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WELFARE TRADEOFFS IN U.S. RAIL MERGERS

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Abstract

Since publication by Williamson (1968) of his seminal paper on antitrust there has been growing recognition of the need to assess tradeoffs between merger-induced efficiency gains and merger-related increases in market power. This paper presents a structural econometric evaluation of the effects of recent mergers in U.S. rail freight markets. It shows how the differentiated product model which has become an important tool for merger analysis can be extended to incorporate parametric estimates of merger efficiencies. Our empirical finding is that the Williamson tradeoff has benefitted railroads and bulk and intermodal shippers at the expense of general freight shippers.

Keywords: merger analysis, differentiated product markets, logit models, railroads
JEL Classification: L11, L13, L41, L92

I. Introduction

Since the publication by Williamson (1968) of his seminal paper on antitrust there has been a growing recognition by merger authorities of the need to assess tradeoffs between merger-related efficiency gains and merger-induced increases in market power. The U.S. Department of Justice (DOJ) and the Federal Trade Commission (FTC) describe these tradeoffs in the *Horizontal Merger Guidelines* jointly issued in 1992 and revised in 1997. The *Guidelines* state:

> Competition usually spurs firms to achieve efficiencies internally. Nevertheless, mergers have the potential to generate significant efficiencies by permitting a better utilization of existing assets, enabling the combined firm to achieve lower costs in producing a given quantity and quality than either firm could have achieved without the proposed transaction. Indeed, the primary benefit of mergers to the economy is their potential to generate such efficiencies.

The European Economic Commission makes a similar acknowledgement in its 2004 *Merger Guidelines*.

> The Commission considers any substantial efficiency claim in the overall assessment of the merger. It may decide that, as a consequence of the efficiencies that the merger brings about, there is no ground for declaring the merger incompatible with the common market. …This will be the case when the Commission is in a position to conclude on the basis of sufficient evidence that the efficiencies generated by the merger are likely to enhance the ability and incentive of the merged entity to act pro-competitively for the benefit of consumers, thereby counteracting the adverse effects on competition which the merger might otherwise have.

Concern with the balanced assessment of merger effects extends also to more specialized agencies such as the Federal Communications Commission (FCC) and the Surface Transportation Board (STB) whose responsibility for economic regulation of particular industries includes merger oversight.[1] In its *Rules Governing Major Railroad Mergers and Consolidations*, for example, the STB states that "mergers serve the public interest only when substantial and demonstrable gains in public benefits-improved service and safety, enhanced competition, and greater economic

[1] The Interstate Commerce Commission (ICC) was established by Congress in 1887 as an independent agency with authority to regulate railroads. It was eliminated by Congress in 1995 and replaced by a three-member STB within the U.S. Department of Transportation (DOT).

efficiency outweigh any anticompetitive effects."[2] The STB describes flexible procedures for conducting merger evaluations which may include "econometric and other statistical analyses."[3]

This paper presents the results of a structural econometric analysis of the welfare effects of U.S. railroad restructuring for the period 1978-2006. The analysis is facilitated by the detailed regulatory data published by the Association of American Railroads (AAR) in its annual *Analysis of Class I Railroads*. The recent history of U.S. railroad freight markets provides a good natural experiment for assessing the economic effects of mergers where there are increases in both market power and efficiency. Since 1978 the number of Class I railroads has dropped from 36 to seven--mostly as a result of mergers and consolidations.[4] A Herfindahl-Hirschman Index (HHI) for the industry--calculated on a national basis with car-miles as the output--grew from 589 in 1978 to 2262 in 2006. (See Figure 1.) This is well above the DOJ's trigger-points of 1000 for "concentrated" and 1800 for "highly concentrated" markets. Class I freight railroads also made notable efficiency gains during the period. Freight car-miles per mile of road (a measure of capital efficiency) grew from 151,000 car-miles per mile of road to 324,000 car-miles per mile of road and labor efficiency grew from 62,000 car-miles per employee to 232,000 car-miles per employee. The effect was to reduce real operating expense per car-mile from \$0.93 (82\$) to \$0.30 (82\$). Real revenue per car-mile dropped from \$0.99 (82\$) to \$0.81(82\$) suggesting that railroads shared their efficiency gains with shippers in the form of lower rates.

[INSERT FIGURE 1. CHANGE IN THE CONCENTRATION LEVEL OF THE RAILROAD INDUSTRY

To address the question of welfare tradeoffs in more detail this paper builds on the work of Anderson, de Palma and Thisse (1992), Berry (1994), Shapiro (1996), Hausman and Leonard (1997), Nevo (2000), Ivaldi and Verboven (2005), and others who have developed the econometric analysis of differentiated product markets into an important tool for merger analysis. A significant limitation of earlier structural merger papers (which their authors acknowledge) is the assumption that the merging firms exhibit constant marginal costs. This prevents to *empirically identify*

[2] STB Guidelines, p. 71.
[3] Ibid., p. 85.
[4] The STB categorizes railroad firms as Class I, Class II or Class III based on annual revenue standards that reflect inflation. Class I railroads are currently defined as firms with annual revenues exceeding \$277 million.

merger-induced efficiency gains--gains which applicants often claim are the key benefits of proposed mergers. The methodological innovation in the current paper is the introduction of a flexible cost function into the structural model in order to *endogenize* the efficiency gains from mergers. This approach improves the goodness-of-fit and the precision of the policy measure.

Our primary aim here is to provide an *ex post* evaluation of the effects of successive mergers in an important industry. Werden, Froeb and Scheffman (2004) note that there are "suprisingly few studies of the competitive effects of mergers". At the same time, we recognize the importance of predictive merger evaluation and we attempt to demonstrate in a preliminary way that an *ex ante* structural analysis that incorporates a rigorous, simultaneous treatment of production technology is feasible and useful.

The basic assumption in the paper is that railroads are multiproduct firms that compete with each other and with other transport modes in national freight markets where services are differentiated by shipment types (bulk, general freight and intermodal) and by rail firm characteristics (especially network characteristics). We use a specification test to determine empirically whether pricing in the bulk, general freight, and intermodal markets is Bertrand or Cournot. The test lead us to conclude that the pricing in all markets is Cournot--a result that is consistent with the Kreps-Scheinkman (1983) model of a two-stage game where capacities are chosen first and then prices are set with the outcome corresponding to Cournot quantities and prices.

Our empirical finding is that shipper surplus declined between 1978 and 1985 following deregulation but that it has recovered since then and grown to pre-deregulation levels. A more detailed analysis shows that bulk and intermodal shippers gained surplus while general freight shippers lost surplus. The change of composition can be attributed to a strategic response by rail managers to deregulation. The primary effect of the mergers has been to increase producer surplus (railroad profits) by modest amounts by reducing unit costs. This finding is not inconsistent with results of Berndt, Friedlaender, Wang Chiang and Vellturo (1993), Wilson (1997), Grimm and Winston (2000), Breen (2004), and Winston, Dennis and Maheshri (2004) who find that mergers contributed significantly to railroad cost savings. What the current study adds is a detailed analysis and delineation of both surplus effects and efficiency effects in a full-scale competition model.

II. Overview of U.S. Railroads and Railroad Mergers

Mergers have been a dominant aspect of U.S. railroading for almost the entire 175-year history of the industry. The first railroads, built in the 1830s and 1840s, were small, privately-owned enterprises, designed to provide short-haul passenger and freight services in the eastern portion of the country. During the second half of the 19th century, as economic activity grew and expanded to the West, these smaller railroads were cobbled together into much larger systems by a *first wave* of mergers and consolidations. Wilner (1997) reports that there were over 900 consolidations between 1870 and 1920 as the post-Civil War rail system grew from about 20,000 route miles to over 300,000 route miles.

The expansionary first wave of railroad mergers continued until the late 1920s when the Interstate Commerce Commission (ICC) was ordered by Congress to develop a comprehensive consolidation plan for the railroads. The ICC's *Complete Plan of Railroad Consolidation*, published that year, mandated that any proposed consolidation adhere to a national system plan drafted by Professor William Z. Ripley of Harvard. The mandate appears to have had a chilling effect on railroad decision-makers since no mergers were formally proposed until after the Ripley Plan was repealed by Congress in the Transportation Act of 1940.

Between 1940 and 1970 the national government invested heavily in non-rail transportation infrastructure, developing a national airspace system of airports and air traffic control facilities for general and commercial aviation, a national highway system for automobiles and trucks, and a national waterways system for inland barges. These government investments in competing modes along with changes in the overall composition of economic output had a profound impact on railroads. Rail share of the intercity passenger market (measured in passenger-miles) dropped from 7.5 percent to 0.9 percent, and rail share of the intercity freight market (measured in ton-miles) dropped from 61.3 percent to 39.8 percent.

The railroads' economic distress precipitated a *second wave* of mergers which reduced the number of Class I carriers from 131 to 71. Nearly all of these mergers were defensive mergers aimed at cutting costs and/or averting financial crises. The biggest merger of the period - the combination of the Pennsylvania Railroad and the New York Central into Penn Central - failed spectacularly in 1970 and this led to a government-financed reorganization of railroads in the northeastern U.S. into Conrail.

