an alternative way to gauge market dominance (STB Ex Parte No 756, 2020). This streamlined approach allows shippers to establish prima facie market dominance by satisfying the following factors:

[5] Indeed, the author of the SAC test states it was "developed for an economic world of profit-constrained rate regulated monopoly, which is not at all like the largely unregulated, not profit-constrained and world of seven major rail networks that constitute this industry" (Faulhaber, 2014).

[6] Of the remaining 39 cases, two were withdrawn and 26 resulted in a settlement (STB, 2019a).

1. The movement has an R/VC ratio of 180% or greater
2. The movement would exceed 500 highway miles between origin and destination
3. There is no intramodal competition from other railroads
4. There is no barge competition
5. There is no pipeline competition
6. The complainant has used truck for 10% or less of its volume (by tonnage) subject to the rate at issue over a five-year period and the complainant has no practical build-out alternative due to physical, regulatory, financial, or other issues (or combination of issues)

This approach highlights the interconnectedness of rail markups, intermodal, and intramodal competition. However, factors three, four, and five for intramodal and intermodal competition are qualitative.[7] The STB states that a shipper may satisfy these components by submitting a verified statement from an "appropriate official". Thus, access to the empirical relationship between shipment rail markups and transport competition may help regulators and market participants in assessing the reasonableness of a rate.

3 Literature Review

This section highlights existing literature related to modeling operations of the firm and how these models have been applied to analyze the structure and competition of the railroad industry. The first subsection briefly describes the evolution of econometric models of costs and markups. The second subsection focuses on how these methodologies have been used to evaluate the structure of the railroad industry.

3.1 Costs and Markups

There is a long history of empirical studies on cost and a long history of applications to the railroad industry.[8] There are many approaches to estimating costs, but most of the

[7]Intermodal and intramodal competition must transport the same commodity between the same origin-destination of the rate in question.

[8]See, for example, Keeler (1983); Chiang and Friedlaender (1985); Bitzan and Wilson (2003).

literature for the last 50 years has focused on the importance of using flexible forms to gauge the structure of costs and productivity through time. The workhorse of this literature is the transcendental logarithmic (translog) function (Christensen et al., 1973). Advantages of the translog function follow from its flexibility and relatively few restrictions it places on the production structure of the firm.

Quadratic cost functions provide a functional form that help account for non-linearities in the factors of production. Suggested by Baumol et al. (1983), Spady (1986) extends this approach by indexing individual production units. The quadratic cost function has a convenient aggregation property that helps facilitate its estimation econometrically. This flexible technique can be used to overcome issues of dimensionality by modeling aggregate costs with first and second moments of production units and remains parsimonious in parameters. Spady notes that these functions are capable of modeling multiproduct network technologies; however, this approach has yet to be applied to transport industries.

Markups and market power are of growing interests in applied economic research, with recent work suggesting market power supresses wages (Azar et al., 2018) and impacts macroeconomic growth (Loecker et al., 2019). Market power is important across various dimensions, with effects nationally and globally, both in traditional and nascent markets (Azar et al., 2017). Modern empirical industrial organization methods estimate markups by analyzing demand in the characteristics space as opposed to the product space (Berry et al., 1995). This approach has many attractive features that make the analysis for differentiated products tractible, starting with aggregate data and allowing for flexible substitution patterns between products. There also exists an alternative production-approach to recovering markups that relies on standard cost minimization conditions. Hall (1988) developed a model of firm behavior that recovers industry-specific markups from production data. Based on a production function, this approach relies on observing inputs and the total value of shipments. De Loecker and Warzynski (2012) adapt this approach by estimating markups through output elasticities.

3.2 Identifying Non-Competitive Behavior

There is evidence that rail rates are responsive to the presence of transport competition (MacDonald, 1987). Rail rates for three major grains are estimated based on measures of intermodal and intramodal competition, such as proximity to competing railroads and distance to barge. The model suggests a move from rail monopoly to duopoly is associated with an 18% decrease in rates. Wilson and Train (2007) model transport mode choice for consumers faced with a choice between rail and barge. Their results suggest access costs, barge and rail rates, and shippers' attributes play an important role in determining which mode consumers select. Anderson and Wilson (2005) examine the relationship between truck-barge and railroads. Their theoretical model suggests a direct relationship between markups and mode choice. In the National Academies of Sciences (2015) study, the authors introduce a benchmarking approach. In this approach, they estimate a pricing relation with measures of competition and identify potentially non-competitive rail rates in excess of rates expected in competitive markets. Controlling for proximity to transport competition allows them to construct benchmark competitive prices, which they compare to actual prices to assess the reasonableness of a rate. In a more recent study, Wilson and Wolak (2020) refine the benchmarking approach to handle additional commodities. This empirical relationship is important in designing tranport regulations; however, a more relevant measure of rate reasonableness should also incorporate costs.

There is a long history of estimating cost functions for railroads; however, many issues that were raised are still of concern today (Winston, 1985). In contrast to the disaggregate accounting approach of URCS, the academic literature of railroad economic costs and markups are aggregate in nature and estimate the average cost over the network (Keeler, 1983; Chiang and Friedlaender, 1985; Bitzan and Wilson, 2003) or the average markup over the network (Ivaldi and McCullough, 2007; Coublucq, 2013; McKenzie and Wilson, 2016). Most rail cost studies use aggregate measures of output and assume railroad output is homogeneous (Spady and Friedlaender, 1978; Caves et al., 1981; Harmatuck, 1981; Caves et al., 2002). Brown et al. (1979) relax this assumption and show the neoclassical cost function provides a flexible multiproduct approach to estimating rail costs. Chiang and Friedlaender (1985) extend the single generic output translog cost function to multiple generic outputs in the motor carrier industry and Bitzan and Wilson (2003) incorporate product heterogeneity via a hedonic translog cost function to model rates in the railroad industry.[9] However, they find that the translog cost function does not perform well for costing individual shipments. Ivaldi and McCullough (2007) use a Generalized McFadden cost function and estimate car-type-specific costs to assess whether Class I railroads are revenue adequate. This approach incorporates the multiproduct nature of railroads but is unable to provide costs at a disaggregate level.

Markups and market dominance in the railroad industry are of considerable interest. Founded in antitrust litigation, the concept of market dominance incorporates both product and geographic competition (Eaton and Center, 1985). Wilson (1996) derives a theoretical model of railroad pricing and markups to examine the regulatory rules defining market dominance. Coublucq (2013) estimates a structural model of the railroad industry to examine the impact of mergers and acquisitions post-Staggers on costs, markups, and consumer welfare. The results suggest increases in firm markups throughout time at an aggregate level. McKenzie and Wilson (2016) estimate markups and scale elasticities in the railroad industry based on production relations. They estimate the model in a Bayesian framework and find markups are well in excess of marginal costs. Their model provides estimates of rail specific markups, which represent the average markup generated from traffic on each firm's network; however, averages often mask underlying heterogeneity.

[9] See Bitzan and Wilson (2007) Table B.1 for a more detailed timeline of advances in rail costing techniques.

4 Conceptual Framework

The problem of estimating markups is isomorphic to the problem of estimating costs. To obtain shipment costs, I model firm-level railroad operations using a quadratic cost function proposed by Spady (1986). The main benefit of modeling railroad costs with this method is that cost estimates reflect shipment features that may influence cost, and thus, markups. The firm can view its costs of producing vector output y at factor prices p under technological conditions t; denoting (y, t) by z:

$$c = \alpha_0 h_0 + \sum_k \alpha_k h_k(p) z_k + \sum_k \sum_m \beta_{km} \phi_{km}(p) z_k z_m \tag{1}$$

An attractive feature of the quadratic cost function resides in its aggregation properties. Suppose that 1 has s shipments and there exists a price index $h(p)$ that is common to all factors of production.[10] Denote the z and c of the i^{th} shipment by z^i and c^i, and the mean of z by $\bar{z}$. Defining $\epsilon^i = z^i - \bar{z}$ allows 1 to be written as:

$$c^i = \alpha_0 h(p) + \sum_k \alpha_k h(p)(\bar{z}_k + \epsilon^i_k) + \sum_k \sum_m \beta_{km} h(p)(\bar{z}_k + \epsilon^i_k)(\bar{z}_m + \epsilon^i_m) \tag{2}$$

Summing 2 over the s shipments yields:

$$\begin{aligned} C &= \sum_s c^i && (3) \\ &= h(p)s\left[\alpha_0 + \sum_k \alpha_k \bar{z}_k + \sum_k \sum_m \beta_{km}(\bar{z}_k \bar{z}_m + \sigma_{km})\right] && (4) \end{aligned}$$

where $\sigma_{km} = \frac{1}{s} \sum_s \epsilon^i_k \epsilon^i_m$ represents the covariance of z_k and z_m. A convenient reexpression of 3 is:

[10]The common price index assumption can be relaxed; however, access to a common price index keeps the model econometrically tractible.

$$\bar{c} \equiv \frac{C}{h(p)s} \tag{5}$$

$$= \alpha_0 + \sum_k \alpha_k \bar{z}_k + \sum_k \sum_m \beta_{km}(\bar{z}_k \bar{z}_m + \sigma_{km}) \tag{6}$$

where $\bar{c}$ is the average cost per shipment and $c(\bar{z})$ is the production unit level quadratic cost function at mean z. Thus, the number of units and the means and variances of the outputs and characteristics provide an exact representation of the aggregate technology.

