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Abstract

This paper reports on results obtained from estimation of a rail cost function using a pooled time-series cross section of Class I U.S. railroads for the period 1973-1986. Based on the results of this cost function, an analysis is performed of short-run and long-run returns to scale, and adjustments in way and structure capital in the heavily regulated and quasi regulated environments. In general, it is found that there is considerable overcapitalization in the rail industry, and that this has persisted in spite of the regulatory freedom to abandon track and service provided by the Staggers Act.

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1. Introduction and Overview

With the passage of the Staggers Act in 1980, US railroads obtained substantial regulatory freedom to adjust their rates and their capital structure through changes in routes and service levels. Although most of the attention on the effects of rail deregulation has been focused upon the issue of rail rates in a quasi-regulated environment,[1] it is important to note that the Staggers act provided the railroads with considerable potential to rationalize their capital structures by permitting them to abandon unprofitable traffic and branch lines, and by establishing a legislative goal that railroads earn a fair rate of return to capital. The first provision was important since it gave railroads the freedom to rationalize their rate structure; the second since it provided the marketplace with a signal that there was a legislative intent for railroads to become "profitable," and at least earn a normal return to their capital. [2]

The issue of adjustments in rail capital is significant because of the considerable amount of evidence that prior to the passage of the Staggers Act, railroads were in a position of substantial capital disequilibrium. On the one hand the common carrier obligation incurred by railroads forced them to sustain excessive route networks; on the other hand railroads suffered from undercapitalization caused by low profitability and a consequent inability to generate adequate internal or external funds to maintain their way and structures capital along high density routes. Given this capital disequilibrium and the evidence of significant scale economies and/or returns to density,[3] it is unlikely that the observed economies of scale at a regulated equilibrium with a non-optimal capital stock are representative of the costs and scale economies that would occur at a deregulated equilibrium with optimal capital adjustments. Moreover, if the short-run and long-run scale economies are substantially different, it is important to consider the transitional path of adjustment and the extent to which railroads have moved toward a long-run capital equilibrium in the period since the passage of the Staggers Act.[4] If, however, the short-run and long-run scale economies are quite similar, then the question of the railroads' ability to adjust their capital in an optimal fashion is less important.

This paper addresses these issues by reporting results from the estimation of a short-run rail cost function based on a pooled cross-section/time series of a sample of Class I railroads for the period 1974-1986. As such it not only presents an updated railroad cost function,[5] but it also provides sufficient information to determine the extent and nature of capital adjustments during a regulated and a quasi-regulated regime.

This paper takes the following form. The next section discusses the specification of the cost function, a number of econometric issues related to its specification, and the data set used in the estimation. Section 3 then reviews various issues related to the measurement of scale economies and their empirical estimation. Section 4 presents the available evidence on the efficiency of the capital stock and adjustments toward equilibrium during the sample period. Section 5 discusses the policy implications of these findings and provides a brief summary and conclusion.

2. Econometric Issues and the Estimation of Rail Costs

Since the capital embodied in the railroads' way and structures is long-lived and difficult to adjust, railroad costs are estimated using a short-run variable cost function of the following general form:

$$C^s = C^s(y, w, t, x_F, F, T) \qquad (1)$$

where y represents output; w is a vector of input prices; t is a vector of factors that affect the technological environment in which the firms operate; x_F the fixed way and structures capital (WS); F is a vector of indicator variables to capture firm-specific effects; and T represents a time trend to capture productivity growth. The data in this analysis come primarily from various sources published by the Interstate Commerce Commission (ICC) or the Association of American Railroads (AAR). The interested reader is directed to Vellturo (1989), who presents a full discussion of the data sources and construction of the variables used in this analysis.