When railroad bankruptcies and service disruptions started to spread beyond Conrail into the Midwestern states in the late 1970s there was political pressure to provide full-scale subsidization of rail infrastructure. The Carter Administration opted instead to accelerate a regulatory reform initiative that had begun with the Railroad Revitalization and Regulatory Reform (4R) Act of 1976. Carter DOT officials, supported by a coalition of major industrial shippers and railroads, argued that the industry could reach a sustainable economic equilibrium without long-term subsidies if it were granted commercial freedom.[5] The Staggers Rail Act of 1980 left the ICC with residual economic regulatory authority but gave railroads freedoms to set rates, to enter into contracts with shippers, and to price themselves out of or to abandon markets where they could not compete with trucks.

The immediate effects of the Staggers Rail Act were a dramatic degree of downsizing and a marked improvement in profitability. Between 1980 and 2006, Class I railroads reduced locomotive stocks by 30 percent, pared track mileage by 40 percent, and cut workforces by 65 percent. Net railroad operating income grew from $1.5 billion (82$) on revenues of $32 (82$) billion to $5.3 billion (82$) on revenues of $36.9 billion (82$).

The 4R Act had given the Secretary of Transportation an affirmative role in facilitating rail mergers and the Staggers Rail Act placed time limits on merger decisions by the ICC. These legislative developments helped to facilitate a *third wave* of mergers of increasing size and scope. A list of the mergers and consolidations during this period is provided in Table 1.[6]

[INSERT TABLE 1. SIGNIFICANT U.S. RAILROAD UNIFICATIONS - 1978-2006]

Consolidation of railroads in the eastern U.S. began in November, 1980, less than three weeks after the Staggers Act was signed by President Carter, when the Chessie System and the Seaboard Coast Line combined to form CSX Corporation. Two years later, the Norfolk and Western Railroad and the Southern Railway combined to form Norfolk Southern Corporation

[5] See U.S. DOT (1978).

[6] Mergers are not the full story. As Class I railroads exited some markets, smaller, short-line railroads entered. In 2005 there were 523 local and 30 regional railroads operating in the U.S. with combined real revenues of $2.4 billion (82$). However, these firms accounted for only seven percent of total rail freight revenue of $33.8 billion (82$). (See AAR, Railroad Facts, 2006 Edition, p. 3.)

(NSC). These two railroads, along with the government-sponsored Conrail, dominated rail traffic in the East. Consolidation of the western railroads also began in November, 1980, when the Frisco Railroad was merged into Burlington Northern. It continued in December, 1982, when Union Pacific gained control of the Missouri Pacific and the Western Pacific. It was completed by "mega-mergers" in September, 1995 when Burlington Northern and Santa Fe combined to form BNSF, and in September, 1996, when Union Pacific gained control of Southern Pacific.

The final result was an industry comprised of four large regional systems— CSX and NSC east of Chicago and BNSF and UP west of Chicago—that originated over 90 percent of Class I rail traffic, and three smaller systems that originated less than 10 percent. The smaller railroads were the Grand Trunk, a subsidiary of the Canadian National (CN), and Soo Line, a subsidiary of Canadian Pacific, which moved rail traffic across the U.S. northern border to Canada, and the Kansas City Southern which moved traffic across the southern border to Mexico.

The Antitrust Division of DOJ was limited by statute and by Supreme Court decisions to an advisory role in these rail mergers. DOJ, whose statutory focus was on the anti-competitive effects of mergers, was required to defer to the ICC whose mandate was to concern itself more broadly with the "public interest". The DOJ had initially opposed the Penn Central merger and had successfully blocked the proposed 1986 merger of Santa Fe and Southern Pacific despite DOT support.[7] In 1995, when the ICC was being restructured into STB, DOJ argued that it should have primary jurisdiction over rail mergers but pro-merger advocates blocked this.[8] The Interstate Commerce Commission Termination Act of 1995 required only that the new STB give "substantial weight" to DOJ opinions. DOJ was subsequently unsuccessful in its opposition to the Union Pacific/Southern Pacific merger which DOT supported.[9]

Shipper response to the third wave of mergers and consolidations was mixed. On the one hand, rationalization of railroad workforces and physical plants has led to a significant decrease in unit operating expenditures and average rail rates. On the other hand, many railroad customers, especially smaller customers, felt threatened by a lack of rail alternatives. In addition, the Burlington Northern/Santa Fe and Union Pacific/Southern Pacific mergers were accompanied by

[7] See Pittman (1990) for an analysis of the DOJ position.
[8] See the Statement of Steven C. Sunshine, Deputy Assistant Attorney General, Antitrust Division, U.S. Department of Justice, Before the Subcommittee on Railroads, Committee on Transportation and Infrastructure, House of Representatives, Concerning Competitive Review of Railroad Mergers after ICC Sunset, January 26. 1995.
[9] See Karikari, Agyei, Brown, and Nadji (2003), Breen (2004), Kwoka and White (2004), and Pittman (2010) for analyses.

significant service disruptions. In 1999 BNSF and CN announced their intention to merge, thereby forming a system that would have covered all of Canada and the western U.S. and linked the Atlantic Ocean with the Pacific. This led to a decision by the STB in March, 2000 to impose a 15-month moratorium on rail mergers while it reevaluated the agency's merger policy. The moratorium ended in June 2001 with issuance of the *Railroad Consolidation Procedures* cited above and there have been no significant merger proceedings since then.

III. Equilibrium Model

The working assumption behind the competition model of the freight industry developed here is that the dense interconnected U.S. network of rail lines, highways and waterways always provides rail shippers with alternative (though sometimes very expensive) truck or barge options and alternative (thought sometimes very circuitous) rail routings. This means that the degree of rail market power is never absolute.[10] Our model posits three separate and independent national markets in which railroads compete among themselves and with other modes-- bulk (grain and coal), intermodal and general freight.[11] These correspond to three basic types of freight operations that railroads conduct, which means that each freight firm produces services differentiated from those of other firms.

A. Demand

For railroads, the characteristic which most differentiates a firm's services from those of its competitors is the location of its track network relative to other transportation infrastructure (including other railroads) and to the production and distribution facilities of potential freight

[10] Grimm and Winston (2000) estimate that about 15 percent of railroad freight movements involve "captive shippers", a term which the STB applies to shippers served by a single railroad who do not have "economic" transportation alternatives by rail, truck or barge. Other assessments reported by Pittman (2010) suggest that 10-20 percent of rail tonnage moves under "captive" conditions. We have no reason to doubt these assessments which are based on surveys of rail users. For modelling purposes—and constrained by the public data available to us--we accept the reality of captive shippers while attempting to give an econometric assessment of the degree of railroad market power.

[11] We share the concern of an anonymous referee that our aggregations of outputs define markets that are overly broad. We tried finer aggregations—separating out tank cars (chemicals) and multi-racks (autos), for example-but this created a degrees of freedom problem with the McFadden Cost function. We did not want to sacrifice flexibility since technological effects are critical to our analysis. We also attempted to estimate a model in which there were specific regional (East and West) markets for the three commodity groups given data limitations that include a lack of information on interchange traffic between railroads and on regional truck movements. Nonetheless this "regional" model did not produce results much different from the ones we are presenting below.

customers.[12] The degree of market power that a particular railroad enjoys in a given market is largely a function of the relative advantage that the location of its network provides. These advantages vary considerably across railroads and across the different types of service.

In each of the markets-- bulk, intermodal and general freight--the shipper decides first the mode of transport – rail or other – and, if it has chosen rail, which particular railroad. There are H +1 service providers with h = 0 corresponding to the service provided by other transport modes.[13] This means there are H railroads operating in G markets corresponding to the G types of commodities that can be shipped.

The customers of the railroad firms are freight shippers or receivers— whichever firm makes the shipment decision. Following the work of McFadden (1981) and its extensions by Anderson, de Palma and Thisse (1992), Berry (1994) and others, we assume that each shipper/receiver has a deterministic utility function consistent with its profit maximizing objectives. Neither we nor the profit maximizing railroads can perfectly observe all of the characteristics influencing shipper/receiver decisions. Therefore, we decompose shipper/receiver utility into two components, one a function of known characteristics common to all shippers in a market, the other a random variable representing unobservable characteristics which influence the individual shipper/receiver decision.

Formally, let U_{gh}^{n} be the utility (profit) that shipper n receives when selecting railroad h (or another transport mode) in market g ($g = 1, 2, ..., G$), V_{gh} the systematic component common to shippers in g, and $\nu_{h}^{n,g}$ the unobserved characteristics of n. We then have

$$U_{gh}^{n} = V_{gh} + \nu_{gh}^{n} . \tag{1}$$

[12] Our use of a differentiated product model to assess differences in the network characteristics of a transportation market is not new. One of the first structural papers was Berry's study of "Airport Presence as Product Differentiation" in *American Economic Review*, Vol. 80 (1990), pp. 394-399.