Modeling shipment costs allows the construction of shipment price-cost markups given by:

$$\mu_i = \frac{r_i}{c_i} \tag{7}$$

where μ_i is the shipment price-cost markup, r_i is the shipment rail rate, and c_i is shipment cost for shipment i. With markups at a disaggregate level, I model the spatial relationship between shipment markups and proximity to transport competition:

$$\log(\mu_i) = \phi_0 + water_i + rail_i \tag{8}$$

where $water_i$ represents competition of waterway transport and $rail_i$ represents competition of rail transport. This approach incorporates the spatial heterogeneity of rail markups as they relate to transport competition, an important component of market dominance inquiry.

5 Data

The primary sources of the data are the Surface Transportation Board (STB) confidential Annual Carload Waybill Sample, the R-1 Annual Report of Finances and Operations, the Oakridge National Laboratory CTA Railroad Network, and the U.S. Army Corps of Engineers Port Series. The waybill data is a confidential and detailed dataset that contains shipment and product characteristics. In the R-1 data, I observe railroad cost components that I use to construct a measure of total annual cost for each railroad. The Oakridge data provides every railroad in North America that has been active since 1993, which I use to construct measures of intramodal competition. The Port Series data provides every port in the U.S., which I use to construct measures of intermodal competition.

The waybill data provides shipment product characteristics for over 369 million shipments covering all Class 1 railroads over the 2000 through 2016 period.[11] These data are a stratified random sample which represents at least 2.5% of all shipments each year. To account for the stratified sampling procedure, I weight each observation by the inverse of its sampling probability.[12] Observations include information of each shipment's rate, URCS variable cost, distance, tons, cars, car type, origin, and destination. The waybill data also contain the Standard Point Location Code (SPLC) that identifies the origin and destination of each shipment. Throughout the sample, there are 119 firm years. The seven Class 1 railroads are comprised of BNSF Railway Co., CSX Transportation, Grand Trunk Corporation[13], Kansas City Southern Railway, Norfolk Southern, Soo Line Corporation[14], and Union Pacific Railroad. In 2016, these seven railroads accounted for 68% of US freight rail mileage, 88% of employees, and 94% of revenue (JOC, 2016).

As noted in Ivaldi and McCullough (2007), different car types have different cost and demand characteristics. Inspection of the data suggests that there is a near perfect correspondence of commodity to car type. Thus, I follow the literature and group each shipment into one of five car type categories: box cars, gondola cars, hopper cars, flat cars, and tank cars. Figure 1 visualizes the relationship between commodity and car type with firm-year averages over the sample. The top displays the number of tons of each commodity by car

[11] Due to substantial merger activity in the 1980's and 90's, I focus on data beginning in year 2000.
[12] Wolfe (2004) provides a more complete description of the waybill data.
[13] Canadian National's operations
[14] Canadian Pacific's operations.

type. The bottom displays revenue of each commodity by car type.[15] Commodity and car type are highly correlated, as the major commodities tend to travel in predictable car types. I leverage this relationship in the empirical section to incorporate the multiproduct features of railroad operations while also keeping the cost function tractible econometrically.

I use the R-1 data for firm-year components of cost, which provide financial and operating information for Class 1 railroads. The R-1 report is the result of railroads reporting to the Interstate Commerce Commission (ICC) and the Surface Transportation Board (STB) and is available for all railroads and all years of the sample. Based on these self-reported figures, I follow the literature (Bitzan and Wilson, 2007) and construct an annual measure of total cost for each of the seven Class 1 railroads:

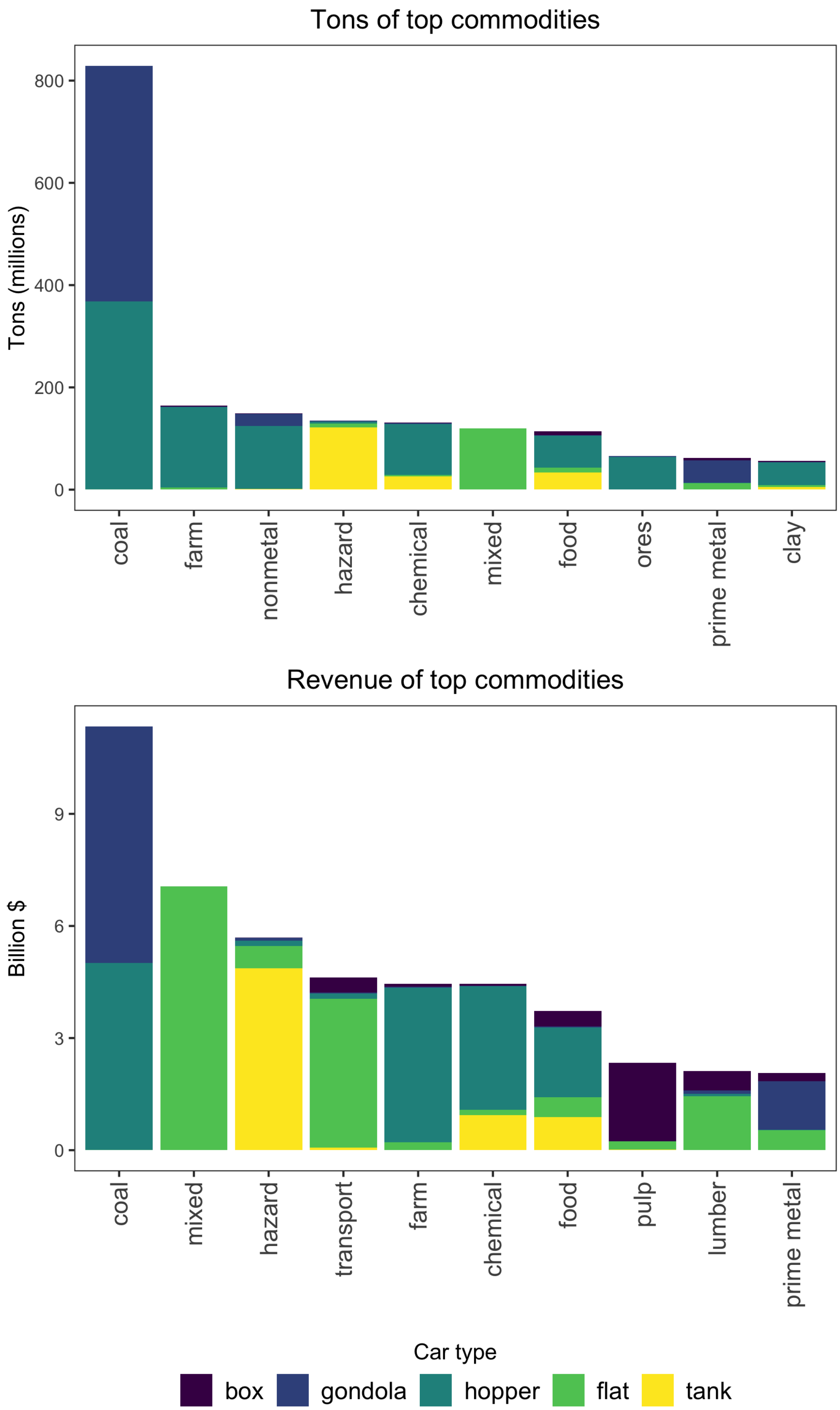
$$C = OpCost - CapExp + RoiRd + RoiLcm + RoiCrs \tag{9}$$

where C is total annual cost, $OpCost$ is operating cost, $CapExp$ is capital expenditure, $RoiRd$ is return on investment in road, $RoiLcm$ is return on investment in locomotives, and $RoiCrs$ is the return on investment in cars.[16] Figure 2 displays annual firm-level cost for the Class 1 railroads.

I use the Oakridge and Port Series data to construct measures of transport competition. The Oakridge data provide spatial coordinates for every railroad route that has been active throughout the sample.[17] I use these data to quantify railroad competition, where I measure the distance from each shipment SPLC to competing railroads. Similarly, I use the Port Series data to measure the presence of water competition. These data provide the location of ports on U.S. waterways along with the commodities handled by each port.[18] I use these data to quantify waterway competition by measuring the distance from each shipment SPLC to the nearest port. For rail competition, I observe 37,721 SPLC points. Figure 3 displays

[15] This figure excludes masked shipments in which I do not observe the rate.
[16] These variables, and all other variables, are defined in Table A.0.
[17] `http://www-cta.ornl.gov/transnet/RailRoads.html`
[18] `http://www.navigationdatacenter.us/ports/ports.htm`

Figure 1


Tons of top commodities
Tons (millions)
800
600
400
200
0
coal
farm
nonmetal
hazard
chemical
mixed
food
ores
prime metal
clay
Revenue of top commodities
Billion $
9
6
3
0
coal
mixed
hazard
transport
farm
chemical
food
pulp
lumber
prime metal
Car type
box
gondola
hopper
flat
tank

a histogram of rail competition for all SPLCs in the US. Notice that the modal SPLC is serviced by one Class 1 railroad and one regional railroad.

