Economic Analysis of an End-to-End Railroad Merger

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End-to-end railroad mergers involve two or more carriers that serve separate regions and connect with each other at relatively few points. Such mergers are likely to increase economic welfare, but the magnitude of the increase depends on the individual markets involved. This study quantifies the effect of the Chessie System–Family Lines merger on economic welfare. Estimates are developed for both the demand and the cost of surface freight transportation in specific transportation markets. The model developed is sufficiently general to allow for rail, truck, and barge competition and for changes in cost, price, service time, market share, and market size as a result of the merger. The cost savings and service time improvements resulting from this end-to-end merger are estimated to increase economic welfare by $340 million to $350 million per year. Although different markets may display different results, it appears that end-to-end railroad mergers with similar characteristics may well confer substantial economic benefits.

The recent deregulation of the surface freight transportation industry has prompted a wave of railroad mergers. The mergers of Grand Trunk Western–Detroit, Toledo and Ironton (1978), Burlington Northern–St. Louis and San Francisco (1979), Chessie System–Family Lines (1980), Norfolk and Western–Southern (1982), Union Pacific–Missouri Pacific–Western Pacific (1982), Soo Line–Milwaukee Road (1985), Norfolk Southern–Conrail (1986), Santa Fe–Southern Pacific (1986), and Pacific Rail–Missouri, Kansas and Texas (1986) have all been either proposed or consummated since 1978. The wave of mergers has renewed the public policy debate over the effect of railroad mergers on economic welfare.

Railroad mergers may be divided into two types. Parallel mergers involve two or more carriers that serve the same region. A merger between two such carriers providing substitute forms of transportation may increase or decrease economic welfare depending on pricing policy and cost savings that result from the merger. End-to-end mergers involve two or more carriers that serve separate regions and connect with each other at relatively few points. The "upstream" railroad carries traffic from origin to interchange, and the "downstream" railroad carries traffic from interchange to destination. End-to-end mergers are likely to increase economic welfare in the affected markets.

Studies by Levin and Weinberg (1) and Harris and Winston (2) suggest that end-to-end mergers are likely to increase economic welfare. Klein et al. (3) suggest that the large fixed costs and specialized assets associated with railroad operation

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may make it difficult to attain financial benefits without merger. However, the magnitude of the increase, and hence the benefits of a public policy permitting end-to-end railroad mergers, depends on the individual markets involved. This study was undertaken to quantify the effect of the Chessie System–Family Lines merger on economic welfare. Estimates are developed for both the demand and the cost of surface freight transportation in specific transportation markets. The model is sufficiently general to allow for rail, truck, and barge competition and for changes in cost, price, service time, market share, and market size as a result of the merger. The cost savings and service time improvements that result from this end-to-end merger are estimated to increase economic welfare by $340 million to $350 million per year, assuming all other factors remain unchanged. End-to-end railroad mergers with similar characteristics may confer similar economic benefits.

MODEL OF THE MARKET

A given surface freight transportation market may be served by any of several transportation modes including a variety of rail routes. An end-to-end merger affects prices, service times, and costs on one or more individual routes. A welfare analysis of end-to-end mergers must therefore use demand and cost functions for individual routes in a market, not the aggregated functions common in studies of transportation deregulation.

Demand for Transportation

A nested multinomial logit model of shipper choice was developed along the lines discussed by Ben-Akiva and Lerman (4). In the most general case, shippers are assumed to have a decision tree like the one shown in Figure 1. Each node of the tree corresponds to a choice probability that is conditional on having reached the node from above. The shipper first chooses among rail, truck, and barge modes (M). A rail shipper then chooses a type of service (T), either single line or multiple line. A shipper choosing multiple line service then makes a choice (N) between two-line and three-or-more line service. Last, the shipper chooses the individual route (R).