2.1 Variables

Total variable cost is derived primarily from conventional "operating costs" as defined in standard railroad accounting. Way and Structures' maintenance costs are removed from operating costs and treated as way and structures' investment. In addition equipment depreciation is removed from operating costs and is replaced by a "user cost" of equipment. The resulting total variable cost measure, therefore, has four components: fuel, labor, materials & supplies, and equipment user costs.[6]

Since rail traffic is very heterogeneous, one would ideally like to have an output measure that would reflect this diversity. Unfortunately, however, two major factors militate against this. First, ton-mile data are not available by broad commodity type;[7] and second, if one estimates a flexible-form second-order approximation of a cost function, a multiple-output vector would generate too many parameters to be estimated. In this cost function we use an aggregate output measure of ton-miles, but take the composition of output into effect by respectively using as technological variables coal and agricultural tons carried as a percent of total tons carried.[8] This breakdown of output is not only useful because of the specialized equipment used for coal and agricultural traffic, but also because of the current policy debate concerning the rate structure facing captive coal shippers.

The variable factors used in the cost function are labor, fuel, equipment capital, and materials and supplies. Price indices for fuel and for materials and supplies are published by the Association of American Railroads on a regional basis and are allocated to the railroads in the sample on this basis. The price index for equipment capital (P_{it}) measures the user cost of equipment for each railroad and each year in the sample.[9] The price of labor was developed by aggregating the seventy-eight different categories of rail labor provided annually by the ICC A-200 wage schedules for each railroad into seven categories, and then using a Divisia index to construct an annual aggregate labor price index for each railroad.

Way and structures (WS) capital represents roadbed, track, bridges, etc. Since this is typically long-lived, we treat it as a fixed factor. Measures of WS capital were estimated following the procedures outlined by Friedlaender and Spady (1981), which in turn were estimated from internal capital stock data provided by Nelson (1974). The basic approach is relatively straightforward and is based on the perpetual inventory identity

$$K_t \equiv K_{t-1} (1 - \delta_t) + I_t$$

where K_t represents capital at the end of the period t, I_t represents the investment during period t, and δ_t represents the rate of depreciation. Since the ICC has made a number of changes in its accounting rules during the sample period, the specific methodology followed was quite complex and the interested reader is referred to Vellturo (1989) for further details.

Because of the importance of the nature of the rail network, it is desirable to include technological variables that reflect principal features of the network and of rail operations. Ideally, we would like to utilize measures that reflect the connectivity and density of the network.[10] Because of the lack of available data, however, we are limited to using route miles and average length of haul as measures of the network and its utilization. A time trend was included to capture productivity growth. In addition, to capture pre- and post-merger efficiencies, another time trend M (defined to be the number of years since the merger of the merged systems) was introduced to capture the adjustment costs associated with consolidation.[11]

Since rail technology is highly complex, it is unlikely that an econometric cost function will fully encompass all of the elements that affect it. Fortunately, a significant number of these unobserved variables relate to the network structures and geographic configuration of each railroad -- functions that remain relatively unchanged over the sample period. Consequently we introduce firm-specific indicators to capture these unobserved network effects as well as any firm-specific differences in technology that are not related to the operations of the firm.[12]

2.2 Sample

The rail cost function was estimated using panel data consisting of major Class I railroads for the period 1974-1986. Of the 42 major railroads initially considered for inclusion in the analysis, 29 were found to have complete and consistent data and thus formed the basis for our analysis. In addition, a significant number of mergers occurred during this period. To handle this problem, each merged system was treated as a separate observation. Thus as railroads merged, they disappeared from our sample and were replaced by a newly merged rail system; of the 27 rail systems used in our analysis, only 9 were observed for all 13 years in our sample (1974-1986). Since we utilize a fixed-effects model, there are no significant econometric problems associated with using unbalanced panel data.[13] Table 1 provides data on the means and standard deviations of the variables in the sample.