[13] The "outside good" refered to here includes truck transportation and (for some bulk shippers) barge transportation. An anonymous referee points out correctly that we are assuming that truckers and barge operators do not react strategically to railroads by varying their prices *a la* Cournot or *a la* Bertrand. We think that the price-taking assumption is a fairly safe assumption given the relatively small size of the firms in the rail-competitive market. We are constrained by the fact that a full-scale competition model would require data on truck prices which is not publicly available. Note however that the time effects that we introduce in the model later on accounts for the fact that truckers and barge operators adapt their prices regularly.

The systematic utility that a shipper in market g receives from using railroad or carrier h can be further decomposed into a mean utility component common to all shippers who use h, a price effect, and a random term representing the unobserved components in V_{gh}. Letting X_{gh} represent a matrix of demand-related variables in market g and β_g a vector of parameters, the expression for V_{gh} is

$$V_{gh} = X_{gh}\beta_g - \alpha_g p_{gh} + \xi_{gh}, \tag{2}$$

where the parameter α_g must be positive.[14]

The unobserved component of the utility, ν_{gh}^n, is itself decomposed into

$$\nu_{gh}^n = \zeta_h^n + \left(1 - \sigma_g\right)\varepsilon_{gh}^n, \tag{3}$$

where the second and the third terms, ζ_h^n and ε_{gh}^n, are random variables reflecting shipper n's deviation from the mean valuation. The term ζ_h^n is the unobserved part of shipper n's utility that affects the choice of mode, and the term ε_{gh}^n is the unobserved part of shipper n's utility that affects the choice of firm h. The parameter σ_g lies between 0 and 1 and measures the correlation of the shippers' utility across firms. If $\sigma_g = 1$, there is a perfect correlation of preferences for firms within the choice of mode; in other words, railroads are perceived as perfect substitutes. As σ_g decreases, the correlation of preferences across railroads decreases. If $\sigma_g = 0$, there is no correlation of preferences and shippers are as likely to switch to other transport modes as to other railroads in response to a price increase. In this case, all railroads and the other transport modes compete symmetrically.

Each shipper n chooses a carrier h (a railroad or other transport modes) that maximizes n's utility. The probability s_{gh} that a shipper chooses h is specified using the nested logit model. This assumes that the random variables ζ_h^n and ε_{gh}^n are distributed such that ζ_h^n and $\zeta_h^n + \left(1 - \sigma_g\right)\varepsilon_{gh}^n$

[14] We adopt here the suggestion of an anonymous referee that we include rail firm specific intercepts in the demand equations.

have extreme value distributions. The mean utility level for the other transport modes is normalized to 0, i.e., $V_{g0} = 0$.

Berry (2004) shows that under these distributional assumptions the probability that a shipper chooses railroad *h* can be expressed as

$$\ln s_{gh} - \ln s_{g0} = X_{gh}\beta_g - \alpha_g p_{gh} + \sigma_g \ln s_{gh|H} + \xi_{gh}, \tag{4}$$

where s_{g0} is the probability that the shipper chooses an alternative transport mode to rail and $s_{gh|H}$ is the conditional probability that the shipper chooses railroad *h* given it has selected the rail mode.

At the aggregate level, the choice probability coincides with the market share of product *h*. The total quantity shipped by carrier *h* on market *g*, y_{gh}, is simply the probability that a shipper chooses product *h* times the market size Y_g. Hence

$$y_{gh} = s_{gh} Y_g. \tag{5}$$

Equation (4) specifies the first element of our structural model - a set of three separate demand equations for the markets in which railroads compete with each other and with other modes for market share.

B. Pricing

The oligopoly assumption is incorporated into the model by adding a set of equilibrium conditions in which each railroad maximizes its profit with respect to prices (or quantities) conditional on the prices (or quantities) set by competitors in the various freight service markets. The objective of each railroad is to solve

$$\underset{p_{gh} \text{ or } y_{gh}}{\text{Max}} \sum_{g=1}^{G} p_{gh} y_{gh} - C\left(y_{gh}, w_{gh}, t_{gh}\right). \tag{6}$$

Given the specification of the demand function described above, under a multiproduct Bertrand-Nash equilibrium, the first order condition for profit maximization yields an expression of the price – cost margins as

$$p_{gh} - c_{gh} = \frac{1-\sigma_g}{\alpha_g \left(1-\sigma_g s_{gh|H} - \left(1-\sigma_g\right) s_{gh}\right)}, \tag{7}$$

where c_{gh} stands for the marginal cost effect of a change in output level for y_{gh}. If the firms behave as Cournot competitors, the expression of price – cost margins is

$$p_{gh} - c_{gh} = \frac{1}{\alpha_g}\left(1 + \frac{s_{gh|H} s_{gh}}{s_{gh|H} - s_{gh}} - \sigma_g \left(1 - s_{gh|H}\right)\right). \tag{8}$$

Equations (7) and/or (8) constitute the second component of our structural model –a set of three independent pricing equations for the bulk, general freight and intermodal markets.

C. A linear approximation to the engineering determination of infrastructure size

We assume that each railroad is active in each of the *G* markets and, at equilibrium, y_{gh} measures the amount of freight service provided by railroad *h* in market *g*. To perform its business the railroad uses rail infrastructure which it must either produce or buy from its competitors.[15] This is why we stipulate below that each railroad produce *G'* products with *G* representing the three types of freight service and $G' = G + 1$ including an infrastructure output. It is reasonable to assume that deregulated railroads are free to vary the level of their operating outputs without significant adjustment costs, but it is not reasonable to assume that they are unconstrained in their ability to produce these outputs independently of infrastructure output. Here we posit that the amount of

[15] The traditional method used to move freight across multiple railroad systems is to interchange cars from one system to another but Class I railroads also operate trains on each other's networks under *trackage rights agreements*. Some of these agreements are entered into voluntarily; others are required by the STB as merger conditions. The *Analysis of Class I Railroads* does not report directly on the amount of freight service that railroads provide under trackage rights agreements but it is possible to estimate the amount of track subject to such agreements. The 2006 *Analysis* lists Miles of Track Operated (Line 341) as 196,493 and the Miles of Track Operated Excluding Trackage Rights (Line 343) as 161,562. This implies that 34,931 miles of track (21.9 percent of the network) are subject to trackage rights.

infrastructure (assumed to be the first output without loss of generality), y_{1h}, used for operations is approximated by the simple linear relation

$$y_{1h} = \eta_0 + \eta_1' t + \sum_{g=2}^{G'} \eta_g y_{gh} + \omega, \tag{9}$$

which specifies also the effect of technological factors *t* and a measurement error ω. This equation can be interpreted as an engineering equation that defines the fixed amount of infrastructure required or as the reduced form of a dynamic, technical adjustment process between capacity and demand. It is the third component in our system of equations.

D. Costs

Our methodological innovation is a more rigorous treatment of production technology than has been used in other structural merger papers. The welfare assessment method used by Nevo, for example, is to simulate a post-merger equilibrium using marginal costs recovered from the demand system and then estimate the magnitude of cost efficiencies that *would be* required to capture pre-merger welfare levels. The assessment method used by Ivaldi and Verboven is to *stipulate* a range of improvements in marginal costs and to evaluate welfare tradeoffs by simulating the effects of these changes in combination with post-merger demand conditions. In neither method are efficiency gains directly estimated since the constant marginal cost assumption rules out the possibility of own-cost or cross-cost complementarities among outputs or from other technological factors.

The technological assumption here is that railroads, as multiproduct network firms, engage in a vertical production process in which, at one stage, quasi-fixed land and other inputs (labor, energy, materials, equipment) are converted into maintained infrastructure (infrastructure outputs), and, at another stage, infrastructure outputs and the other inputs are converted into multiple commercial freight services. The production process itself is represented by a flexible cost function which allows for the possibility of complementarities (or anti-complementarities) across outputs.

Let $C(y,w,t)$ be the variable cost of doing business in a year, where *w* be the *I*-dimensional vector of input prices, *t* the *J*-dimensional vector of quasi-fixed technological factors, *y* the G'-

dimensional vector of outputs. The functional form we adopt is the multiproduct Generalized McFadden cost function applied to railroads by Ivaldi and McCullough (2008). This function is an extension of the single product functional form derived from McFadden (1978) and introduced by Diewert and Wales (1987).[16] The main feature of this function is that it provides an approximation of the true cost function on a set which can arbitrarily be defined by the analyst. This is an especially desirable property when the objective is to perform a historical study.

Formally, the cost function is

$$C = C(w, y, t, u, \varepsilon) = a'w + 0.5\frac{w'\Delta w}{\theta' w}(b'y)^2 + w'\Lambda z + 0.5(\theta' w) z'\Gamma z + w'u + y'\varepsilon\,, \tag{10}$$

where z is a K-dimensional vector ($K = G' + J$) that includes y and t, a is an unconstrained I-dimensional parameter vector, Δ is an I by I symmetric parameter matrix, Λ is an I by K parameter matrix of nonnegative elements, Γ is a K by K symmetric parameter matrix, and b and θ are column vector of fixed parameters of dimension G' and I.[17] Following McElroy (1987), we account for measurement errors on input prices through the I-dimensional vector u and for measurement errors on output quantities though the G'-dimensional vector ε .