The nested multinomial logit model simplifies this complex decision problem in two important ways. First, as with any logit model, the number of choice variables is reduced. Shippers consider a variety of characteristics such as price, speed, reliability, and other unmeasured or random factors in deciding which route to use. Shippers are assumed to consider the utility of the entire bundle of attributes associated with
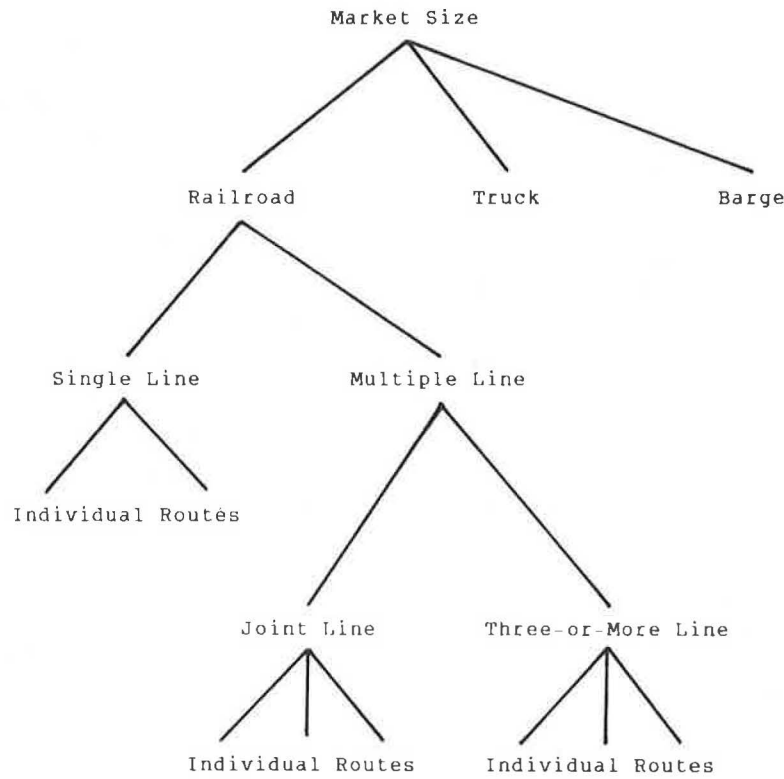
FIGURE 1 Shippers' decision tree.

each route and then choose the route with the maximum utility. This reduces the problem to that of choice over one summary variable, maximum utility.

Second, in contrast to other logit models, the choice of route may be broken down into separate decisions. The quantity carried on a given route may be written as the product of conditional probabilities.

$$Q_i = S \times P\,(M\,|\,S) \times P\,(T\,|\,M) \times P\,(N\,|\,T) \times P\,(R\,|\,N) \qquad (1)$$

where $P\,(M\,|\,S)$, for example, denotes the probability of mode M being chosen given the total quantity shipped. Each conditional probability may then be estimated by a separate equation.

It is usually assumed for simplicity that the parameters of the shipper utility functions in the nested multinomial logit model are linear. If so, each of the conditional probabilities is a linear function of the form

$$LN\,(Q_i/Q_j) = \Phi_R d + \theta_{R1}\,(p_i - p_j)$$
$$+ \theta_{R2}\,Y\,(h_i - h_j) + U_R \qquad (2)$$

$$LN\,(Q_{N3}/Q_{N2}) = \Phi_N d + \theta_N\,(I_{N3} - I_{N2}) + U_N \qquad (3)$$

$$LN\,(Q_{T2}/Q_{T1}) = \Phi_T d + \theta_T\,(I_{T2} - I_{T1}) + U_T \qquad (4)$$

$$\cdot\;LN\,(Q_{M2}/Q_{M1}) = \Phi_{M2} d + \theta_{M2}\,(I_{M2} - I_{M1}) + U_{M2} \qquad (5)$$

$$LN\,(Q_{M3}/Q_{M1}) = \Phi_{M3} d + \theta_{M3}\,(I_{M3} - I_{M1}) + U_{M3} \qquad (6)$$

$$LN\,(S) = \Phi_S d + \theta_S\,I_S + U_S \qquad (7)$$

where

$$
\begin{aligned}
p \;&=\; \text{rate per ton,} \\
h \;&=\; \text{commodity value per ton,} \\
Y \;&=\; \text{commodity value per ton,} \\
I \;&=\; \text{expected maximum utility of the choices} \\
&\quad\text{available,} \\
d \;&=\; \text{vector of dummy variables for individual} \\
&\quad\text{geographic markets,} \\
\Phi \text{ and } \theta \;&=\; \text{estimated coefficient vectors, and} \\
U \;&=\; \text{error term that is approximately normally} \\
&\quad\text{distributed.}
\end{aligned}
$$

Furthermore, McFadden (5) has shown that the expected maximum utility, I_{N3} for example, may be written as

$$I_{N3} = LN\left(\sum_{N=3}\{\exp\,[\Phi_R d + \theta_{R1}\,(p_i - p_j)\right.$$
$$\left.+\, \theta_{R2}\,Y\,(h_i - h_j)]\}\right) \qquad (8)$$

so that each quantity is, ultimately, entirely a function of observable variables.