Table 1

Means and Standard Deviations of Variables used
in Analysis of Railroad Costs

	Units	Mean	Std Dev.	Min	Max
Variable Cost	$ bil	1.141	1.148	0.019	5.040
Price of Labor	$ of comp/hr	9.677	2.843	5.390	17.740
Price of Equip	Index[b]	0.396	0.131	0.190	0.674
Price of Fuel	Index[a]	1.637	0.742	0.684	2.844
Price of M+S	Index[a]	1.173	0.260	0.652	1.495
Ton Miles	bil	45.245	41.876	1.910	203.000
Pct Ag	%	19.117	9.025	6.298	69.175
Pct Coal	%	26.403	17.816	0.291	79.378
WS Capital	$ bil	1.906	1.923	0.118	8.303
ALH	1,000	0.392	0.145	0.173	0.780
Track Miles	1,000	7.930	6.428	0.543	25.810
Year		6.476	3.594	1.000	13.000
Labor Expend	$ bil	0.460	0.464	0.004	1.940
Equip Expend	$ bil	0.373	0.416	0.003	2.175
Fuel Expend	$ bil	0.116	0.123	0.003	0.547
M+S Expend	$ bil	0.192	0.205	0.001	1.137
Lab Share		0.397	0.081	0.105	0.664
Equip Share		0.333	0.091	0.068	0.585
Fuel Share		0.105	0.039	0.036	0.301
M+S Share		0.165	0.064	0.008	0.459

[a] 1977 = 1.000
[b] 1971 = 0.100

2.3 Specification

To estimate rail costs, we utilize the familiar translog cost function and its associated (n-1) factor share equations, which take the following form:[14]

$$
\begin{aligned}
\ln(C^{s}) = {} & A_o + \sum_{i=1}^{n} A_i \ln(w_i) + B_1 \ln(y) + \sum_{j=1}^{m} C_j \ln(t_j) + D_1(T) + M_1(M) + \\
& + \tfrac{1}{2} \sum_{i=1}^{n} \sum_{c=1}^{n} AA_{ic} \ln(w_i) \ln(w_c) + \tfrac{1}{2} BB_{11} (\ln(y))^{2} + \sum_{i=1}^{n} AB_{i1} \ln(w_i) \ln(y) \\
& + \sum_{i=1}^{n} \sum_{j=1}^{m} AC_{ij} \ln(w_i) \ln(t_j) + \sum_{i=1}^{n} AD_{i1} \ln(w_i) T + \sum_{j=1}^{m} BC_{j1} \ln(t_j) \ln(y) \\
& + BD_{11} \ln(y) T + \tfrac{1}{2} \sum_{j=1}^{m} \sum_{\psi=1}^{m} CC_{j\psi} \ln(t_j) \ln(t_{\psi}) + \tfrac{1}{2} D_{11}(T^{2}) + \tfrac{1}{2} M_{11}(M^{2})
\end{aligned}
\tag{2}
$$

where $i, c = 1, \ldots, n$ is the number of inputs

$j, \psi = 1, \ldots, m$ is the number of technological variables

$$
\begin{aligned}
\frac{\partial \ln C^{s}}{\partial \ln w_i} = \frac{\sum_{i}^{n} w_i x_i}{C^{s}} = {} & A_i + \sum_{c=1}^{n} AA_{ic} \ln((w_c) + AB_{i1} \ln(y) \\
& + \sum_{j=1}^{m} AC_{ij} \ln(t_j) + AD_{i1} T
\end{aligned}
\tag{3}
$$

$i, c = 1, \ldots, n$

$j = 1, \ldots, m$

In estimating this equation system, we encountered a number of econometric issues. Of these, the most significant were the appropriate treatment of the error structures; the specification of fixed effects and their associated coefficient restrictions; and output endogeneity.