Finally, I follow the literature and account for changes in factor prices using the productivity-adjusted Railroad Cost Adjustment Factor (RCAF-A) index (Ivaldi and McCullough, 2007). This index is used for regulatory purposes and provides a convenient measure that reflects changes in the price of major railroad operating costs such as labor, fuel, materials, equipments rents, and interest on debt (National Academies of Sciences, 2015). The RCAF-A is published annually by the Association of American Railroads (AAR) and submitted to the STB for approval.[19]

6 Results

In this section, I present the results for shipment price-cost markups and how they relate to transport competition. The first subsection estimates a quadratic cost function for railroads. The second subsection constructs markups by pairing cost estimates with observed rates. The final subsection estimates these markups as a function of transport competition.

6.1 Cost

In this section, I present the results for shipment costs. I start by using the full waybill sample to estimate a quadratic cost function for railroads. The variables described in the preceding paragraphs will now be used to estimate equation 5. In this regard, I estimate shipment costs using the following form:

$$\bar{c}_{it} = \sum_k \alpha_k \bar{z}_k + \sum_k \sum_m \beta_{km} [\bar{z}_k \bar{z}_m + \sigma_{km}] + \kappa_{it} + \phi_i + \lambda_t + \varepsilon_{it} \tag{10}$$

[19] https://www.aar.org/wp-content/uploads/2018/03/Index_RCAFDescription.pdf

Figure 2
Annual Cost for Class I Railroads

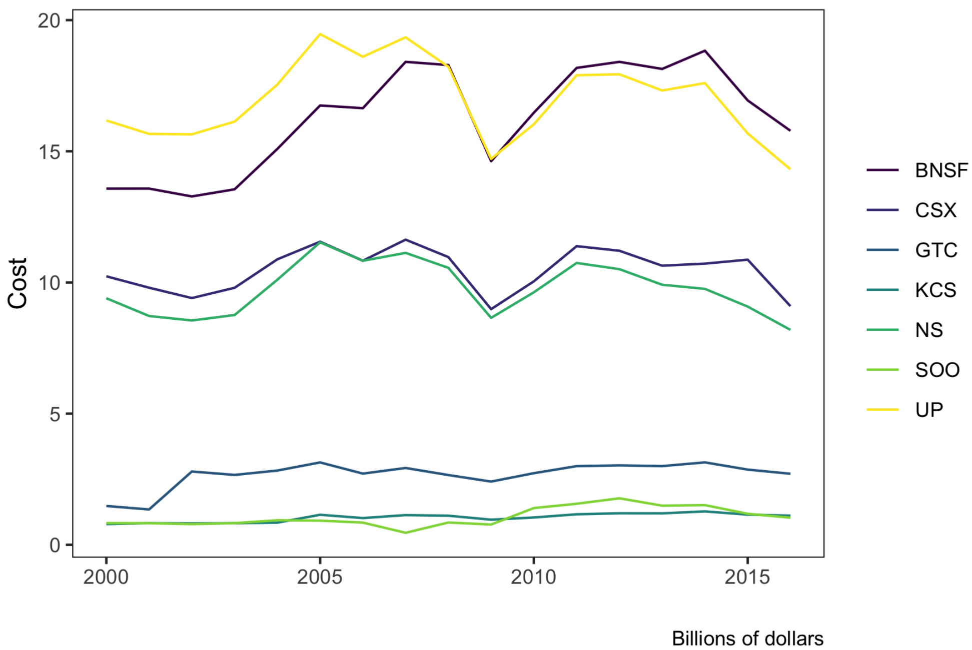
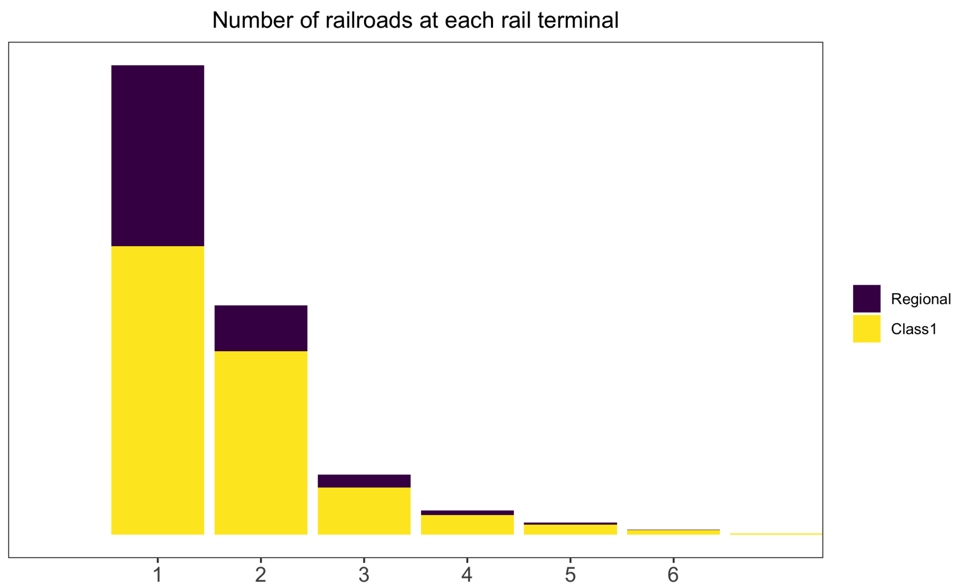


Figure 3



where $\bar{c}_{it}$ is firm cost per shipment for firm i. Product and technological characteristics ($\bar{z}_k$) include average distance, average tons, and average unit. Average unit is defined as the percent of total shipments that have 50 or more cars. Car type is defined as the percent of total shipments using the specific car type. Additionally, σ_{km} represents the covariance between product characteristics, such as average distance, average tons, and average unit. Car type controls κ_{it} represent the percentage of shipments that use a specific car type within a given firm-year. Distance, tons, and unit help control for product characteristics, while car type controls proxy for commodity. Firm fixed effects (ϕ_i) control for firm level differences that affect firm cost per shipment. Year fixed effects (λ_t) control for changes that affect cost in all markets.

Table 1 displays the results of equation 10, where average distance, average tons, and average unit are statistically significant across all specifications. Note that cost is increasing in ton-miles ($\bar{d} \cdot \bar{n}$) and is statistically significant across all specifications.[20] I use model (4) as the preferred specification for the remainder of the analysis, as it accounts for features that are known to be associated with costs and also incorporates the multiproduct nature of railroad operations through car type controls. Recall that the quadratic cost function allows for non-linearities in the production units. Thus, to better understand the marginal impact for product and technological characteristics, I present marginal cost per shipment in Figure 4. In line with economic theory, costs are increasing in both distance and tons.

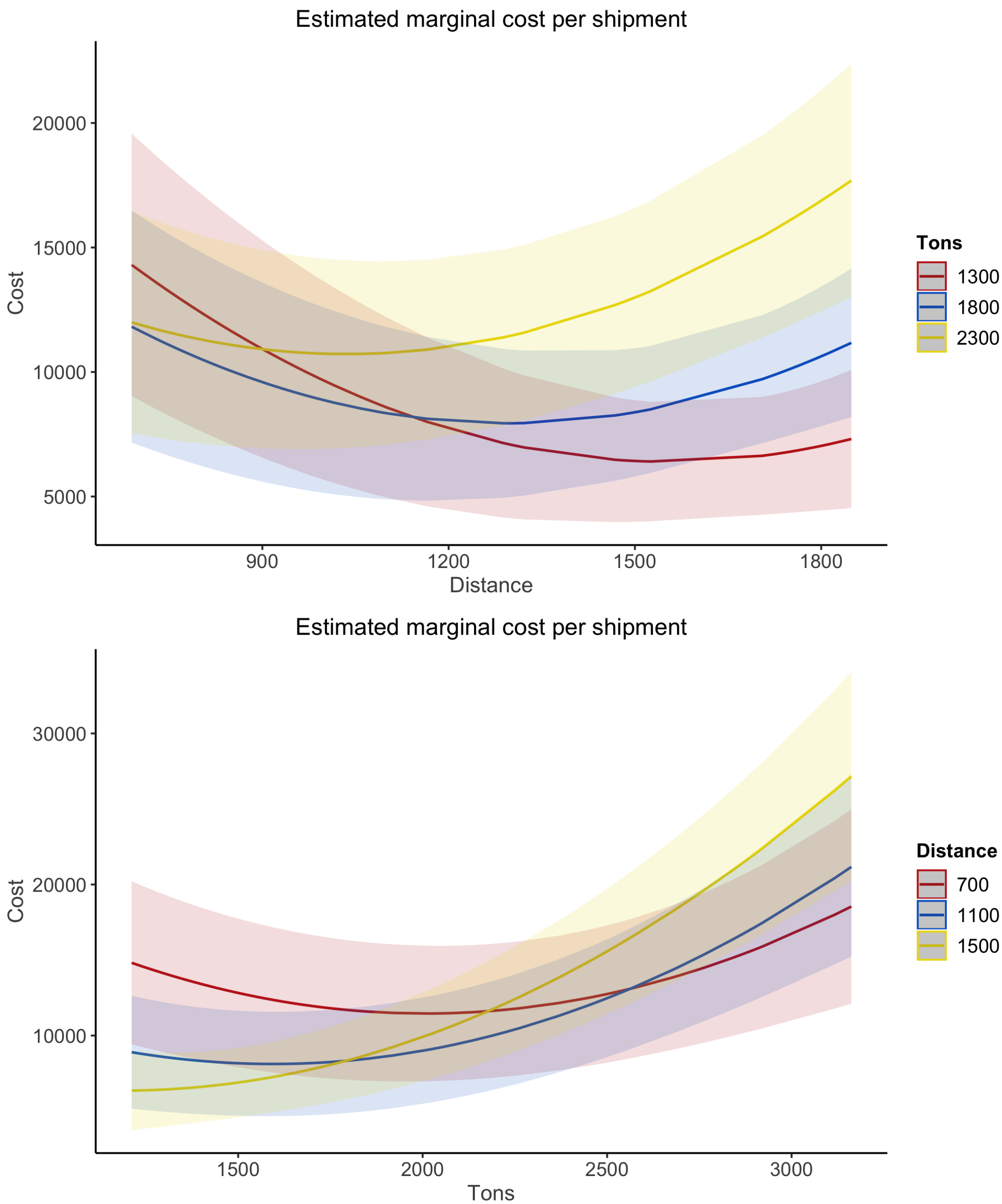
[20]I present shipment cost comparisons in the Appendix Figure A.2.