Economic theory imposes a number of coefficient restrictions on the parameters in this system of equations. First, it is necessary that $\theta_{R1} < 0$ in order for a price reduction to increase the quantity carried on a given route. Second, it is necessary that $\theta_{R2} < 0$ in order for a service time reduction to increase the quantity carried on a given route. This restriction also implies that higher-valued commodities should travel over the

quicker route, all else equal. McFadden (5) has also shown it is necessary that

$$0 \leq \theta_N \leq \theta_T \leq \theta_{M2} = \theta_{M3} \leq \theta_S \leq 1 \qquad (9)$$

in order for this system of demand equations to be consistent with expected utility maximization on the part of shippers. If statistical tests show that all but the last of these coefficients are less than 1.0, then satisfaction of Equation 9 also implies that the shippers' decision tree in Figure 1 is correctly specified.

Cost of Transportation

Existing cost estimates were used to approximate the long-run marginal cost of transportation on each route. Railroad costs were estimated using Friedlaender and Spady's (6) estimate of short-run marginal costs (SRMC)

$$
\begin{aligned}
SRMC = \hat{C}_i \Bigg\{ (1/\psi_2) \Bigg[&\gamma_2 + \sum_{i=1}^{5} D_{i2} \, \text{LN} \, (w_i) \\
&+ \sum_{j=1}^{5} F_{j2} \, \text{LN} \, (t_j) + G_{1,\,2} \, \text{LN} \, (\psi_1) \\
&+ 2 \, G_{2,\,2} \, \text{LN} \, (\psi_2) \Bigg] + (1/\psi_{2m}) \Bigg[\beta_5 \\
&+ \sum_{i=1}^{5} B_{i5} \, \text{LN} \, (w_i) \; F_{5,\,2} \, \text{LN} \, (\psi_2) \Bigg] \Bigg\}
\end{aligned}
\qquad (10)
$$

in the case of manufactured commodities and

$$
\begin{aligned}
SRMC = \hat{C}_i \Bigg\{ (1/\psi_2) \Bigg[&\gamma_2 + \sum_{i=1}^{5} D_{i2} \, \text{LN} \, (w_i) \\
&+ \sum_{j=1}^{5} F_{j2} \, \text{LN} \, (t_j) + G_{1,\,2} \, \text{LN} \, (\psi_1) \\
&+ 2 G_{2,\,2} \, \text{LN} \, (\psi_2) \Bigg] - (1/\psi_{2b}) \Bigg[\beta_5 \\
&+ \sum_{i=1}^{5} B_{i5} \, \text{LN} \, (w_i) + F_{5,\,2} \, \text{LN} \, (\psi_2) \Bigg] \Bigg\}
\end{aligned}
\qquad (11)
$$

in the case of bulk commodities where

$\hat{C}_i$ = variable costs of firm i;
w_1 = factor price of equipment;
w_2 = factor price of general labor;
w_3 = factor price of yard and switching labor;
w_4 = factor price of on-train labor;
w_5 = factor price of fuel and materials;
t_1 = way, structures, and equipment capital;
t_2 = low-density route-miles;
t_3 = total route-miles;
t_4 = length of haul;
t_5 = ratio of manufactured to bulk commodity ton-miles;
$\psi_1, \psi_2, \psi_{2m}, \psi_{2b}$ = passenger, freight, manufactured, and bulk outputs, respectively; and

$\beta, \gamma, B, D, F, G$ = coefficients estimated by Friedlaender and Spady.

The average railroad firm in 1979 had an elasticity of short-run marginal cost with respect to output of 1.14, indicating slightly decreasing returns to scale. The long-run costs were less than the short-run costs at the point of approximation; they were also less elastic. In addition, economies of scope appear in the cost function only through the length of haul variable, which reflects a reduction in switching costs as length of haul increases. Constant or increasing returns to scale, economies of scope, or the ability of railroad firms to change fixed factor levels will all lower costs relative to the estimates used here. Lower railroad cost estimates imply that gains from merger are greater than estimated in this study.

Friedlaender and Spady (6) specify the long-run marginal cost (*LRMC*) of a specialized commodity trucking firm as

$$
\begin{aligned}
LRMC = \hat{C} \Bigg\{ (1/\psi) \Bigg[&\gamma + \sum_{i=1}^{4} D_i \, \text{LN} \, (w_i) \\
&\sum_{i=1}^{3} F_i \, \text{LN} \, (t_i) + G \, \text{LN} \, (\psi) \Bigg] \Bigg\}
\end{aligned}
\qquad (12)
$$

where

$\hat{C}$ = estimated total costs of average trucking firm,
w_1 = factor price of labor,
w_2 = factor price of fuel,
w_3 = factor price of capital,
w_4 = factor price of purchased transportation,
t_1 = average load per truck,
t_2 = average length of haul,
t_3 = insurance per ton-mile,
ψ = firm's output in ton-miles, and
D, F, G = coefficients estimated by Friedlaender and Spady.