We assume that the cost equation and its associated input share equations have an additive error structure of the following form:

$$C^{s}_{rt} = F\,(w,\ y,\ t,\ T,\ x_F;\ \beta)\big|_{rt} + \epsilon_{rt} \tag{4a}$$

$$S_{irt} = A_i + G(w,\ y,\ t,\ T,\ x_F;\ \beta)\big|_{rt} + \mu_{irt} \tag{4b}$$

where the variables have their previous definitions and β represents the vector of parameters associated with the estimated equations. This provides a sequence of seemingly unrelated equations (if we ignore for the moment the cross-equation constraints), and within each equation there are error terms that may be both firm-specific and autocorrelated. We decompose each error term into three components: a firm specific error (α_r and α_{ir}); an error that exhibits first order autocorrelation within a given equation (b_t and γ_{it} ; we assume no error autocorrelation across equations); and a normally distributed term that may be contemporaneously correlated across equations only (c_{rt} and ω_{irt}): Thus

$$\epsilon_{rt} = \alpha_r + b_t + c_{rt};$$

$$\mu_{irt} = \alpha_{ir} + \gamma_{it} + \omega_{irt}\ (i = 1 \ldots 4) \tag{5}$$

Only c_{rt} and ω_{irt} are contemporaenously correlated across equations. We correct for each non-spherical disturbance problem in turn.

First, we consider the origin of the firm-specific error term (α_r, α_{ir}). Since we expect this term to reflect some fundamental network differences between Class I railroads (i.e., the spatial configurations of their routes; for example, whether their network is primarily hub-and-spoke, end-to-end, etc.), it seems reasonable to assume that this effect is fixed for a given railroad over time. Thus we can eliminate the firm specific error component by introducing an indicator variable for each firm. We also assume that fixed effects (the unobserved network configuration) can influence input utilization[15] and hence introduce indicator variables into the linear term of the input share equations.[16] Finally, we assume that these firm-specific effects are known to the railroads and enter into their cost-minimizing decisions.[17]

Once the firm-specific effects are introduced, we estimate the full system of equations under full information maximum likelihood (FIML) and thereby obtain consistent estimates. From these estimates we can construct residuals for each equations (b_t, γ_{it}) which capture any existing first-order autocorrelation (e.g. $b_t = \rho\ b_{t-1} + \psi_t$; and similarly for the share equation γ_{it}). From this we can estimate the ρ's for each equation,[18] transform the data as appropriate for the presence of first-order serial correlation, and re-estimate the equation.

Cross equation correlation (c_{rt}, ω_{irt}) is accommodated through the use of a systems-estimation procedure, and we implicitly assume that the correlations between the remaining components of the error term (after adjustment for fixed effects and serial correlation) are independent across firms and across time. Since the sum of the error terms on the four input share equations must equal zero, joint estimates of all the input share equations will yield a singular cross-equation covariance matrix. The materials and supplies input share equation was consequently dropped from our analysis.[19] Finally heteroskedasticity tests performed on the fully corrected FIML residuals indicated the existence of heteroskedasticity. Consequently all of the variables were scaled by the square root of the log of output to correct for its effects in the cost and input share equations.

Because of the rate-setting freedom introduced by the Staggers Act, it is reasonable to ask whether output should be treated as being exogenous, as has been done in previous studies of rail costs.[20] If, however, output is endogenous, output and its components will be correlated with the cross-equation error terms, so that estimates based on generalized least squares will be biased and inconsistent. To deal with this problem we utilized instrumental variables and followed the analysis of Hausman (1978) and Hausman et. al (1988) to determine if endogeniety exists.

Specifically, insofar as output is determined endogenously through the profit maximizing behavior of the railroads, it should be related to demand variables that do not enter the cost function. Consequently we utilized an appropriate set of demand-related variables as instruments including coal production, mine-mouth prices, oil rates, farm income, value of shipments, population, etc.[21] With these variables as instruments, we performed a test for exogeniety and could not reject the null hypothesis that the output variables were uncorrelated with the equation disturbances, i.e., we could not reject the null hypothesis of exogeneity.[22]

2.4 The Estimated Cost Function

Tables 2 and 2a present the coefficient estimates of the parameters in the cost function and their associated large sample t-statistics. Note that since the cost function was estimated using actual observations rather than by using the observation as deviations from the grand sample mean, the specific coefficients cannot be inferred as measuring a given cost elasticity at the sample mean.[23] For the most part the signs of the coefficients are as expected, and the parameters are generally significant.[24]