Table 1
Quadratic Cost Estimates

	$\bar{c}$			
	(1)	(2)	(3)	(4)
$\bar{d}$ (distance)	-55.66^{***}	-55.25^{***}	-47.06^{***}	-47.71^{***}
	(8.65)	(8.43)	(7.94)	(7.97)
$\bar{n}$ (tons)	-11.75^{***}	-16.45^{***}	-18.84^{***}	-21.69^{***}
	(3.69)	(4.46)	(3.74)	(4.47)
$\bar{u}$ (unit)			822,644.20	829,268.10
			(660,337.60)	(671,011.60)
$\bar{d} \cdot \bar{n}$	0.01^{***}	0.01^{***}	0.01^{***}	0.01^{***}
	(0.002)	(0.002)	(0.002)	(0.002)
$\bar{d} \cdot \bar{u}$			251.46	143.57
			(479.82)	(516.16)
$\bar{n} \cdot \bar{u}$			$-1{,}615.22^{***}$	$-1{,}609.33^{***}$
			(420.98)	(433.66)
$\bar{d}^2$	0.01^{***}	0.01^{***}	0.01^{***}	0.01^{***}
	(0.002)	(0.002)	(0.002)	(0.002)
$\bar{n}^2$	0.001	0.001	0.01^{***}	0.01^{***}
	(0.001)	(0.001)	(0.001)	(0.001)
$\bar{u}^2$			$156{,}568{,}285.00^{**}$	$153{,}227{,}876.00^{**}$
			(60,964,790.00)	(61,186,869.00)
$\sigma_{\bar{n}\bar{d}}$	-0.0002	0.0000	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
$\sigma_{\bar{n}\bar{u}}$			24.24	33.86^{*}
			(17.45)	(18.56)
$\sigma_{\bar{d}\bar{u}}$			-284.04	-270.57
			(254.68)	(272.50)
Car controls?	No	Yes	No	Yes
Firm, Year FEs?	Yes	Yes	Yes	Yes
Observations	119	119	119	119
R^2	0.94	0.95	0.96	0.96

Notes: This table reports estimates of Equation 10. An observation is a year. The dependent variable is cost per shipment. Annual fixed effects are included. Heteroskedastic robust standard errors in parentheses. Stars indicate p values: *p<0.1; **p<0.05; ***p<0.01

Figure 4



Estimated marginal cost per shipment
Cost
20000
15000
10000
5000
900
1200
1500
1800
Distance
Tons
1300
1800
2300
Estimated marginal cost per shipment
Cost
30000
20000
10000
1500
2000
2500
3000
Tons
Distance
700
1100
1500

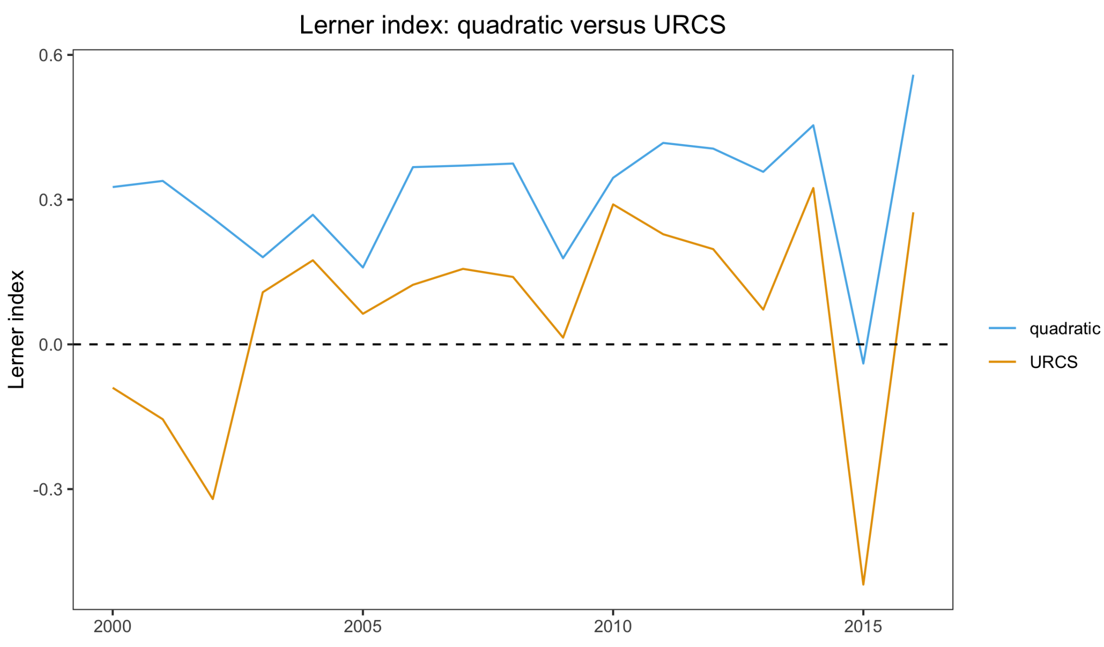
6.2 Markups

In this section, I use the results from the quadratic cost function along with observed rail rates to construct shipment price-cost markups. I construct Lerner indices given by:

$$\eta = \frac{\sum_{i=1}^{S} \frac{r_i - c_i}{c_i}}{S} \tag{11}$$

where η is the Lerner index, r_i is the rate for shipment i, c_i is the cost for shipment i, and S is the total number of shipments. In Figure 5, I present a time-series of markups calculated using different cost methodologies. It appears that, on average, both costing approaches are picking up similar market trends throughout time. Note that although URCS suggests competitive behavior, estimating shipment costs with the quadratic cost function suggests relatively healthy markups. Note that while URCS suggests 20 to 30% of shipments have costs exceeding revenue, the quadratic approach reduces amount to 7%.

Figure 5



Recall that for regulatory purposes, only shipments that exceed a price-cost markup threshold are eligible for rate relief inquiry. To better understand shipment markups, I compare quadratic price-cost markups to URCS price-cost markups for identical shipments, given by:

$$\mu_i = \frac{r_i}{c_i} \tag{12}$$

where μ_i is the price-cost markup, r_i is the rate, and c_i is the cost for shipment i. If the quadratic approach and the URCS method yielded identical estimates for markups, then plotting the estimated values against each other graphically would yield a 45-degree line. Figure 6 compares the price-cost markups for a random sample of 1,000 shipments. The two cost approaches provide similar markups for smaller shipments; however, as the value of the shipment increases, the quadratic model estimates markups larger than those produced using URCS. Notice the URCS approach yields a clustering of shipments close the price-cost markup threshold of 180%, which suggests railroads price shipments near the threshold to increase profits and avoid the dispute resolution process.[21]

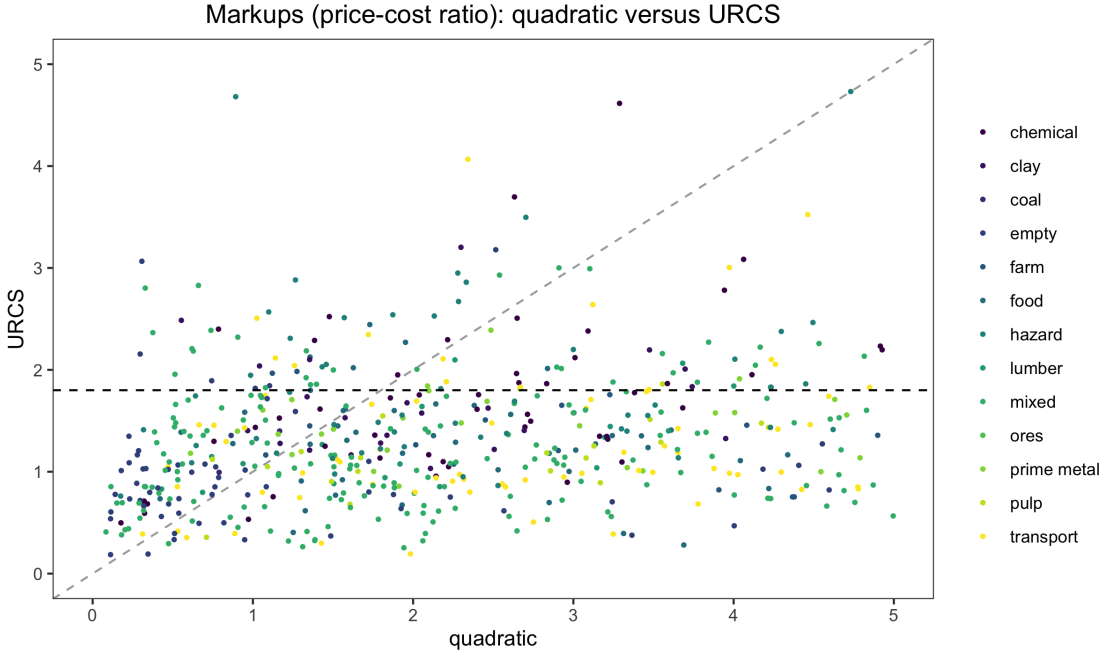
6.3 Markups, Intramodal, and Intermodal Competition

Market dominance inquiry relates shipment price-cost markups to transport competition. In this section, I present results that measure the relationship between shipment markups, intramodal, and intermodal competition. I start by mapping the spatial relationship between shipment quadratic markups and intramodal competition using bidirectional maps. Figures 7 display the relationship between origin-county and destination-county level shipment markups as they relate to the degree of intramodal competition.[22] I define intramodal competition as the number of Class 1 railroads within a given county.