The average specialized commodity trucking firm in 1979 had an elasticity of long-run marginal cost with respect to output of 0.96, indicating slightly increasing returns to scale. The hypothesis that these firms exhibit constant returns to scale cannot be statistically rejected. In addition, economies of scope appear in the cost function only through the length of haul variable. Increasing returns to scale or economies of scope will lower truck costs relative to the estimates used here. Lower truck cost estimates imply that gains from railroad mergers are less than estimated in this study.

Long-run marginal costs for individual barge trips have been estimated by DeSalvo (7). In his specification the long-run marginal cost of barge service on a given route may be written as

$$
LRMC = \frac{(c_t + c_b b) \; \{ [\xi_1 (LOH/v)] + [\xi_2 + \xi_3 b] + [l/(\mu - \lambda)] \}}{q \times LOH}
\qquad (13)
$$

where

c_t and c_b = cost per hour of tow boat and barge, respectively,

b = maximum number of barges in tow,
LOH = length of haul,
v = velocity of tow,
l = number of locks traversed,
μ, λ = service and arrival rates of tows at average lock,
q = maximum tonnage in tow, and
ξ_1, ξ_2, ξ_3 = coefficients estimated by DeSalvo.

This trip-specific cost function is probably a good approximation of the long-run marginal cost of barge service on a given route.

DATA

The recent Chessie System–Family Lines (CSX) merger was analyzed using data published for or updated to 1979. A detailed description of the data and their development is presented by Dennis (*8*).

The United States was divided into the nine regions that are shown in Figure 2. Each region served as both an origin and a destination. All traffic in each origin-destination pair was divided into the 18 commodity groups given in Table 1. Commodity groups that account for 5 percent or more of the railroad tonnage in each origin-destination pair were identified as major commodities. The major commodities in each origin-destination pair defined the surface freight transportation markets to be analyzed.

Traffic within each surface freight transportation market was classified first by mode and then by firm. Rail routes were identified by as many as three carriers using the One Percent Waybill Sample with Carrier Identification, a 1 percent sample of all railroad shipments terminated in the United States. All routes with 5 percent or more of the railroad traffic in a market were explicitly included in the analysis. The other rail routes were classified as one-, two-, or three-carrier miscellaneous

routes. The truck and barge modes were each given their own generic route encompassing all traffic carried by those modes.

Demand Variables

The demand variables in this study were affected by three main data limitations. First, most econometric estimates of logit models use individual decisions as the unit of observation. Because data were lacking on individual shippers, an equivalent approach that used data aggregated over groups of shippers was adopted. Second, the data used were developed from a variety of sources because there is no one unified data set applicable to all modes. Ben-Akiva and Lerman (*4*) have shown that systematic errors resulting from this problem are entirely incorporated into the geographic coefficients, leaving the other coefficients unaffected. Third, although many characteristics affect shipper choice, suitable data were available only for tonnage, rates, and service time. The demand analysis was therefore limited to these variables. Of these three limitations, only the service time data appear to have had any substantial effect on the results.

Price data for railroad routes were taken directly from the One Percent Waybill Sample. Prices were assumed to be equal to estimated costs for the truck and barge modes. Service time data were developed using estimates by DeHayes (*9*) for the rail and truck modes and DeSalvo's (*7*) estimated process function for the barge mode. Data on commodity values were derived from the *Census of Transportation* (*10*) and a variety of other sources. Railroad tonnages were taken directly from the One Percent Waybill Sample. Truck tonnages were taken from the *Census of Transportation* and U.S. Department of Agriculture statistics. Barge tonnages were derived from the *Census of Transportation* and *Waterborne Commerce of the United States* (*11*).

The DeHayes study is somewhat dated and also appears to underestimate rail service time. Underestimating service time

FIGURE 2   Origin and destination regions.