Differentiating the cost function with respect to the G first elements of the output vector y yields the parametric expression of operating marginal costs as

$$c = c(w, y, t, \varepsilon) = \frac{\partial C(w, y, t, u, \varepsilon)}{\partial y} = \left(\frac{\partial C}{\partial y_{gh}}\right) = \frac{w'\Delta w}{(\theta' w)^2}(b'y)b_G + w'\Lambda_G + 0.5(\theta' w)\Gamma_G y + \varepsilon\,, \tag{11}$$

where the vectors and matrices indexed by G are the G-dimensional sub-vectors and sub-matrices of the corresponding vectors and matrices that enter the cost function. Because of the infrastructure constraint, the full marginal cost of an operating output g ($g = 2,\cdots,G'$) for railroad h is given by

$$c_{gh} = \frac{\partial C}{\partial y_{gh}} + \eta_g \frac{\partial C}{\partial y_{Fh}}\,. \tag{12}$$

[16] Khumbakar (1994) proposes a different extension of the McFadden cost function to the multiproduct case.
[17] We account for firm-level fixed effects within the factor demand equations by fixing the values of the θ parameters at the average values of each firm's input quantities.

This includes the direct effect of a change in the level of operating output and the indirect effect though the change in the level of infrastructure usage defined by the infrastructure constraint (9).

The parametric expressions of marginal costs provided by Equation (12) are inserted in the pricing equations (7) or (8). Note that the measurement errors ε on output prices affect the marginal costs and the margins.

The standard method of estimating a flexible cost function of this type is to derive the set of factor demand equations which contain all of the parameters of the cost function. Following Shephard's lemma, these are derived by differentiating (10) with respect to each of the elements in the input price vector *w*. The result is a vector of input demands

$$x = x\left(w, y, t, u\right) = a + \left[\frac{\Delta w}{\theta' w} - 0.5\frac{w'\Delta w}{\left(\theta' w\right)^2}\right]\left(b'y\right)^2 + \Lambda z + 0.5\theta\left(z'\Gamma z\right) + u\,, \tag{13}$$

The elements of this vector comprise the fourth component of our structural model - a set of *I* input demand equations for factors of production. In our model we identify four such factors - fuel, labor, materials and equipment as described below.

IV. Data

The primary sources for the data are the *Analysis of Class I Railroads* and *Railroad Cost Indexes* published annually by the AAR. The *Analysis* is based on regulatory accounting data that railroads submit to the government. The *Cost Indexes* are synopses of the indices that the AAR is required to file quarterly with the government. Construction of the railroad operating and cost data follows procedures described in Ivaldi and McCullough (2001). We focus on a sample of 24 Class I rail companies that operated between 1978 and 2006 as shown in Table 2. We eliminate from the database a number of very small or highly-specialized Class I freight railroads that and the Long Island Railroad that specialized in passengers. We also eliminate some annual observations for particular firms where merger accounting makes it difficult to properly identify cost and output levels. Statistics for the database are presented in Table 3.

[INSERT TABLE 2. U.S CLASS I RAILROADS 1978-2006]

[INSERT TABLE 3. STATISTICS ON CLASS I RAILROAD DATA]

The measure of *conditional costs* in this paper is based on freight services expenditures listed in the *Analysis* (Lines 250-259). These are grouped into four categories of expenditures directly interpreted as variable costs - labor (Lines 250, 251), materials (Line 252), fuel (Line 253) and equipment (Lines 254-259 less road depreciation (Line 173)). Railroads also report a significant amount on annual maintenance expenditures as "road capital expenditures" (Line 378). These are allocated to labor and materials expenses. We define these as conditional costs because they do not take into account the opportunity cost of the network. We control for network size with a technological variable for miles of road (Line 342).

For *outputs*, we use detailed information in the *Analysis* on loaded car-miles by type and empty car-miles by type for 15 types of equipment like 40-foot box cars, 50-foot box cars or plain gondola. The 15 car-type miles are aggregated (by addition) into three categories: *Bulk* car-miles (y_b), *general* freight car-miles (y_e) and *intermodal* freight car-miles (y_v). The y_b category includes all open hopper (typically coal) and closed hopper (typically grain) cars. The y_e category includes all other car-types except intermodal. This aggregation enables us to account for differences in the operational characteristics without ignoring the differential cost effects of weight. Cars in the y_v and y_e category typically range between 20 and 60 tons and those in the y_b category range between 80 and 100 tons.

One problematic category of output is the "Work Equipment and No Payment" car-mile item in the AAR *Analysis* (Line 657). This accounts for about 25 percent of reported car-miles in some years but these car-miles are not classified in the *Analysis* by car-type. They are movements in shipper-owned railcars for which the railroads receive revenue but for which they make no standard payments to the owners for car rental. These car-miles are included in our bulk output category based on more detailed regulatory accounting information in Schedule 755 (Line 84) of the R1 Reports which railroads submit to the STB.

For *input prices*, we use annual input price indices for fuel, labor and materials and equipment assembled by the AAR and based on surveys of prices paid by member firms. The *technological variables* in the model are time, length of haul, miles of road, percent of car-miles in unit-trains (Line 691), and a measure of congestion, train-miles-per-mile of road, from the *Analysis*. We follow Vellturo (1989) in using a set of exogenous, demand-related variables that are constructed on a firm-specific basis. These variables--coal consumption (CCON) and state population (SPOP)--are measured on a state-by-state basis and then aggregated across states to conform to each railroads' operating territory. The aggregations vary from year to year as railroad organizations restructure and add or discontinue route segments. They are based on annual data from the AAR, the U.S. Energy Information Administration and the Statistical Abstract of the U.S.

Construction of a data series representing railroad pricing decisions in this period is not as straightforward as assembling the production and cost data. Pricing information is available in the *Official Waybill Sample* which the STB collects for regulatory purposes but the detailed records are confidential. Nor does the AAR make pricing information directly available in the *Analysis*. The *Analysis* reports revenues by commodity, tons by commodity, and carloads by commodity, but it does not report ton-miles or car-miles by commodity. This means it is not possible to directly estimate proxies for rates (average revenues) which reflect commodity, weight, and distance. Nevertheless, the car-types we have identified (bulk, general freight, intermodal) can be linked to commodity groups. To estimate rates, we use the railroad-specific and commodity-specific revenue data in the *Analysis* (Lines 577-596) to calculate the average revenue-per car-mile associated with each car-type and each railroad for each year.

Estimation of the total market size for railroads and their competitors in bulk, general freight and intermodal markets is a key aspect of a differentiated product model. The size of the bulk market is projected by combining bulk car-mile data from the *Analysis* with estimated rail market shares for coal and grain movements from the U.S. Departments of Energy and Agriculture. The intermodal and general freight market sizes are estimated by combining rail car-mile data from the *Analysis* with truck mileage data from the annual U.S. Department of Transportation Federal Highway Administration (FHWA) *Highway Statistics* reports. Our assumption is that general freight and intermodal rail movements are competitive with combination trucks for distances of 500 miles or more. Details on truck distances by truck type are contained in the U.S. Department of Commerce Bureau of the Census *Vehicle Inventory and Use Survey*.

V. Estimation Results

The model defined in Section III requires us to estimate alternative systems of equations, depending on whether we are assuming Bertrand competition in prices or Cournot competition in capacities. Each system is composed of 11 equations - three demand equations for bulk, general freight and intermodal rail services, three behavioral equations (Bertrand or Cournot) for these three markets, factor share equations for labor, fuel, materials and equipment to establish marginal costs, and the engineering constraint. In fact, there are multiple systems to estimate since there is no reason to assume that firms adopt uniform Bertrand or Cournot strategies in all three markets. It is equally likely *a priori* that they could adopt Bertrand strategies in one or two of the markets and Cournot in the other(s). This gives eight alternative combinations of conduct ranging from Bertrand in all markets (denoted by BBB for bulk, general and intermodal), to Cournot in all markets (denoted by CCC), with six combined cases: BBC, BCB and so on.[18]

Each equilibrium model is estimated by means of nonlinear three stage least squares (NL3SLS) which requires us to define a set of instruments. This set includes the factor prices for labor, fuel, equipment and materials, the technological variables and the demand-related variables.

A. Specification test on behavioral assumptions

To compare the different behavioral assumptions, we first implement a specification test based on the Vuong ratio which allows for testing pairs of non-nested models.[19] If the Vuong statistic is less than 2 in absolute values, then one cannot favor one model or the other. Otherwise, positive values favor the model represented in the numerator while negative values favor the model represented in the denominator. The results in Table 4 eliminate all but the CBB and CCC alternatives.[20] While the behavior in the bulk market definitely appears to be Cournot, the Vuong results suggest that behavior in the intermodal and general freight markets could be either Bertrand or Cournot.

[18] As two anonymous referees pointed out, it is also possible that a given railroad would change strategies in a given market over time. It is formally possible to assess this possibility using our model but we believe that the results presented below are clear enough to avoid going in that direction.
[19] See Vuong (1989).
[20] As suggested by an anonymous referee, we also compare the in-sample predictive fit of two competing conduct models, namely BBB and CCC, by computing the mean-squared errors. The predictive quality of the CCC case over the BBB case has been confirmed.