[21] It is important to note that the disaggregate price-cost markups generated by the quadartic approach are similar to a previous study that estimate aggregate price-cost markups (Ivaldi and McCullough, 2007).

[22] Figure 7 displays the average shipment markup across all commodities, but the results are disaggregate and could be analyzed by commodity.

Figure 6

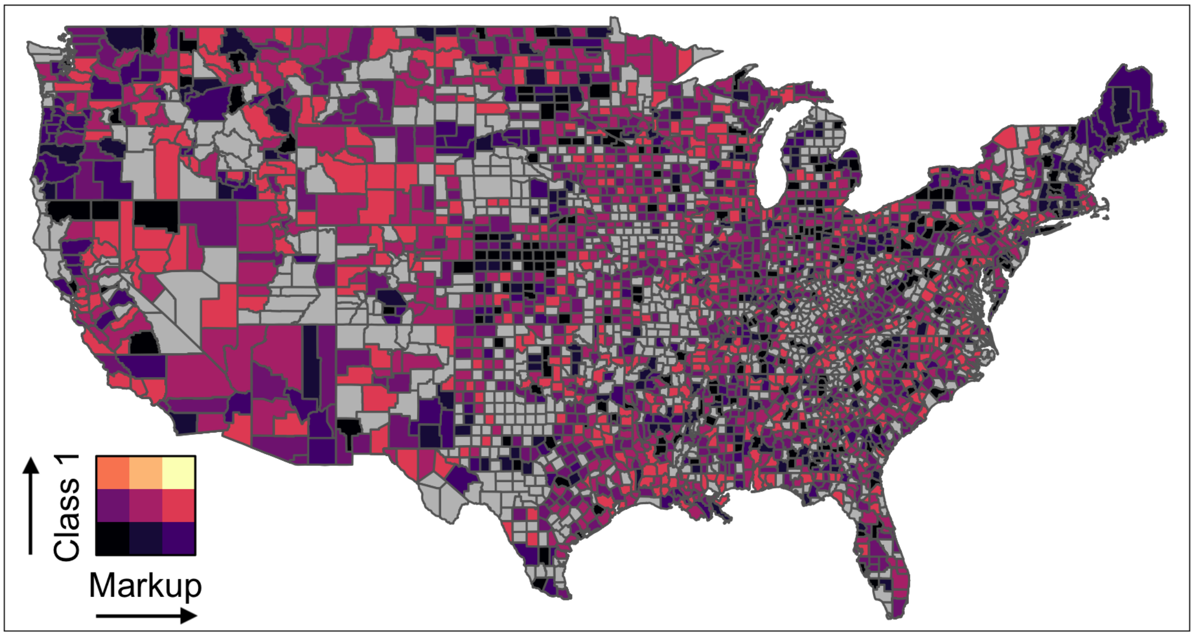


To start, note that the gray areas represent counties in which there do not exist any SPLCs. The top map represents markups and the number of Class 1 railroads within a given county, while the bottom map represents markups and the number of all railroads within a given county. The lower left part of the legend represents counties that have low markups and low degrees of intramodal competition. The upper right part of the legend represents counties that have high markups and high degrees of intramodal competition. Although this region of the legend indicates high markups, the high degree of intramodal competition usually indicates a lack of market dominance over the movement. The bottom right corner of the legend represents counties that have high markups and low degrees of intramodal competition. This purple area is of interest in market dominance inquiry, as it may indicate that captive shippers are facing excessive rates with few alternatives.

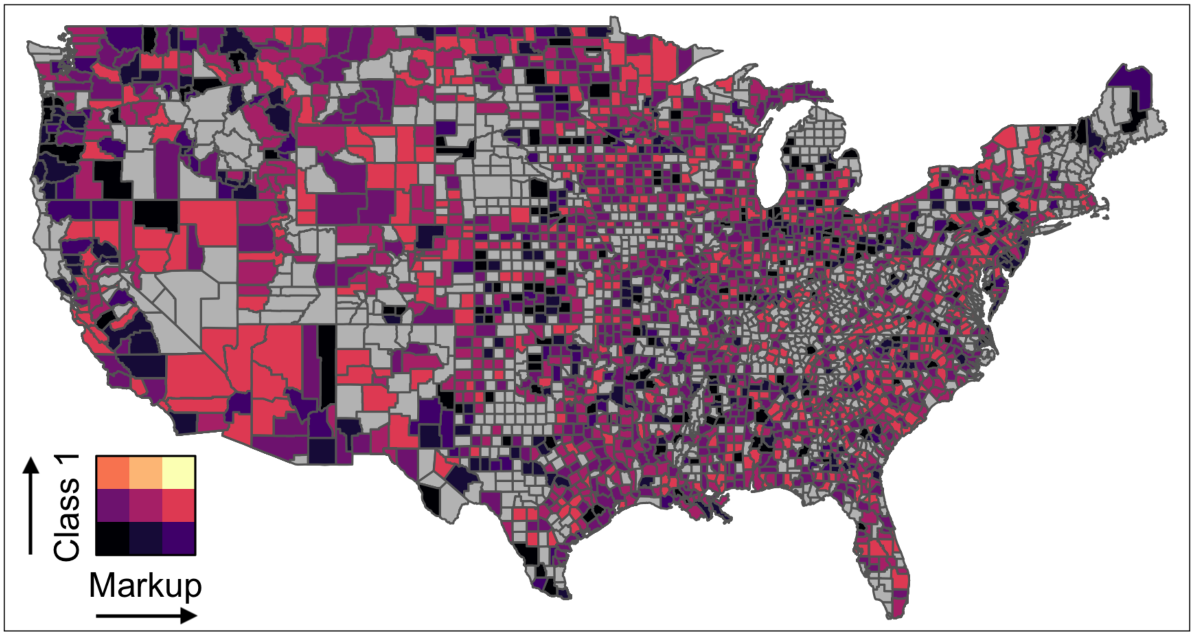
For Class 1 rail competition by origin, notice that the purple area of interest is predominatly in northern California, the Pacific Northwest, the Northeast, and some areas in Texas and South Dakota. This suggests that shipments that originate on the coasts may face high markups and few alternative options via Class 1 rail. Additionally, the areas in Texas and

Figure 7

Markups and Class 1 railroads by origin



Markups and Class 1 railroads by destination



South Dakota indicate that shipments originating in these landlocked areas may also face high markups with few alternatives. For Class 1 rail competition by destination, notice that the purple area of interest is predominatly in northern California, Oregon, Maine, Arizona, and New Mexico. This suggests that shipments that terminate on the coasts may face high markups and few alternative options via Class 1 rail. Additionally, the areas in Arizona and New Mexico indicate that shipments terminating in these landlocked areas may also face high markups with few alternatives.

Next, I quantify the relationship between shipment markups, intramodal, and intermodal competition. Economic theory in competitive markets suggests an inverse relationship between markups and the degree of competition. To test this empirically, I estimate shipment price-cost markups using the following form:

$$\log(\mu_{itm}) = \beta_0 + \beta_{ft} + \beta_{ol} + \sum_{k=1}^{10} \beta_k X'_{k,itm} + \varepsilon_{itm} \tag{13}$$

where μ_{itm} is the shipment price-cost markup for shipment i in time t for commodity m. The model assumes shipment price-cost markups are a function of distance (X_1), tons (X_2), the number of Class I railroads within 10 miles of the origin (X_3) and destination (X_4), the number of all railroads within 40 miles of the origin (X_5) and destination (X_6), the distances of the origin (X_7) and destination (X_8) from the nearest port that handles a specific commodity, an interaction between the number of Class I railroads within 10 miles of the origin and the distance from the nearest port (X_9), and an interaction between the number of Class I railroads within 10 miles of the destination and the distance to the nearest port (X_{10}). These shipment characteristics were selected based on previous empirical research on the determinants of shipment rates.[23] Tons and distance are measured in natural logarithms. Finally, fixed effects are included: β_{tf} for firm-month-of-year and β_{ol} for the state origin-destination of the shipment.