TABLE 1 COMMODITY DATA

	COMMODITY	STCC	VALUE PER TON ($)		
			RAIL	TRUCK	BARGE
1.	Fresh Fruit & Veg.	012-019,09	1385	1385	1385
2.	Grain	011,204,209	140	140	140
3.	Minerals	10,14	26	26	26
4.	Food	20,x204,209	490	733	638
5.	Clothing	22,23,31	6998	4280	4833
6.	Lumber	08,24	170	155	74
7.	Furniture	25	2053	2300	1597
8.	Pulp and Paper	26	418	677	526
9.	Chemicals	28	278	589	195
10.	Refinery Products	13,29	126	101	131
11.	Rubber Products	30	2148	2266	2816
12.	Cement	32	104	64	50
13.	Primary Metals	33	506	769	694
14.	Fabricated Metals	34	1426	1612	2402
15.	Machinery	35,36	3602	5513	2546
16.	Transport Equipment	37	2590	3055	20723
17.	Miscellaneous	19,21,27,38	5293	2748	4128
18.	Coal	11	24	24	24

may bias the service time coefficient upward and may tend to overestimate both service time elasticity and gains from improved service. However, the DeHayes study remains the most complete study of which the author is aware and was therefore used in the analysis.

Cost Variables

Railroad factor prices were developed using *Indexes of Railroad Materials Prices and Wage Rates* (12). Railroad fixed factor levels were derived from reports to the Interstate Commerce Commission, as were both railroad output variables. Market length of haul and the proportion of manufactured ton-miles were taken from the One Percent Waybill Sample and *Moody's Transportation Manual* (13), respectively.

Truck factor prices were developed from *Trinc's Blue Book* (14) as was the estimate of insurance per ton-mile. Average load per truck and market length of haul were taken from reports to the Interstate Commerce Commission and the *Census of Transportation*, respectively.

Tow boat and barge operating costs were taken from annual estimate by the U.S. Army Corps of Engineers (15). The physical attributes of waterways and all other barge cost variables were taken from a Bechtel study (16) of the inland waterway system.

DEMAND ESTIMATION

Estimation Method

A nested multinomial logit model based on these aggregate data was estimated using the Berkson-Theil method as employed by Levin (17). Two-stage generalized least squares were used to estimate Equations 2–4 and 7 separately and to estimate Equations 5 and 6 jointly. This method of estimation accounts for heteroskedasticity resulting from sample size and will yield consistent estimates of the parameters.

Railroad and truck quantities were adjusted downward in cases in which waterways serve some but not all of a region. This adjustment eliminated the downward bias of model coefficients identified by Koppelman and Ben-Akiva (18). Last, variances were adjusted upward for Equations 3–7. This adjustment eliminated the downward bias of model variances identified by Amemiya (19).

Estimation Results

The estimated coefficients for Equations 2–7 and their adjusted *t*-statistics are given in Table 2. All of the price, service quality, and expected utility coefficients in Table 2 have the expected signs, and almost all are statistically significant at greater than the 95 percent confidence level. Only the

TABLE 2 DEMAND REGRESSION EQUATIONS

VARIABLE	(2)	(3)	(4)	(5)	(6)	(7)
OR1	-1.0742	2.5783	-2.6837	–	–	15.2791
	(-5.39)	(6.28)	(-6.28)	–	–	(69.42)
OR2	-1.1449	1.5841	-1.8716	0.4409	-1.9201	16.2002
	(-12.75)	(6.39)	(-7.80)	(0.82)	(-2.22)	(114.91)
OR3	-1.1632	1.3374	-0.2683	–	–	16.3902
	(-13.54)	(4.90)	(-0.82)	–	–	(105.30)
OR4	-1.0087	–	-1.7886	-0.1174	0.2836	16.3939
	(-8.26)	–	(-3.89)	(-0.07)	(0.10)	(67.70)
OR5	-0.9607	0.7818	-0.4675	0.9018	-1.2193	15.4053
	(-7.01)	(2.14)	(-1.08)	(1.19)	(-0.99)	(58.75)
OR6	-0.6593	1.4361	-0.5951	–	–	16.2064
	(-5.30)	(3.84)	(-1.54)	–	–	(62.74)
OR7	-1.5301	1.2048	-3.4201	-0.8747	-2.1019	18.0218
	(-5.64)	(2.58)	(-7.55)	(-0.48)	(-0.71)	(53.80)
DES1	0.7294	–	1.4792	–	–	-1.1409
	(1.13)	–	(2.45)	–	–	(-2.30)
DES2	0.3318	-2.7705	1.3111	0.4053	-4.5935	-0.6877
	(1.88)	(-5.04)	(1.48)	(0.41)	(-2.88)	(-2.88)
DES3	–	–	–	–	–	–
	–	–	–	–	–	–
DES4	0.2450	-2.4961	1.0894	1.5311	-0.1831	-2.1460
	(1.90)	(-8.03)	(2.38)	(0.95)	(-0.07)	(-8.32)
DES5	0.4712	-2.1789	0.1313	0.0386	0.8787	-0.3259
	(4.15)	(-5.30)	(0.34)	(0.10)	(1.52)	(-1.72)
DES6	0.2340	-2.1748	-0.5675	-1.1664	0.0765	-0.9870
	(2.03)	(-7.24)	(-1.62)	(-3.79)	(0.15)	(-4.39)
DES7	0.2953	–	-0.2157	-0.8167	-1.8777	-1.6345
	(1.82)	–	(-0.57)	(-0.56)	(-0.80)	(-5.98)
DES8	0.4256	-2.5990	1.2190	0.1559	1.5969	-1.5840
	(3.91)	(-7.88)	(4.00)	(0.50)	(3.17)	(-9.44)
DES9	0.1518	-2.3008	1.0300	–	–	-1.5073
	(1.03)	(-6.58)	(3.11)	–	–	(-8.73)
θ_1	-0.02053	0.21501	0.65368	0.65368	0.65368	0.97002
	(-3.05)	(2.72)	(16.88)	–	–	(11.27)
θ_2	-0.00029	–	–	–	–	–
	(-1.01)	–	–	–	–	–
N	1058	356	325	90	90	356
F	42.02	11.17	29.28	–	–	6961.90
R^2	.5672	.4881	.7415	.7450	.7450	.9985
SEE	5.606	1.281	6.373	1.277	1.277	28.044