[INSERT TABLE 4. TEST OF ALTERNATIVE STRATEGIC BEHAVIORS]

This is consistent with the legal and institutional context within which Class I railroads currently operate. Since passage of the Staggers Rail Act a large amount of rail traffic has been moving under contract agreements between railroads and shippers. Stone (1991) reports that by 1988 some 60 percent of all Class I freight traffic moved under contract rates. These contracts are negotiated between well-informed shipping executives (many of whom deal with multiple railroad carriers) and well-informed railroad executives. It is reasonable to expect that the outcome of these negotiations could be a Bertrand "market price" that reflects both the value of the shipments to shippers and the cost of providing service for the railroads.[21] Common knowledge about available rail capacity (especially in the bulk market) also plays an important role, however, which would explain why the market for bulk corresponds to the Cournot solution.[22] It is also reasonable that the general freight and intermodal markets, where there are relatively large numbers of shippers and few railroads, would allow for strategic coordination among railroads *a la* Cournot. These considerations lead us to favor the CCC configuration over CBB.

Interestingly these results are in line with the theoretical model of Cournot strategic behavior in Kreps-Scheinkman's (1983).[23] Given that competition involves capacities and prices in these freight markets, it is not surprising to find that the Cournot-Nash solution provides an adequate representation of the data-generating process. Viewing these results in the light of Kreps-Scheinkman, we would conjecture that competition follows a two-stage game: After capacities are chosen in the first stage, the Nash equilibrium in the second stage pricing subgame yields Cournot outcomes. We recognize that we would have to build a more explicit model to test this conjecture and that is left for future research. What we really do here is to estimate what Tirole (1988) would term a "reduced form" Cournot model.

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[21] The Nash equilibrium in the classic Bertrand pricing game is the point where price equals marginal cost. If railroads are natural monopolies (as our cost results suggest) then the Bertrand game with well-informed carriers and shippers would lead to prices above marginal cost in order to guarantee revenue adequacy. (See Laffont and Tirole 1994.)

[22] We believe that data on contracts between shippers and railroads are required to investigate the conduct in the bulk market in more detail.

[23] See also Vives (1999).

B. Analysis of estimates

In what follows we report the results from the CCC scenario. In all but a few cases, the parameter estimates under the CBB assumption are very close. Estimates of the main parameters of interest under the CCC scenario are provided in Table 5a below while other parameters of interest are gathered in Table 5b.[24]

[INSERT TABLE 5a. NL3SLS ESTIMATES OF PARAMETERS OF INTEREST]

[INSERT TABLE 5b. PARAMETRIC ESTIMATES]

The key structural parameters in Table 5a reflect shipper sensitivity to prices (α_b, α_e, and α_v) and to differentiation between transport modes (σ_b, σ_e, and σ_v). They all are significant, the former having proper positive signs and the latter positive and less than one. This guarantees that the results are consistent with utility maximization. All of the demand parameters are well identified by the set of instruments selected for the estimation. The first stage R-square statistics associated with these parameters are mostly at or higher than 90 percent. The higher σ -values for bulk and intermodal indicate that the preferences of shippers in these markets are more highly correlated across railroads than between railroads and other transport modes. The lower σ-value for general freight indicates that railroads are more differentiated among themselves in this market. The implication is that bulk and intermodal movements are less sensitive to competition from other modes than general freight movements.

Moving to Table 5b, we first observe the relatively high values of demand elasticities. This is not surprising in this context since these elasticities do not bear on the market as a whole but on the demand sensitivities confronting individual railroads.[25] These elasticities suggest that at the observed equilibrium competition is at work. The results also suggest that the overall demand for railroad freight services in each of the three markets is primarily dependent on the size of the network on which the railroad operates and on the level of economic activity along that network. These results are consistent with earlier and more specialized studies that establish the derived

[24] The full list of parameter estimates, standard errors and first-stage R-square statistics are available from the authors are not provided for saving spaces but are available upon request.

[25] We agree with the important suggestion of an anonymous referee that the price sensitivities in bulk and general freight categories which involve multiple commodities also reflect changes in the composition of these output categories. This is a modeling limitation also discussed in Footnote 11 above.

nature of freight demand. Aggregate elasticities for the bulk, general freight and intermodal services are, respectively, equal to -0.11, 0.11 and -0.03, which indicate inelastic demand as expected.[26]

The parametric estimates of railroad costs and technology are extrapolated from the results of the McFadden Cost function. The most important results on the cost side are the marginal cost estimates which play a key role in the pricing equations and in the analysis of shipper surplus. Marginal cost estimates for y_b, y_e and y_v and y_i are estimated as a sum of the partial derivatives of factor demands weighted by input prices. The effects of technology and second-order output related effects are estimated using similar extrapolations.

The first point to notice is that the marginal costs of the different freight services vary considerably across types: The estimated average value for the marginal cost of bulk services is \$0.29 (82\$) compared to \$1.16 (82\$) for general freight services and \$0.53 (82\$) for intermodal services. These estimates, which are independent of infrastructure costs, are consistent with expectations. General freight operations involving boxcars and marshalling yards have a higher degree of operational complexity than bulk and intermodal services which involve dedicated trains operating on fixed routes. Intermodal trains are typically operated at higher speeds and higher levels of service than bulk which explains why their estimated marginal costs are higher than those of bulk. Bulk services are not inexpensive but the higher infrastructure costs which these operations impose are captured in our model in the estimated marginal cost of infrastructure. This averages \$578.73 per replacement tie, an estimate that is consistent with expectations since the ties-laid-in-replacement variable is meant to capture the full cost of maintaining infrastructure — cleaning and replacing ballast, inspecting and replacing ties, grinding and refastening rail, and so on.[27]

A second point to notice about costs in Table 5b is that U.S. freight railroads still show positive productivity gains and positive returns to density after decades of consolidation. It is standard practice in dealing with transportation networks to distinguish between returns to scale and returns to density. Scale effects are measured by the relationship between network costs and network size while density effects are measured by the relationship between network costs and

[26] The elasticity of the aggregate demand in each market is the percent change in the total quantity of the corresponding freight service following a one percent change in the prices of all the products of that market.

[27] Class I railroads installed 14.7 million replacement ties in 2006 [Analysis Line 350] and reported accounting expenditures of \$4.8 billion (82\$) on Way and Structures [Analysis Line 174]. The \$329 average variable cost estimate does not take into account the operational impacts that are captured in our estimate.

output levels. The average value of the derivative of costs with respect to miles of road (scale effect) in our study was a positive 0.14 which rules out significant returns to scale. The average level of returns to technical progress is 1.85 percent and the average level of returns to density is 2.21.[28] From a policy perspective this means that railroads could continue to pose challenges for antitrust authorities if they are able to convince regulators that mergers increase densities and facilitate technological progress without unduly increasing scale. On the other hand, the technological results also suggest that there are limits to the amount of traffic that railroads can efficiently move on their existing networks with existing capacity. The cost parameter for train-miles-per-mile-of-road is a positive 0.10 suggesting *ceteris paribus* that as congestion increases costs also increase.

We have contrasted our approach to the approach taken by Nevo (2000), Ivaldi and Verboven (2005) and others who use the estimated demand system to recover marginal costs. In Nevo's seminal paper on ready-to-eat cereal, for example, marginal costs (mc_r) are recovered from an estimated demand system by assuming a pre-merger Nash Bertrand equilibrium of the form

$$s_j(p) + \sum_r (p_r - mc_r) \frac{\partial s_r(p)}{\partial p_j} = 0, \tag{14}$$

where r is the set of brands and s_j is the observed share of brand j and p is the observed price vector. If one uses a Vuong test to compare our full model (under the CCC configuration) to a Nevo-like model containing only the demand side of our specification, the Vuong statistic has the value 0.37 which does not favor either model. We interpret this to mean that our cost model does not distort the estimates of the demand parameters and allows us to slightly improve the overall quality of the fit.

If, however, one looks carefully at the marginal costs recovered from the Nevo-style model (assuming however that the conduct corresponds to the CCC case), one observes a large number of negative marginal costs for intermodal service and very high marginal costs for bulk. In fact, the average value for the *recovered* marginal cost of intermodal service is -\$0.04 (82\$) while the

[28] The returns to density that we find in this data can be attributable either to own-cost complementarities within traffic types or to complementarities across types. We find evidence of cost complementarities between bulk and general freight operations and between bulk and intermodal services. These are indicated by a negative second-order coefficient for y_b and y_e in the McFadden cost equation. Ivaldi and McCullough (2008) provide a more detailed analysis of railroad economies of scope using the McFadden Cost Function.

estimated value in our full model with technological effects is \$.53 (82\$). For bulk services, the average value of *recovered* marginal costs is \$3.48 (82\$) while it is \$0.29 (82\$) with our full model. The latter values in both cases are consistent with the views of rail experts. In other words, including a flexible cost function within the structural model provides much more accurate estimates of the technology. We consider the importance of these estimates in the next section. It is also easier to test alternative behavioral models when the cost-side model is available.