When an unconstrained cost function was estimated, it was found that the regularity conditions were violated for a substantial number of observations, making it impossible to obtain meaningful estimates of the long-run equilibrium value of the capital stock and returns to scale for these observations.[25] In an effort to deal with the problem, the CC_{11} coefficient (on the squared WS term) was restricted to equal zero instead of using its unrestricted value of $CC_{11} = 0.0585$ (with a standard error of .2001). This increased the number of observations that met the regularity conditions to 209 out of a total number of observations equal to 229, while having an insignificant effect upon the log of the likelihood function.[26] Thus in the ensuing analysis we use the elasticity estimates based on the restricted cost function where $CC_{11}=0$, and where output is exogenous.

Table 2

Parameter Estimates for Restricted Translog Specification

Coeff.	Var.	Estimate	Standard Error	T-stat	Coeff.	Var.	Estimate	Standard Error	T-stat
B1	y	5.0053	1.0312	4.85 *	AA12	w1w2	-0.1368	0.0192	-7.13
C1	t1	0.5824	0.6104	0.95	AA13	w1w3	0.0144	0.0119	1.21
C2	t2	-5.8325	1.4578	-4.00 *	AA14	w1w4	-0.0364	0.0280	-1.30
C3	t3	-5.4147	1.3745	-3.94 *	AA23	w2w3	0.0137	0.0119	1.15
C4	t4	5.1360	0.7944	6.47 *	AA24	w2w4	-0.0267	0.0202	-1.32
C5	t5	-2.1006	0.2788	-7.53 *	AA34	w3w4	-0.1128	0.0141	-8.01 *
AB11	w1y	0.0223	0.0181	1.23	BC11	t1y	0.4712	0.1215	3.88 *
AB21	w2y	-0.1937	0.0135	-14.31 *	BC12	t2y	-0.2537	0.1820	-1.39
AB31	w3y	0.0552	0.0131	4.23 *	BC13	t3y	-0.6067	0.1447	-4.19 *
AB41	w4y	0.1161	0.0249	4.67 *	BC14	t4y	0.1910	0.1013	1.89 *
AC11	w1t1	0.0712	0.0353	2.01 **	BC15	t5y	-0.0667	0.0379	-1.76 *
AC21	w2t1	0.0692	0.0260	2.66 *	BB11	yy	0.1867	0.1612	1.16
AC31	w3t1	0.0813	0.0254	3.21 *	CC11	t1t1	0.0000	na	na
AC41	w4t1	-0.2217	0.0491	-4.52 *	CC12	t1t2	-0.5434	0.1481	-3.67 *
AC12	w1t2	-0.0013	0.0358	-0.04	CC13	t1t3	-0.2753	0.0972	-2.83 *
AC22	w2t2	0.1184	0.0236	5.01 *	CC14	t1t4	0.5833	0.1039	5.61 *
AC32	w3t2	0.0186	0.0230	0.81	CC15	t1t5	-0.1703	0.0279	-6.11 *
AC42	w4t2	-0.1357	0.0449	-3.02 *	CC22	t2t2	0.4915	0.2585	1.90 *
AC13	w1t3	0.0530	0.0246	2.16 **	CC23	t2t3	0.7326	0.2140	3.42 *
AC23	w2t3	0.0051	0.0180	0.29	CC24	t2t4	-0.3868	0.1193	-3.24 *
AC33	w3t3	-0.0184	0.0176	-1.04	CC25	t2t5	0.0528	0.0441	1.20
AC43	w4t3	-0.0397	0.0341	-1.17	CC33	t3t3	0.8776	0.2009	4.37 *
AC14	w1t4	0.0328	0.0166	-1.98 **	CC34	t3t4	-0.7289	0.1065	-6.84 *
AC24	w2t4	-0.0368	0.0121	-3.05 *	CC35	t3t5	0.2428	0.0379	6.40 *
AC34	w3t4	0.0050	0.0118	0.42	CC44	t4t4	0.0961	0.0862	1.11
AC44	w4t4	-0.0009	0.0228	-0.04	CC45	t4t5	-0.1199	0.0255	-4.70 *
AC15	w1t5	-0.0092	0.0042	1.96	CC55	t5t5	-0.0291	0.0086	-3.38 *
AC25	w2t5	0.0109	0.0034	3.17 *	DT	T	0.0382	0.0062	6.16 *
AC35	w3t5	-0.0174	0.0034	-5.14 *	DTT	TT	-0.0007	0.0007	-0.98
AC45	w4t5	0.0157	0.0066	2.40 *	M1	MD	-0.0557	0.0215	-2.59 *
ADT1	w1T	-0.0048	0.0012	-4.18 *	M2	MDMD	0.0057	0.0043	1.32
ADT2	w2T	0.0016	0.0008	1.95 *					
ADT3	w3T	-0.0058	0.0008	-7.44 *					
ADT4	w4T	0.0090	0.0016	5.81 *					
AA11	w1w1	0.1588	0.0281	5.65 *					
AA22	w2w2	0.1499	0.0272	5.52 *					
AA33	w3w3	0.0847	0.0089	9.55 *					
AA44	w4w4	0.1760	0.0345	5.10 *					