service time coefficient is not statistically significant, probably because of the limitations of the service time data discussed previously. White (*20*) tests on Equations 2–4 and 7 indicate that the residuals of these equations are homoskedastic, so that heteroskedasticity is not a concern in these equations and the equations are likely to be correctly specified. There is no analogous test for Equations 5 and 6.

The initial estimates of the coefficients in Equations 5 and 6 did not satisfy the inequality restrictions in Equation 9. Viola-tion of these restrictions would lead to perverse forecasting results. Equations 5 and 6 were therefore reestimated to satisfy this constraint by setting $\theta = 0.65368$. An approximate chi-squared test indicated that this restriction was statistically significant at the 95 percent confidence level.

Adjusted *t*-tests on the estimates of θ_N, θ_T, θ_{M2}, and θ_{M3} all rejected the hypothesis that any of these coefficients were equal to 1.0 at better than the 95 percent confidence

level. The shippers' decision tree in Figure 1 therefore correctly represents the routing decisions reflected in the data.

Interpretation

Price and service elasticity calculations depend on the modes present in the market and on the values of the demand variables. Assume in Figure 1 that shippers choose from among two single-line routes, three joint-line routes, a three-line route, a generic truck route, and a generic barge route. The elasticity of quantity (Q) carried on a given route with respect to an attribute (X) on this or any other route may then be written as

$$
\begin{aligned}
\varepsilon = {} & \theta_S\,\theta_M\,\theta_T\,\theta_N\,\alpha\,X\,P\,(M\,|\,S) \times P(T\,|\,M) \times P\,(N\,|\,T) \\
& \times P\,(R\,|\,N) + \theta_M\,\theta_T\,\theta_N\,\alpha\,X\,[\delta_{mm} - P\,(M\,|\,S)] \\
& \times P\,(T\,|\,M)\,P\,(N\,|\,T) \times P\,(R\,|\,N) + \theta_T\,\theta_N\,\alpha\,X\,\delta_{mm}\,[\delta_{tt} \\
& - P\,(T\,|\,M)]\,P\,(N\,|\,T) \times P\,(R\,|\,N) \\
& + \theta_N\,\alpha\,X\,\delta_{mm}\,\delta_{tt}\,[\delta_{nn} - P\,(N\,|\,T)]\,P\,(R\,|\,N) \\
& + \alpha\,X\,\delta_{mm}\,\delta_{tt}\,\delta_{nn}\,[\delta_{rr} - P\,(R\,|\,N)]
\end{aligned} \tag{14}
$$

where

θ = estimated expected maximum utility coefficients,
α = estimated attribute coefficient,
P = conditional probabilities, and
δ = indicator function ($\delta_{mm} = 1$ if $m = m$, 0 otherwise)

Intuitively, each additive term represents a different level of the decision tree. The first additive term takes account of the effect on overall market size; the last four terms take account of the effect on market share. The $\delta - P$ terms represent the amount of other traffic available at that level of the tree, and the $\theta\alpha X$ terms represent how much a change in one route's attribute affects traffic at that level of the tree. The conditional probability terms represent how much of the change in traffic filters down to the individual route.