We also tested our model against the type of model used by Ivaldi and Verboven (2005) which includes a simple cost function with constant marginal costs. In this case the conclusion is unambiguous: A Vuong test clearly favors our approach.[29] It is interesting to note in this regard that a flexible functional form like the McFadden we use imposes more structure on the overall model. The lack of structure in earlier merger model may explain why many of these studies have had to utilize larger number of instrumental variables to get their models to converge.

C. Welfare analysis

The primary aim of this research is to evaluate the welfare effects of the structural changes that have taken place in the U.S. railroad industry since 1978. Since then, a handful of U.S. railroads have increased their market shares dramatically, but they have also reduced their labor forces and physical plants and they appear to have shared their efficiency gains with shippers in the form of lower real rates. What are the welfare effects of these structural changes?

The primary measure used here is the change in overall shipper surplus in the markets for bulk, general freight and intermodal rail services, where net shipper surplus is given by the expected value of the maximum of utilities. Using the assumptions of the nested logit model developed in Section III this net shipper surplus measure is:

$$CS_g = \frac{1}{\alpha_g} \ln\left(1 + D_g^{1-\sigma_g}\right). \tag{15}$$

This formula is derived in Anderson, de Palma and Thisse (1992).[30]

[29] Detailed results for this section are available from the authors upon request.
[30] Since the markets served by freight railroad firms are factor markets, it is not necessarily the case that the surplus generated in these markets is completely passed on to consumers. This will depend on market structure and behavior in downstream markets. To fully model these effects would require a general equilibrium model that is beyond the scope of this paper and beyond the requirements of current merger practice.

[INSERT TABLE 6. SHIPPER SURPLUS TRENDS]

The results of the net real surplus calculations are presented in Table 6 and in Figures 2 and 3. The results show that aggregate shipper surplus declined between 1978 and 1985 following deregulation but recovered starting in 1986. Total shipper surplus in rail freight grew to $103.7 billion (82$) in 2006, an increase of 38 percent from its low point in 1985, but below the 1979 level of $108.5 billion (82$). The average annual level of shipper surplus from 1978 to 2006 was $91.1 billion (82$) and the total surplus generated during the 29-year period was $2.6 trillion (82$).

[INSERT FIGURE 2]

[INSERT FIGURE 3]

Looking more carefully at the results in Table 6, one notices that it is the *composition* of shipper surplus rather than the *level* of surplus that changes most significantly. Surplus in the bulk market grew from $23.5 billion (82$) to $35.1 billion (82$) and surplus in the intermodal market grew from $21.5 billion (82$) to $31.4 billion (82$). The large gains in intermodal and bulk were offset by a decline in general freight surplus from $62.1 billion (82$) to $37.2 billion (82$).

The changes in the composition of shipper surplus are not completely unexpected. First, as framers of the Staggers Rail Act had anticipated, the law enabled railroad firms to withdraw from general freight markets where their operations were unprofitable. In 1981 the industry generated 7.8 billion box car car-miles but by 2006 that had cut that number to 3.4 billion.[31] Second, the reduction in resources needed to serve general freight shippers allowed firms to devote additional resources to the intermodal market where they could retain high-value traffic while operating more efficiently. Intermodal car-miles grew from 2.7 billion in 1981 to 4.4 billion in 2006.[32] Third, and perhaps most important, the Staggers Rail Act gave firms legal authority for the first time to sign contracts with shippers. This created incentives for railroads to invest in unit train capacity and to

[31] Analysis of Class I Railroads, Lines 811-813,819-820,828-830, and 836-837.
[32] Analysis of Class I Railroads, Lines 821 and 838.

provide expanded bulk services at lower real rates. In 1981 5.2 percent of originated Class I rail carloads moved in unit trains while in 2006 the percentage was 19.6.[33]

There has also been a significant improvement in producer surplus (rail profits) reported in Table 6 and illustrated in Figure 4. Estimated producer surplus was negative in 1978 but grew steadily in the years following deregulation. Producer surplus averaged $2.1 billion (on average real revenues of $27.2 billion) between 1978 and 1985 and $5.8 billion (on average real revenue of $27.7 billion) between 1986 and 2006. Total welfare, the sum of producer and shipper surplus, declined into the mid-1990s as a result of the loss in general freight surplus but after that it was buoyed by increases in rail profits and in intermodal and bulk shipper surplus. Total welfare in 2006 was $107.3 billion (82$)–about equal to the level of welfare in 1978. Average annual level of welfare generated in the Class I freight market between 1978 and 2006 was $105 billion (82$) and the total welfare generated was $3 trillion (82$).

[INSERT FIGURE 4]

There are two important *caveats* to add regarding the welfare analysis. First, our analysis does not attempt here to develop a counter-factual case of what rail industry performance would have been *with* deregulation and *without* mergers. It is difficult to separate these effects analytically. Our view is that the market-specific effects cited above—the decline of general freight and the growth of bulk and intermodal—were the result of strategic railroad responses to deregulation and that the change in composition of surplus alone could have taken place without mergers. But the shift from *higher-priced* general freight to *lower-priced* bulk and intermodal meant a significant increase in the physical volume of rail output without an increase in revenue. In fact, the annual volume of car-miles in our sample grew by 31 percent while average real revenue was virtually unchanged. It is unlikely that the railroads could have maintained the low level of overall costs without the significant technological improvements and labor savings that accompanied mergers.

Figure 4 illustrates the thin margins which railroads maintained between 1978 and 2006. Annual real revenues fluctuated between $25 and $30 billion (82$) and estimated annual real costs fluctuated between $20 and $25 billion (82$) despite the increase in physical output. Figure 4 also

[33] Analysis of Class I Railroads, Lines 890-892

presents a "passive" cost curve drawn on the assumption that the average real cost of a car-mile had remained constant at its 1978 level. It is clear that railroads would have had to increase rates (or reduce service levels) significantly, thus reducing traffic levels and welfare, or face bankruptcy. The other alternative would be government subsidization.

The second *caveat* has to do with the broader welfare implications of this analysis. The loss of general freight traffic was accompanied by an increase in intermodal traffic, but this increase is dwarfed by the increase in combination truck traffic on U.S. highways.[34] This traffic, which imposes externalities on other highway users and the general public, grew from 62.9 billion vehicle miles in 1978 to 164.4 billion vehicle miles in 2006. The increase is mostly attributable to the growth of gross domestic product-- not to diversion from rail-- but to the extent that general freight traffic was *not* moving on the rail network, it represents some loss of potential welfare. The U.S. DOT(2000) estimates that, on average, combination trucks pay only 50-80 percent of their cost responsibility for infrastructure, and impose additional marginal costs of \$0.05 (82\$) to \$0.21 (82\$) per mile in congestion, crash, air pollution and noise externalities.[35] If this freight traffic were on the rail network, the infrastructure costs would be internalized and the external costs would be reduced.

D. Lerner Indices

The positive density effects reported in Section 5B mean that, even at current output levels, the marginal costs of most services are below average costs. This means that in order to be revenue adequate railroads must charge prices that are above marginal costs using differentiated markups that reflect differences in marginal costs and elasticities of demand.[36] Rail regulatory policy in the U.S. explicitly mandates that railroads should use differential prices to remain viable but the difficult set of problems associated with implementing second-best pricing continue to challenge the Surface Transportation Board.

The structural model that we present here allows us to provide estimates of the existing markups in the form of Lerner indices which reflect both supply and demand. The estimates of

[34] Combination truck is the FHWA designation for tractor-trailers of various configurations.
[35] U.S. Department of Transportation (2000), Table 13.
[36] See Baumol and Bradford (1970).

these indices by market segment and by region are presented in Table 7. To eliminate temporal bias they are averaged over the period 1978-2006.

[INSERT TABLE 7. AVERAGE LERNER INDICES BY MARKET SEGMENT AND REGION]

The relative magnitudes of these indices are consistent with expectations based on known market characteristics. The smallest markups overall (37.5 percent) are in the general freight market where railroads compete with truckers and with each other for relatively short-hauls on higher value commodities such as paper, food, lumber, automotive parts and finished chemicals. General freight markups are slightly higher in the western U.S. where longer distances give railroads a greater cost advantage over long distance trucks and this helps to offset the level of service advantage that trucks enjoy.

The highest markups overall of 73.2 percent are in the intermodal markets where railroads are able to provide higher levels of reliability and speed with significant cost advantages over trucks. These advantages are especially strong in the Western markets where the lengths of haul are long and railroads have their greatest advantages. Intermodal markups of 85.7 percent in the West compare to markups of 56.3 percent in the East.

Our initial expectation was that markups in the bulk markets would be higher than those in intermodal markets since the latter shippers have easier access to truck alternatives. Though there are barge (and even truck) alternatives for shippers of bulk commodities, many bulk shippers must rely on one or two railroads to move their commodities to market. Two factors may explain the lower markups in bulk. First, as indicated above, a significant portion of bulk movements are subject to bilateral contract negotiations between carriers and shippers. Second, in the bulk markets especially, there is a credible threat of regulatory intervention by the STB. Whatever the cause, average overall markups in the bulk markets were 62 percent. Western railroad markups of 77.8 percent were significantly higher than those of eastern railroads which averaged 41 percent. The high markups in the West were due in part to the low estimated marginal costs of unit train service in the West.