Table 2 (continued)

(*) indicates estimate is significantly different from zero at .05 level
(**) indicates estimate is significantly different from zero at .10 level
Standard errors are estimated from a heteroskedasticity-consistent matrix.

Coefficient Abbreviations:
A0-- Constant
A -- Logged factor price (1-labor,2-equipment,3-fuel)
B -- Logged Output (1-output, BB_{11} - output squared)
C -- Logged Technical factors (1-capital,2-ALOH,3-miles,4-% agric,5-% coal)
CC-- Squared Logged Technical Factors
BC-- Cross-term between output and capital
AA-- Cross-products between logged factor prices
DT-- Time (DTT Time-squared)
M -- Years after merger for merged roads (1-time,2-time squared)

Statistics on the Estimated Cost Function:

R-Squared =	0.998
Durbin-Watson Stat =	1.703
Sum of Squared Resids. =	0.326
Standard Eror of Reg. =	0.038

Statistics on the Estimated Share Equations:

(a) Labor Share Equation

R-Squared =	0.938
Durbin-Watson Stat =	1.402
Sum of Squared Resids. =	0.080
Standard Error of Reg. =	0.019

(b) Equipment Share Equation

R-Squared =	0.972
Durbin-Watson Stat =	1.738
Sum of Squared Resids. =	0.042
Standard Error of Reg. =	0.014

(c) Fuel Share Equation

R-Squared =	0.853
Durbin-Watson Stat =	1.232
Sum of Squared Resids. =	0.041
Standard Error of Reg. =	0.013

Table 2A

COEFFICIENT ESTIMATES ON FIRM-SPECIFIC COST AND FACTOR SHARE TERMS

CONSTANT TERM

RAILROAD		ESTIMATE	STANDARD ERROR	T-STAT
Base Road:				
2	ATSF	12.955	5.006	2.588 *
Other Roads:				
6	BN	-0.143	0.137	-1.040
9	CNWT	-1.315	0.163	-8.057 *
11	CS	-2.481	-0.479	5.175 *
13	DRGW	-1.570	0.323	-4.856 *
20	FWD	-3.804	0.447	-8.505 *
21	GTW	-1.616	0.379	-4.266 *
22	ICG	-0.485	0.134	-3.624 *
23	KCS	-1.893	0.365	-5.191 *
26	MKT	-1.618	0.335	-4.828 *
27	MP	-0.610	0.114	-5.371 *
28	NW	0.218	0.152	1.432
32	SLSF	-1.191	0.212	-5.626 *
35	SOO	-1.543	0.241	-6.409 *
36	SPTC	0.139	0.081	1.720 *
37	SOU	0.160	0.146	1.093
38	UP	0.097	0.077	1.253
40	WP	-1.873	0.358	-5.232 *
41	CRC	0.188	0.266	0.706
43	CHES1	0.449	0.202	2.219 *
44	SBDSYS	-0.067	0.171	-0.392
46	BNSL	-0.312	0.186	-1.681 *
51	BNSYS	-0.186	0.186	-0.998
45	CSX1	0.453	0.283	1.603
52	CSX2	0.459	0.259	1.772 *
50	NS	0.640	0.182	3.518 *
49	UPSYS	0.176	0.153	1.155