The own-price and own-service elasticities for this example decision tree follow.

Elasticity	*Value*
Single-line	
Own price	−0.40
Own service	−0.67
Joint-line	
Own price	−0.52
Own service	−0.86
Three-line	
Own price	−0.17
Own service	−0.27
Truck	
Own price	−0.07
Own service	−0.11
Barge	
Own price	−0.07
Own service	−0.11

The own-price elasticities of demand for an individual route, calculated at the sample means, are in the range of the aggregate price elasticities calculated by Levin (*17*), Friedlaender and Spady (*6*), and others.

The own-service elasticities at the sample means are uniformly higher than the own-price elasticities. Service becomes even more important for higher-valued commodities whereas price is more important for sufficiently low-valued commodities such as coal and grain. These observations support the contention that most shippers value service competition more than they value price competition.

The coefficients in Equation 2 may also be used to compute shippers' implicit value of time. Dividing the service time coefficient (utility per day in transit) by the price coefficient (utility per dollar of rate) indicates that each dollar is worth about $1.014 per day in transit. This high discount rate may reflect a variety of different factors including the opportunity cost of capital, service time acting as a proxy for other reductions in nontransport logistics costs, or an upward bias in the service time coefficient.

WELFARE ANALYSIS

Theory

Changes in prices, service times, and costs result in changes in the total surplus generated in a surface freight transportation market. If income effects are zero, the total surplus (*TS*) resulting from the merger in an individual market may be written as

$$
\begin{aligned}
TS = \sum_R \{ & Q_R'\,[-(c_R'' - c_R')] \\
& + (p_R' - c_R'')\,(Q_R'' - Q_R') + 0.5[(p_R'' - p_R') \\
& + (h_R'' - h_R')\,Y]\,(Q_R'' - Q_R') \}
\end{aligned} \tag{15}
$$

where

$'$ = premerger values,
$''$ = postmerger values,
R = route indexes,
Q = demand function, and
c = marginal cost.

The first term in Equation 15 represents the cost savings on route *r* attributable to the merger. The second term represents the additional gain or loss in producers' surplus. The third term represents the gain or loss in consumers' surplus. Pure transfers from producers to consumers as a result of lower prices are not counted as part of the change in total surplus.

Simulation

Equation 15 was used to estimate the change in total surplus in 61 surface freight transportation markets as a result of the CSX merger.

Premerger values for prices, quantities, service times, and commodity values were taken directly from the sources

described in the third section of this paper. Premerger marginal costs for railroads were estimated using Equations 10 and 11 and the data described in the third section of the paper. The marginal costs for the upstream and downstream segments were estimated using length of haul and other variables pertaining to the firm operating that segment. Costs were computed for each segment and then added to get the cost of the route. Marginal costs for truck and barge were estimated using Equations 12 and 13 and the data described in the third section of the paper.

Postmerger prices were generated by assuming that improved service on the newly merged route allows the merged firm a 10 percent greater markup over its new costs. All other firms were assumed to maintain their premerger rates. Faster postmerger service times on the merged route were developed using the DeHayes estimates described in the third section of the paper. Postmerger quantities were developed by using postmerger prices and service times in Equations 2–7. Postmerger marginal costs on the merged routes were estimated using Equations 10 and 11. Length of haul on the merged route was taken as the sum of the lengths of haul on the upstream and downstream segments. This lowered the marginal cost of the merged route relative to the marginal costs of the two unmerged segments, thus generating a cost savings. All other cost function arguments for the merged firm were evaluated at ton-mile weighted averages of the premerger values.

Analysis

The results of the CSX merger simulation are given in Table 3. The first three columns of this table list the origin, destination,

and commodities that define the individual surface freight transportation markets. The change in total surplus resulting from the merger is given in the fifth column. The simulation indicates that the CSX merger increases total surplus by $345 million per year, assuming all other factors are unchanged. This gain in total surplus results mainly from railroad cost reductions associated with increased length of haul on the merged route. Reduced transit time on the merged route also increases total surplus, especially for higher-valued commodities for which the value of improved service is greater.

In 46 of the 61 transportation markets studied, costs on the merged route declined, prices also declined, and service time improved. These effects caused consumers' surplus, producers' surplus, and total surplus all to increase unambiguously. These transportation markets accounted for the vast majority of the welfare changes associated with the merger. The simultaneous increase in consumers' surplus, producers' surplus, and total surplus is consistent with an efficiency explanation of end-to-end railroad mergers.