E. Merger Simulation

The primary objective in this paper has been to analyze *ex post* the effects of a sequence of mergers in the U.S. railroad industry by estimating a static model of the industry at each period. We recognize that an important aspect of a model of this type is its *ex ante* ability to simulate and predict merger outcomes. In this section we offer a preliminary demonstration of the feasability of using this model ex ante for policy purposes. In an actual application by merger proponents and/or regulators, of course, the model would be considerably improved by the use of detailed proprietary data.

The main difficulty in simulating merger outcomes is to know the values of the exogenous variables that enter into the model. Ultimately, if one wants to simulate *ex ante* the impact of a merger, one needs to predict the values of all of these exogenous variables. Based on the suggestion of an anonymous referee, we test our model by simulating the equilibrium outcomes of railroads for the last five years (2002-2006) in our sample after omitting this data from the estimation. The obvious choice of predicted 2002-2006 exogenous values for our demonstration is the set of observed values since these are known to us. This is a luxury that competition experts do not have when they simulate unilateral effects.

We focus on railroads in the eastern portion of the country following the absorption of Conrail into CSX and NSC. We use the 1978 – 2001 values to predict prices in a national market when the number of major eastern railroads has been reduced from three to two. The mean predicted values of the endogenous prices for the 2002-2006 period are \$0.77 (82\$) for bulk, \$2.08 (82\$) for intermodal, and \$2.44 (82\$) for general freight. The mean squared errors associated with these prices are 0.33, 0.58 and 1.19 respectively. This suggests that the current model provides a good degree of accuracy in predicting merger effects. We should stress that this is only a feasability exercise and that in a real-world merger application an econometrician would have access to detailed proprietary data which could improve both the demand-side estimates and the cost estimates.

VI. Conclusion

The focus in this paper has been on the development and application of a structural econometric model for evaluating mergers where there are significant increases in *both* market power and firm efficiency. The recent history of U.S. freight railroads provides a good natural experiment for assessing such effects. We extend the work of Anderson, de Palma and Thisse, Berry, Shapiro, Hausman and Leonard, Nevo, Ivaldi and Verboven, and others by using a flexible cost function to incorporate simultaneous parametric estimates of merger efficiencies into our structural model. Our analysis focuses *ex post* on actual (as opposed to simulated) merger effects, an exercise that we feel is valuable in itself given the key role that freight railroads play in the U.S. economy. We also demonstrate in a preliminary way that a structural model that incorporates a robust technological specification can be used more generally to predict unilateral merger effects *ex ante*.

Our empirical finding is that real shipper surplus declined in the early 1980s immediately following rail deregulation but has recovered since then despite a dramatic degree of consolidation in the industry. A closer analysis of the surplus effects shows large gains of surplus in the intermodal and bulk markets offset by losses of surplus in general freight. These changes in the *composition* of surplus can be attributed to deregulation which granted rail managers commercial freedom to shift their strategic emphasis from general freight to bulk and intermodal services. The primary effect of mergers has been a reduction in unit costs which has enabled railroads to remain revenue adequate. Our overall conclusion is that the Williamson trade-off has benefitted railroads and bulk and intermodal shippers but has resulted in a loss of surplus to general freight shippers.,

We have also shown that competition in the three freight service markets we have considered is consistent with or close to the Cournot solution. We interpret this result as an indirect test of the Kreps-Scheinkman's (1983) theory which describes a two-stage game where, after capacities are chosen in a first stage game, a Cournot-Nash equilibrium is realized in a second stage pricing subgame. Direct testing of this conjecture will require a more explicit model which is left for future research. We also recognize a clear need for a dynamic analysis of the railway industry that fully addresses the question of investment choice in addition to the merger-and-acquisitions decisions.

It is interesting to speculate on what implications our results have for railroad systems in Europe which are also undergoing significant transformation. Most systems in Europe differ from those in the U.S. in that passenger traffic dominates their output. Neverthless there are significant efforts underway in Europe to increase the amount of freight traffic by giving freight operators "open access" to the trans-European network. Our results suggest that the freight operators on these networks may grow quite large due to returns to density and that this will give them market power but that—for the foreseeable future—the market power gains will be offset by efficiency gains. The question of how these competing will be realized on systems where operations may be separated from infrastructure is also a topic for further research.

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Table 1. Main Significant U.S. Railroad Unifications - 1978-2006

Year	Merging Firms	Merged Firm	Combined Employees	Combined Route Miles	Combined Revenue $82
1980	Chessie/Seaboard	CSX	47,803	22,887	4.56
1982	N&W/Southern	NSC	34,857	17,520	3.36
1994	UP/CNW	UP	35,001	22,785	5.57
1995	BN/Santa Fe	BNSF	43,731	35,208	6.55
1996	UP/SoPac	UPSP	52,533	34,946	7.80
1999	CSX/ConRail	CSX	34,283	23,320	4.80
1999	NSC/ConRail	CSX	33,344	21,759	4.87

Note: In 1999 ConRail was divided between CSX and NSC.

Table 2. U.S Class I Railroads 1978-2006

Railroad (Abbreviation)	Years
Atchison, Topeka & Santa Fe (ATSF)	1978-1995
Baltimore & Ohio (BO)	1978-1983
Burlington Northern (BN)	1978-1995
Burlington Northern & Santa Fe (BNSF)	1996-2006
Chesapeake & Ohio (CO)	1978-1983
Chicago & Northwestern (CNW)	1978-1994
Consolidated Rail Corporation (CRC)	1978-1998
CSX Corporation (CSX)	1986-2006
Denver, Rio Grande Western (DRGW)	1978-1993
Grand Trunk Western (GTW)	1978-2001
Illinois Central Gulf (ICG)	1978-2001
Kansas City Southern (KCS)	1978-2006
Louisville & Nashville (L&N)	1978-1982
Chicago, Milwaukee, St. Paul & Pac. (MILW)	1978-1984
Missouri-Kansas-Texas (MKT)	1986-1987
Missouri Pacific (MP)	1978-1985
Norfolk Southern Corporation (NSC)	1986-2001
Norfolk & Western (NW)	1978-1983
Seaboard Coast Line (SBD)	1978-1985
SOO Line (SOO)	1978-2006
Southern Railroad (SOU)	1978-1985
Southern Pacific Railroad (SPRR)	1978-1996
Union Pacific (UP)	1978-1996
Union Pacific Southern Pacific (UPSP)	1997-2006

Table 3. Statistics on Class I Railroad Data

Variable	Mean	Std Dev	Minimum	Maximum
State Population (000)	74711.12	45149	4631	176161
Labor Price (Index)	2.2914	0.7729	1.0940	4.0020
Fuel Price (Index)	2.0857	0.7944	1.0430	5.8580
Materials Price (Index)	1.6369	0.4022	1.0570	2.9680
Equipment Price (Index)	1.9806	0.4101	1.0730	2.6730
Labor Quantity (000)	435,631	350902	40939	1731572
Equipment Quantity (000)	350,117	359894	16782	1639082
Fuel Quantity (000)	97,696	104116	6584	480339
Materials Quantity (000)	108,221	90043	7574	510510
Bulk Car-miles (000)	1,276,568	1788913	26336	9411832
General Car-miles (000)	775,997	727398	41301	3752543
Intermodal Car-miles (000)	293,936	344506	2649	1782614
Replacement Ties (000)	1,212	1020	27	4896
Bulk Rate ($/car-mile)	0.7189	0.2075	0.2230	1.6606
Intermodal Rate ($/car-mile)	1.4290	0.7153	0.4537	7.1397
General Rate ($/car-mile)	1.7698	0.4822	0.6586	3.5894
Time (Years)	11.9114	7.9649	1.0000	29.0000
Miles of Road (000)	9.6820	7.7955	0.5500	34.9460
Train-miles per Mile of Road	3.2117	1.4309	0.7863	9.4475
Fraction Unit Train Car-miles	0.1791	0.1593	0	0.6862
Bulk Rail (000 Car-miles)	14,373,998	3,771,499	9,976,553	23,387,706
Intermodal Rail (000 Car-miles)	3,474,763	533,142	2,463,004	4,406,773
General Freight Rail (000 Car-miles)	9,868,202	1,914,757	7,977,470	14,021,385
Bulk Market (000 Car-miles)	28,820,948	7,753,996	19,892,049	45,678,796
General Market (000 Car-miles)	21,670,091	3,083,196	17,782,222	31,149,905
Intermodal Market (000 Car-miles)	15,276,651	3,642,777	10,519,023	24,956,023

Table 4. Specification Test for Comparisons of Alternative Strategic Behaviors

Model 2	Model 1						
	BBB	BBC	BCB	BCC	CBB	CBC	CCB
BBC	-2.88						
BCB	-0.96	1.46					
BCC	-3.21	-0.83	-3.12				
CBB	-7.09	-6.17	-6.95	-6.12			
CBC	-6.65	-5.99	-6.44	-5.85	2.44		
CCB	-5.94	-5.06	-5.96	-5.13	3.67	0.48	
CCC	-6.46	-5.73	-6.48	-5.84	1.37	-0.90	-1.62

Note: When the Vuong statistic takes a value lower than -2, it favors model 2. Otherwise it favors model 1. In between one cannot discriminate between the two models.