I follow the literature by focusing on the primary commodities of grain, coal, petroleum,

[23]See, for example, MacDonald (1987); Wilson and Burton (1994); Wilson and Wolak (2020). I provide a data based approach to selecting shipment characteristics in the Appendix Figure C.1.

and chemical and display the results in Table 2. Across the primary commodities and evaluated at mean values of other variables, I find that a movement from rail monopoly to duopoly is associated with an average 6.8% decline in rail markups. The results suggest that shipment markups are statistically significantly associated with both intramodal and intermodal competition. Distance to ports is positive across almost all primary commodities, suggesting that landlocked shippers may face relatively higher markups. The interaction between intramodal and intermodal competition across all primary commodities suggests that nearby ports decrease the impact of rail competition on rail markups, as shippers are able to substitute away from rail and towards movement by barge.

Finally, I evaluate the marginal effects of intramodal and intermodal competition on shipment markups for the primary commodities of grain, coal, petroleum, and chemical products. Figure 8 presents the marginal effects for these primary commodities based on the number of Class 1 railroads within 10 miles of the origin and the distance from the origin to the nearest port.[24] For coal, petroleum, and chemical shipments, my model suggests the number of Class 1 competitors at the origin constrains rail markups. For coal and chemical shipments, ports close to the origin decrease the impact of rail competition on rail markups. Abiding by the rule of 180, my model suggests that most grain shipments as well as coal shipments with an origin over 200 miles from a port may be eligible for rate relief. Figure 9 modifies this analysis and presents the marginal effects based on the number of Class 1 railroads within 10 miles of the destination and the distance from the destination to the nearest port. For petroleum and chemical shipments, my model suggests the number of Class 1 competitors at the destination constrains rail markups. The rule of 180 suggests regulators may be interested in taking a closer look at grain markups for shipment destination that have few Class 1 competitors and are far from ports.

[24]Shaded regions represent 95% confidence intervals.

Table 2
Rail Markups and Transport Competition

	log(markup)			
	Grain	Coal	Petroleum	Chemical
C1 RR in 10m of origin	0.012^{***}	0.070^{***}	-0.024^{***}	-0.031^{***}
	(0.003)	(0.011)	(0.005)	(0.003)
C1 RR in 10m of destination	0.012^{***}	0.052^{***}	-0.024^{***}	-0.046^{***}
	(0.003)	(0.019)	(0.004)	(0.003)
RR in 40m of origin	-0.015^{***}	0.005	0.005^{***}	0.002^{*}
	(0.001)	(0.003)	(0.002)	(0.001)
RR in 40m of destination	0.002	-0.006^{**}	-0.001	-0.003^{***}
	(0.001)	(0.003)	(0.001)	(0.001)
Origin miles to port	0.0003^{***}	0.004^{***}	0.001^{***}	0.001^{***}
	(0.00003)	(0.0003)	(0.0001)	(0.00004)
Destination miles to port	0.0002^{***}	0.002^{***}	0.0001^{**}	0.0001^{***}
	(0.0001)	(0.0004)	(0.0001)	(0.00004)
Origin miles to port	-0.00003^{**}	-0.001^{***}	-0.0003^{***}	-0.0003^{***}
· C1 RR in 10 miles	(0.00001)	(0.0002)	(0.00003)	(0.00002)
Destination miles to port	-0.0001^{***}	-0.0002	-0.0001^{***}	0.0001^{***}
· C1 RR in 10 miles	(0.00002)	(0.0002)	(0.00003)	(0.00002)
FEs	Yes	Yes	Yes	Yes
Observations	36,440	9,816	18,706	90,363
R^2	0.846	0.898	0.811	0.706

Notes: This table reports estimates of Equation 8. An observation is a shipment. The dependent variable is the log of the markup. Fixed effects include firm, month-of-year, and state origin-destination. Bootstrap standard errors in parentheses. Stars indicate p values: *p<0.1; **p<0.05; ***p<0.01.

Figure 8
Markups and Class 1 competition within 10 miles of the origin

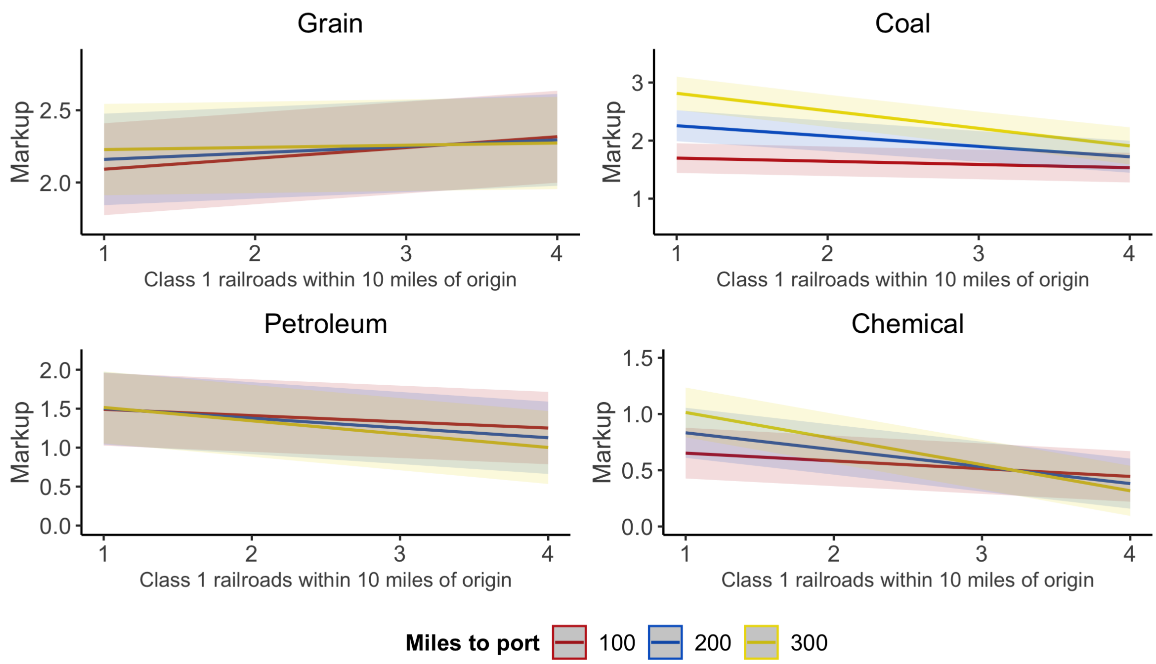
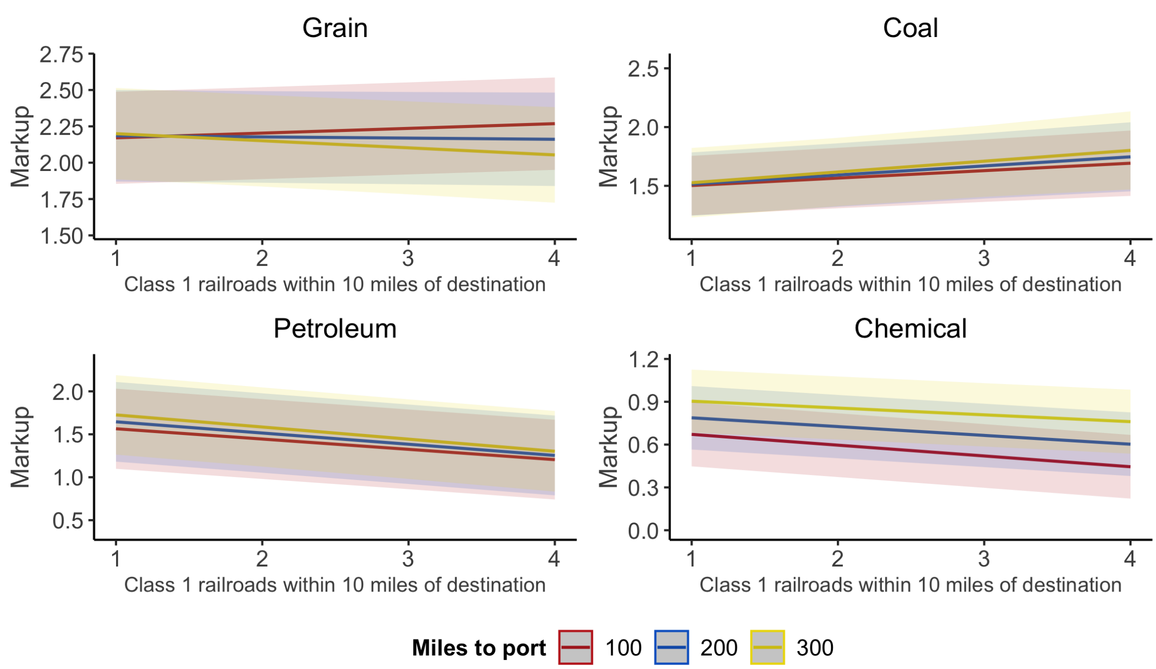


Figure 9
Markups and Class 1 competition within 10 miles of the destination



7 Concluding Remarks

Most firms are multiproduct, but traditional analysis of costs focus on single products. This is especially true in the massively multiproduct railroad industry, where regulators are congressionally mandated to use an accounting procedure to measure the cost and markup of a generic shipment. Eligibility for rate relief in market dominance inquiry depends on how these markups relate to transport competition, which is based on testimony from an expert witness. Thus, regulators may benefit from an empirical analysis of how shipment costs and markups relate to transport competition.