Although an unambiguous increase in consumers' surplus, producers' surplus, and total surplus was the most common simulation outcome, different markets displayed different results. In one market involving a high-valued commodity, the averaging process for the cost function arguments caused a cost increase and consequent price increase. The resulting losses in consumers' and producers' surplus were more than offset by valuable service improvements so that total surplus increased in this market.

In eight markets, mostly involving low-valued commodities, the assumed price increases outweighed the value of service improvements so that the change in consumers' surplus was negative. However, cost savings in these markets

TABLE 3 EFFECT OF CSX MERGER ON TOTAL SURPLUS

ORIGIN	DESTINATION	MAJOR COMMODITIES	TS1	TS2	TS3
1	4	6,7,8,9	7.8	7.9	8.0
1	6	8,12	7.0	7.1	7.1
1	7	8	2.1	2.1	2.1
2	4	3,6,8,9,12,13,18	16.9	16.9	17.1
2	6	8,12,13,16	107.8	108.6	108.8
2	7	4,8,9,16	71.0	71.7	73.8
3	4	2,8,12,16,18	-0.2	-0.2	1.3
3	5	2,3,18	-9.3	-9.3	-9.2
3	6	2,8,10,12,13,16	36.4	37.1	37.7
3	7	2,8,9,16	9.9	10.1	10.5
4	4	2,3,6,12,18	14.4	14.4	14.4
4	5	18	11.0	11.0	11.0
4	6	2,6,8,9,12,18	21.5	21.5	21.5
4	7	3,4,8,9,12	12.5	12.5	12.5
5	6	2,6,12,18	33.1	33.1	33.7
		TOTAL	341.9	344.5	350.3

increased producers' surplus enough that total surplus increased.

In five markets, all involving low-valued commodities, the assumed price increases outweighed the value of service improvements so that the change in consumers' surplus was negative. Cost savings were not sufficient to eliminate these losses, so total surplus declined.

In one market involving a low-valued commodity, the averaging process for the cost function arguments again caused a cost increase and consequent price increase. Service improvements in this market had relatively little value and were insufficient to offset losses in consumers' and producers' surplus. Total surplus therefore declined in this market.

Sensitivity of Results

The sensitivity of the analysis to the assumed pricing policy was tested by simulating two alternative pricing policies. In the first scenario the merged firm sets rates on its newly merged route at the assumed regulatory maximum while all other firms maintain their premerger prices. This corresponds roughly to monopolistic behavior on the part of the merged firm. In the second scenario the merged firm engages in the same pricing that it did in the simulation. All other firms lower their rates to the merged firm's new rate or to their cost, whichever is greater. This scenario corresponds to a price war between competitors.

The results of these simulations vary from $340 million to $350 million per year as shown in Columns 4 and 6, respectively, of Table 3. The results are fairly insensitive to the assumed pricing policy for three reasons. First, the premerger prices tended to be near the assumed regulatory maximum so that there was relatively little change in price between the simulation and the first scenario. Second, the CSX lines tended to have higher rates than their competitors even after the merger. This made price wars among competitors fairly infrequent and caused relatively little change in prices between the simulation and the second scenario. Third, the relatively low price elasticities resulted in fairly small quantity changes for a given change in prices.

Changes in total surplus resulting from the merger are likely to be larger in the long run. Changes in transport rates or service will make shippers more likely to switch modes, relocate, use alternative commodities, or find other sources or markets for existing commodities. Any of these actions will make the demand for transportation on a given route more elastic, increasing both the welfare gains and the welfare losses associated with the merger. Alternatively, stricter regulations on the abandonment of fixed factors such as track would raise costs and reduce welfare gains.

CONCLUSIONS

The results of this study indicate that the CSX merger increased total surplus by $340 million to $350 million per year, assuming all other factors remained unchanged. The main source of increase was railroad cost reductions. These cost reductions resulted from increased length of haul on the merged route. Reduced transit time on the merged route also increased total surplus, but by a lesser amount. This effect was

relatively more important for higher-valued commodities. Price changes had little effect on total surplus. Because the demand for transportation on an individual route was relatively inelastic, price changes resulted mainly in pure transfers between producers and consumers.

These results should not be interpreted to mean that any and all end-to-end mergers confer massive benefits. As noted before, different markets in this study displayed different results, and the benefits of improved service may be overestimated. In addition, there is the question of whether firms need to merge in order to gain the benefits of merger. However, it does appear that end-to-end railroad mergers with similar characteristics may well confer substantial economic benefits.

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