Table 5a. NL3SLS Estimates of Parameters of Interest

Market	Bulk		General freight		Intermodal freight	
Parameter	α_b	σ_b	α_e	σ_e	α_v	σ_v
Estimate	0.4698	0.9751	0.5039	0.8251	0.2274	0.8972
t-value	*11.86*	*34.87*	*9.01*	*16.01*	*6.57*	*21.37*

Table 5b. Parametric Estimates

Equation	Product	Variable	Mean value	t-value
Demand	Bulk	Own price elasticity	-12.3852	-0.90
		Cross price elasticity	0.0149	11.86
	General freight	Own price elasticity	-4.7361	-3.84
		Cross price elasticity	0.0319	9.01
	Intermodal freight	Own price elasticity	-2.9134	-3.16
		Cross price elasticity	0.0063	6.57
Cost	Bulk	Marginal cost	0.2935	4.96
	General freight		1.1635	13.39
	Intermodal freight		0.5335	4.43
	Infrastructure		578.7312	20.89
		Congestion effect	0.0974	2.77
		Returns to technical progress	-0.0185	3.89
		Returns to density	2.2141	6.58

Table 6. Welfare Trends (Billion 1982 dollars)

Year	General	Market Bulk	Intermodal	Shipper surplus	Rail surplus	Total welfare
1978	62.14	23.49	21.52	107.15	-1.25	105.90
1979	60.30	26.11	22.12	108.53	1.07	109.60
1980	56.35	30.23	20.55	107.14	3.42	110.56
1981	54.10	29.95	22.28	106.33	2.45	108.77
1982	42.22	28.50	21.67	92.39	2.53	94.93
1983	40.22	27.10	23.19	90.50	2.69	93.19
1984	37.31	25.54	21.73	84.58	3.54	88.12
1985	34.40	22.60	18.04	75.04	2.54	77.58
1986	48.09	28.47	21.32	97.88	6.93	104.81
1987	41.49	27.70	20.43	89.61	5.02	94.64
1988	40.81	28.46	20.70	89.97	6.54	96.51
1989	37.05	27.25	20.01	84.31	5.93	90.23
1990	33.99	27.33	19.97	81.29	5.08	86.37
1991	32.98	26.69	20.14	79.81	5.25	85.06
1992	33.86	25.76	19.44	79.05	4.10	83.15
1993	34.60	25.32	19.73	79.64	4.08	83.73
1994	36.23	26.36	22.65	85.25	5.79	91.04
1995	35.40	28.42	23.33	87.16	6.12	93.28
1996	36.55	26.96	22.37	85.88	6.35	92.23
1997	37.12	27.28	24.69	89.09	6.10	95.20
1998	37.90	28.95	25.28	92.13	6.69	98.82
1999	35.76	27.07	24.90	87.73	7.86	95.59
2000	36.77	25.82	24.14	86.72	7.32	94.05
2001	35.59	27.23	23.91	86.73	7.17	93.90
2002	42.92	23.14	27.52	93.57	6.14	99.71
2003	36.01	29.31	30.73	96.05	6.35	102.39
2004	38.02	28.69	28.32	95.03	5.12	100.15
2005	37.93	33.19	28.48	99.60	4.09	103.69
2006	37.22	35.14	31.40	103.76	3.53	107.29

Table 7. Average Lerner Indices by Market Segment and Region (percent)

Market	Overall	East	West
Bulk	62.0	41.0	77.8
General freight	37.5	35.2	39.3
Intermodal freight	73.2	56.5	85.7

Figure 1. Change in the concentration level of the railroad industry

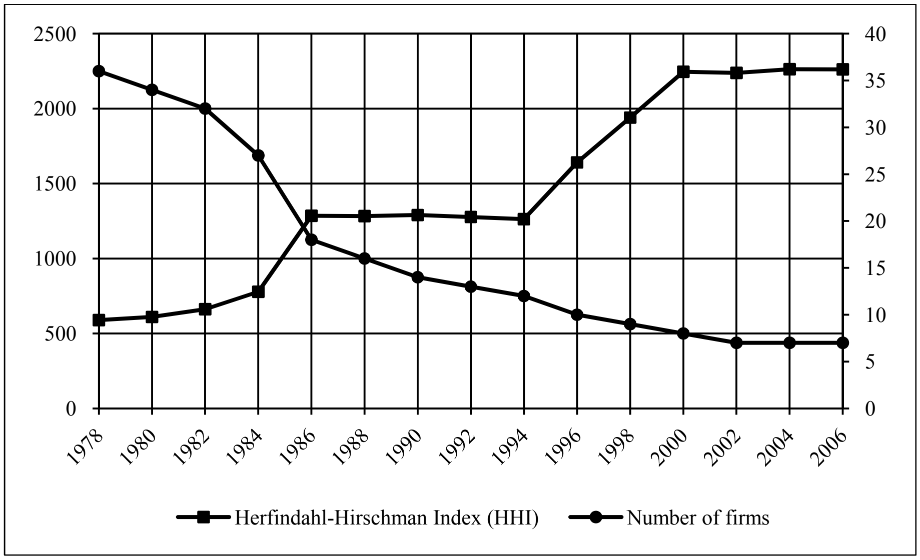

Figure 2. Total Shipper Surplus

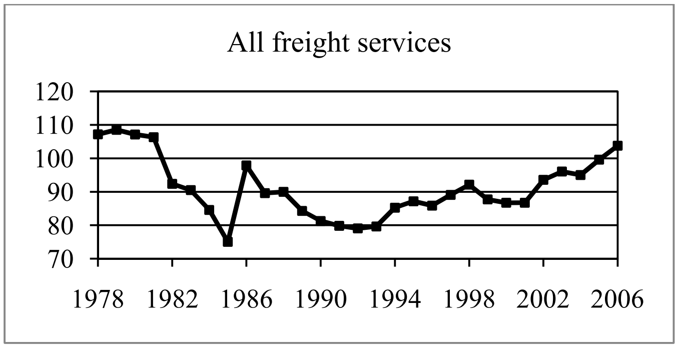

Figure 3. Shipper Surplus by Market Segments

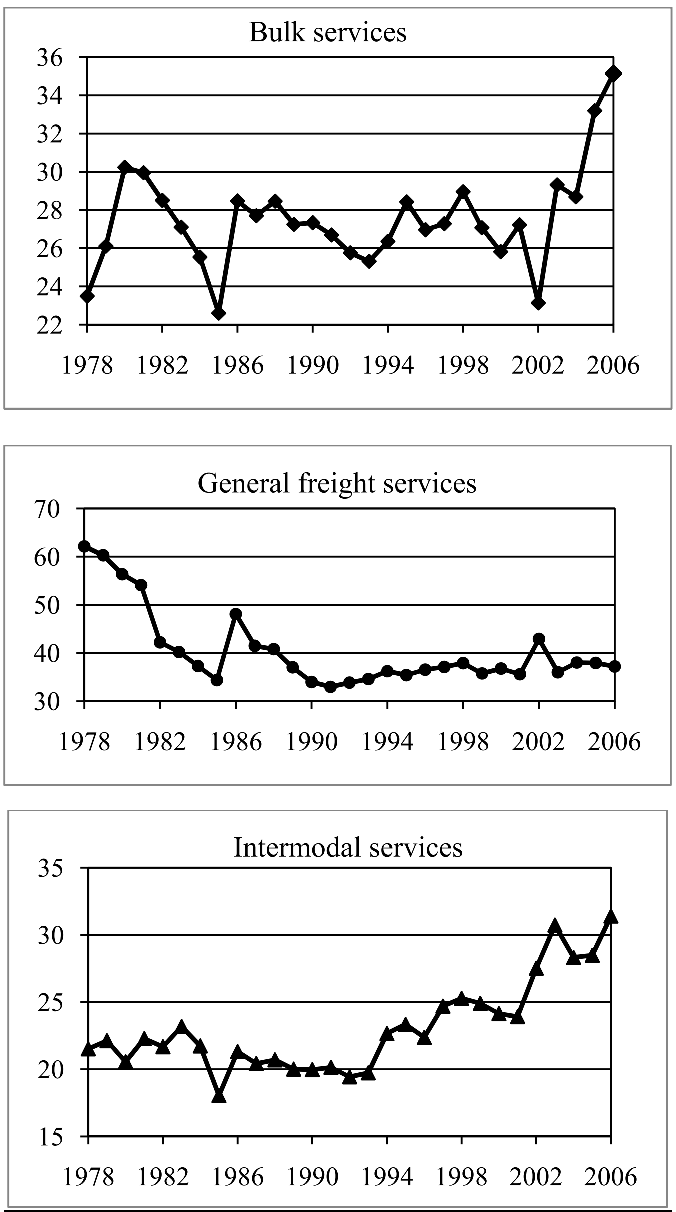

Figure 1. Welfare effects