To assist regulators and market participants in market dominance inquiry, I developed and estimated a model of railroad costs and markups in a way that retained their disaggregate properties. In contrast to the heavily criticized regulatory approach of allocating accounting costs of a generic shipment, my model provides shipment costs and markups that are grounded in economic theory. I use these results to provide empirical evidence of how transport competition impact shipment markups and find evidence of commodity heterogeneity. I find that a movement from rail monopoly to duopoly is associated with an average 6.8% decline in rail markups. The results suggest that nearby ports decrease the impact of rail competition on rail markups. These results can be operationalized by regulators and market participants to assess the reasonableness of a rate and to streamline and expedite market dominance inquiry.

The analysis provides an alternative approach to evaluating costs and markups and then illustrates how key relevant variables of competition may improve and advance our understanding of market dominance in the railroad industry. Collecting firm-level costs at a more regular interval, such as quarterly, would allow regulators to overcome dimensionality issues associated with estimating shipment costs. The recently approved streamlined approach to market dominance inquiry also requires an assessment of competition from pipeline. Although this form of intermodal competition is only relevant for a few commodities, future research may benefit from incorporating this alternative mode of transport into the model.

Appendix A

Table A.0
Variable Definitions

Variable	Definition	Source
C	Total cost	R1
s	Number of shipments	Waybill sample
$\bar{c}$	Real total cost per shipment	R1, Waybill
d	Distance (miles)	Waybill sample
t	Tonnage	Waybill sample
u	Unit train	Waybill sample
$CarType$	Type of rail car	Waybill sample
$h(p)$	Railroad cost adjustment factor	AAR Railroad Facts
$OpCost$	Railroad operating cost	R1, Sched. 410, ln. 620, Col F
$CapExp$	Capital expenditures	R1, Sched. 410, ln. 12-30, 101-109, col. F
$RoiRd$	Return on investment in road	$(RoadInv - AccDepr) * CostK$
$RoadInv$	Road investment + $CapExp$ (cumulative)	R1, Sched. 352B, ln. 31, col. B
$AccDepr$	Accumulated depreciation in Road	R1, Sched. 335, ln. 30, col. G
$CostK$	Cost of capital	AAR *Railroad Facts*
$RoiLcm$	Return on investment in locomotives	$[(IboLoco + LocInvl)-$ $(AcdoLoco + LocAcdl)] * CostK$
$IboLoco$	Investment base in owned loc.	R1, Sched. 415, ln. 5, col. G
$LocInvl$	Investment base in leased loc.	R1, Sched. 415, ln. 5, col. H
$AcdoLoco$	Accum. depr. owned loc.	R1, Sched. 415, ln. 5, col. I
$LocAcdl$	Accum. depr. leased loc.	R1, Sched. 415, ln. 5, col. J
$RoiCrs$	Return on investment in cars	$[(IboCars + CarInvl)-$ $(AcdoCars + CarAcdl)] * CostK$
$IboCars$	Investment base in owned cars	R1, Sched. 415, ln. 24, col. G
$CarInvl$	Investment base in leased cars	R1, Sched. 415, ln. 24, col. H
$AcdoCars$	Accum. depr. owned cars	R1, Sched. 415, ln. 24, col. I
$CarAcdl$	Accum. depr. leased loc.	R1, Sched. 415, ln. 24, col. J
$SPLC$	Standard Point Location Code	Waybill sample
$RR - Mi$	Railroad within X miles	CTA Railroad Network
$Port - Mi$	Port within X miles	Port Series data

Notes: All R-1 variables available at the annual level. All Waybill variables are aggregated to the annual level, from data available at the shipment level.

Figure A.1

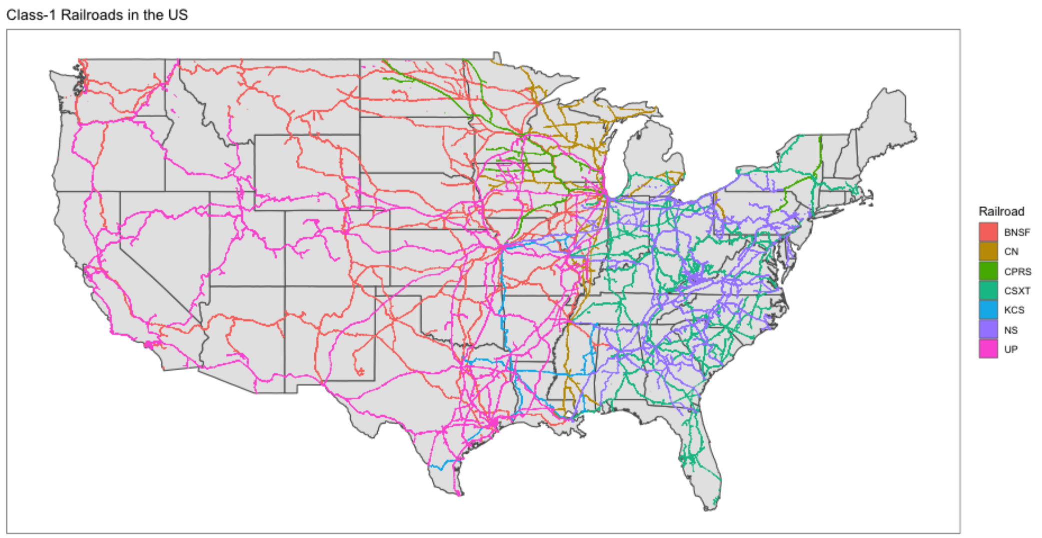
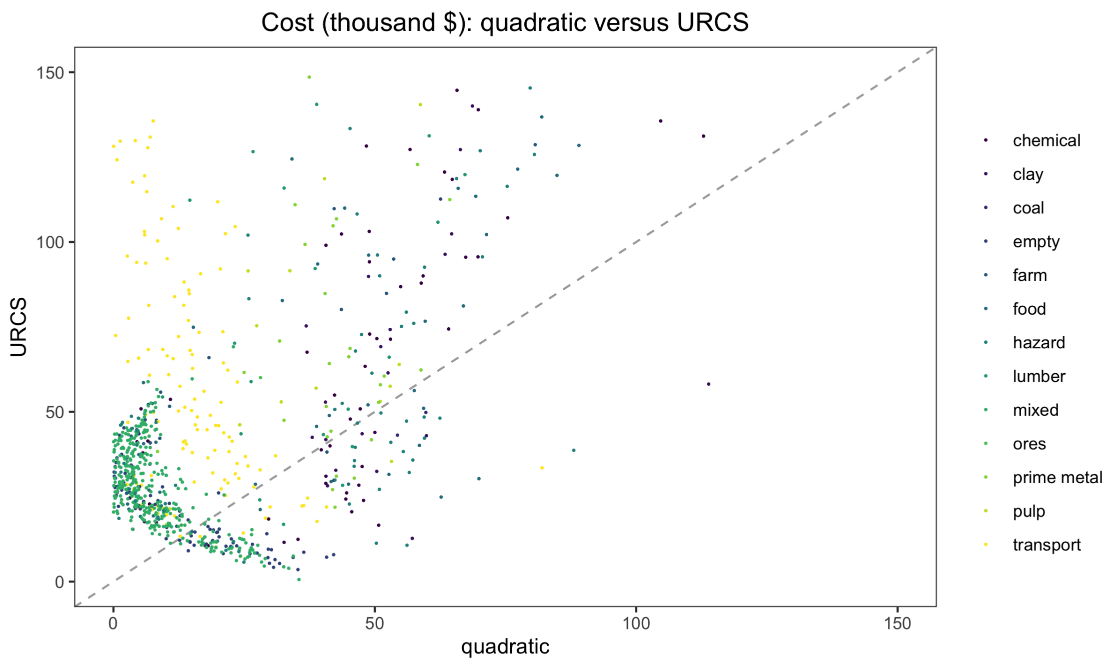


Figure A.2



Appendix B Markups and Intramodal Competition

To better understand how these shipment markups relate to intermodal competition, I group shipments based on the price-cost markup threshold rule of 180. Figure B.1 displays the number of Class 1 railroads within 10 miles of the origin and Figure B.2 displays the number of Class 1 railroads within 10 miles of the destination. Recall that exceeding the rule of 180 for shipment URCS markups is a necessary condition for a shipment to be eligible for rate relief. It appears that the degree of competition does not vary much based on whether the shipment is above or below the price-cost markup threshold.

Figure B.1
Markup thresholds and intramodal competition:
Number of Class 1 railroads within 10 miles of the origin -
Quadratic versus URCS

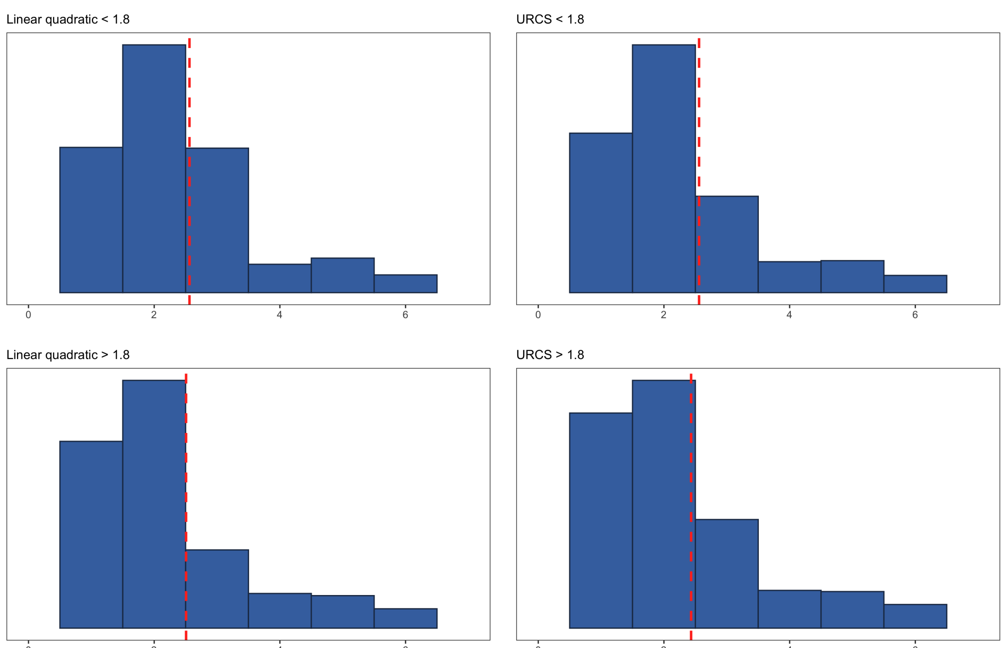
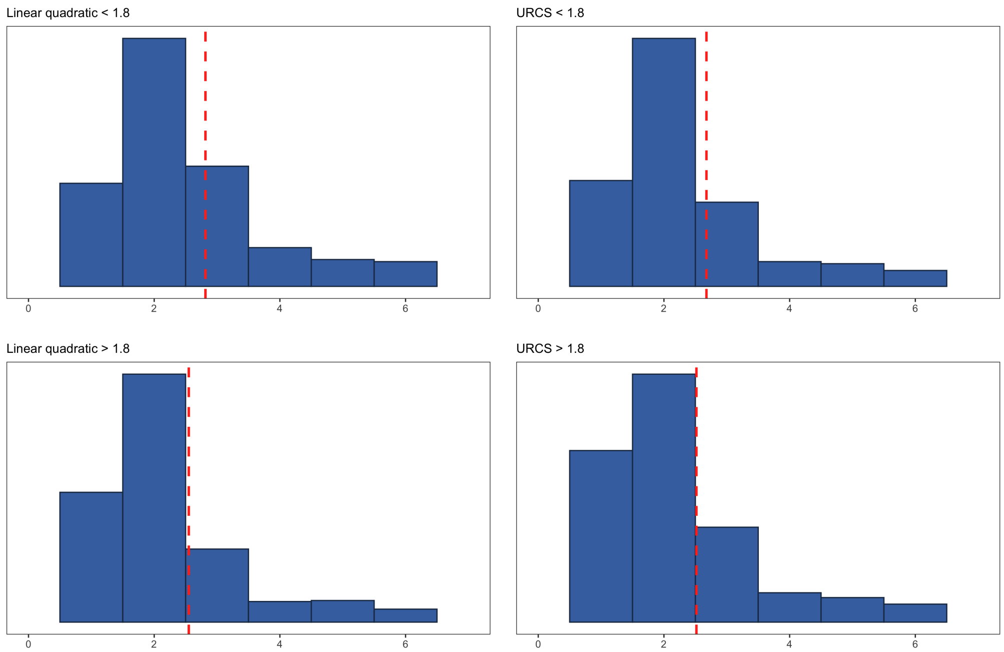


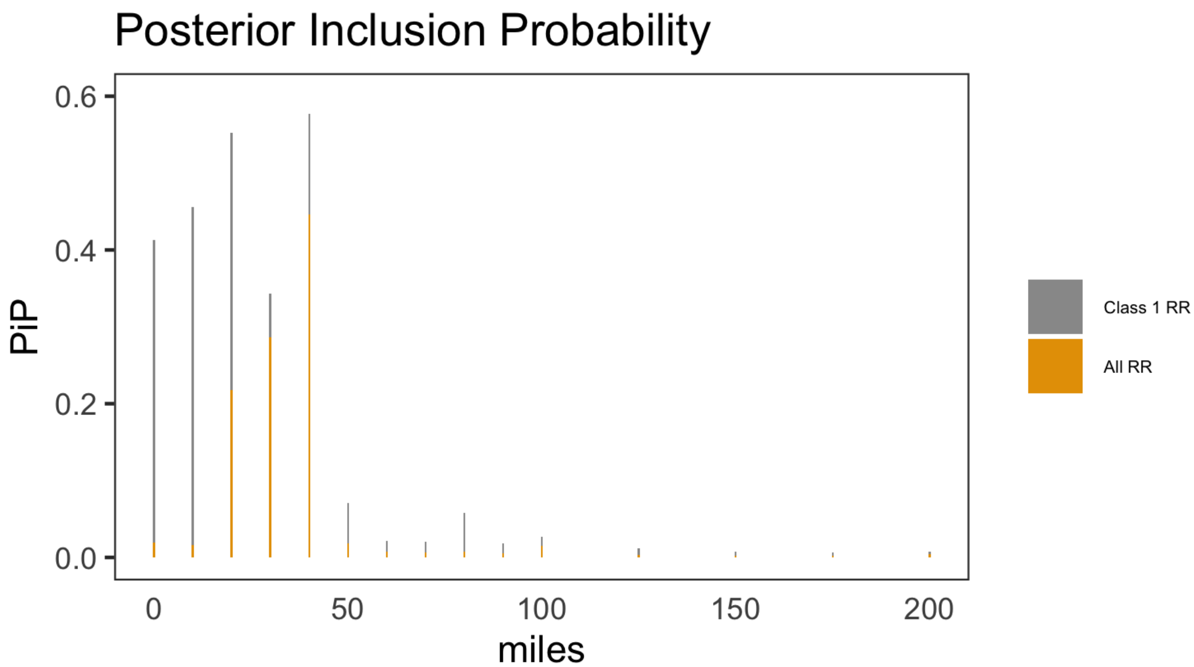
Figure B.2
Markup thresholds and intramodal competition:
Number of Class 1 railroads within 10 miles of the destination - Quadratic versus URCS



Appendix C Model Uncertainty

I quantify the model uncertainty of estimating shipment rail markups based on proximity to transport competition. Incorporating measures of spatial competition may help explain variation in markups; however, there exists model uncertainty regarding which distances should be included in the model. I quantify this uncertainty with Bayesian model averaging (BMA), which I implement with the Markov-chain Monte Carlo Model Composition (MC^3) approach of Madigan and York (1993). I set benchmark priors (Fernández et al., 2001) that assign equal weight to all distances of competition. Figure C.1 displays the posterior inclusion probability for competing railroads, which estimates shipment markups based on distance to Class 1 railroads and distance to all railroads. The results suggest that rail markups are associated with competition from Class 1 railroads within a distance of 10 miles and competition from all railroads within a distance of 40 miles.

Figure C.1
Markups and Proximity to Transport Competition



Number of competing modes of transport within a given distance

Appendix D Uniform Rail Costing System

To better understand URCS, I detail its accounting cost allocation procedure. Following the notation of Rhodes and Westbrook (1986), the URCS "variable cost" function is represented by:

$$VC = R(q;1)C(q;1) + R(q;2)C(q;2) + ... + R(q;K)C(q;K) \tag{14}$$

where R is the variability ratio, C is the cost function for the k^{th} cost category, and q is railroad output. The cost function itself is composed of fixed costs (F) and variable costs (V):

$$C(q;k) = F(k) + V(q;k) \tag{15}$$

Within each cost category, the variability ratio represents the portion of total cost that varies with output:

$$R(q;k) = \frac{V(q;k)}{F(k) + V(q;k)} \tag{16}$$

The URCS accounting based approach proceeds by establishing the variability ratio. To accomplish this task, regulators estimate a linear cost function of the k^{th} cost category:

$$C(k) = \alpha S + \sum_m \beta_m q_m \tag{17}$$

where α and β are parameters to be estimated, S is a measure of fixed capacity, and q_m are individual output measures.[25] Estimating the cost function in this way allows for αS to represent fixed costs of the k^{th} category and $\sum_m \beta_m q_m$ to represent variable costs. The corresponding estimates from equation 17 help to form the variability ratio:

$$R(k) = \frac{\sum_m \beta_m q_m}{\alpha S + \sum_m \beta_m q_m} \tag{18}$$

Individual output variability ratios are then established by:

$$R(k,m) = \frac{\beta_m q_m}{\alpha S + \sum_m \beta_m q_m} \tag{19}$$

The resulting estimates are used to construct the "variable cost" of specific shipments by measuring "the amount of output associated with specific shipments (train miles) and their corresponding impacts on various activity expenses" (Bitzan and Wilson, 2007). URCS also requires an enormous amount of data to develop its measure of "variable cost" (ICC, 2016). Possible amendments to URCS have been proposed throughout the last several decades; however, the large number of product-origin-destination combinations has precluded regulators from estimating an econometrically tractible model of shipment specific costs, with recent work calling for the abandonment of URCS (Wilson and Wolak, 2016).

[25] I omit the k indices of the parameters and variables for notational convenience, where k represents only one of the cost activities.

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