LABOR TERM

COEFFICIENT		ESTIMATE	STANDARD ERROR	T-STAT
Base Road:				
2	ATSF	-0.6800	-0.2270	2.996 *
Other Roads:				
6	BN	-0.0282	0.0297	-0.951
9	CNWT	0.2070	0.0372	5.570 *
11	CS	0.1824	0.1226	1.488
13	DRGW	0.2842	0.0848	3.352 *
20	FWD	0.5200	0.1137	4.573 *
21	GTW	0.4196	0.1017	4.126 *
22	ICG	0.0804	0.0319	2.519 *
23	KCS	0.2852	0.0959	2.974 *
26	MKT	0.2476	0.0875	2.830 *
27	MP	0.0720	0.0263	2.741 *
28	NW	0.0540	0.0360	1.500
32	SLSF	0.1961	0.0525	3.733 *
35	SOO	0.2111	0.0604	3.497 *
36	SPTC	-0.0364	0.0196	-1.860 *
37	SOU	-0.0060	0.0343	-0.175
38	UP	-0.0004	0.0193	-0.021
40	WP	0.2760	0.0880	3.136 *
41	CRC	0.0556	0.0509	1.092
43	CHES1	0.0522	0.0435	1.201
44	SBDSYS	-0.0054	0.0367	-0.147
46	BNSL	-0.0399	0.0421	-0.947
51	BNSYS	-0.0650	0.0368	-1.764 *
45	CSX1	-0.0771	0.0579	-1.332
52	CSX2	-0.0575	0.0516	-1.114
50	NS	-0.0685	0.0384	-1.786 *
49	UPSYS	-0.0656	0.0339	-1.938 *

Notes: Railroads 46 and 51 represent the Burlington Northern System over two phases: 1979-80, before the aquisition of FWD and CS; 1981-86, after the aquisition.

Railroads 45 and 52 represent the two phases of the CSX merger: 1981-82 and 1983-86.

TABLE 2a (continued)

COEFFICIENT ESTIMATES ON FIRM-SPECIFIC COST AND FACTOR SHARE TERMS

EQUIPMENT TERM

RAILROAD		ESTIMATE	STANDARD ERROR	T-STAT
Base road:				
2	ATSF	1.4850	0.1705	8.708 *
Other Roads:				
6	BN	-0.0294	0.0216	-1.360
9	CNWT	-0.1113	0.0276	-4.036 *
11	CS	-0.2120	0.0893	-2.373 *
13	DRGW	-0.1779	0.0617	-2.882 *
20	FWD	-0.4336	0.0831	-5.218 *
21	GTW	-0.1969	0.0739	-2.665 *
22	ICG	-0.0094	0.0231	-0.407
23	KCS	-0.0737	0.0698	-1.056
26	MKT	-0.0520	0.0642	-0.810
27	MP	-0.0007	-0.0184	0.038
28	NW	0.0892	0.0260	3.428 *
32	SLSF	-0.1326	0.0383	-3.464 *
35	SOO	-0.1416	0.0439	-3.224 *
36	SPTC	0.0612	0.0142	4.295 *
37	SOU	0.1048	0.0249	4.203 *
38	UP	0.0103	0.0144	0.716
40	WP	-0.3228	0.0641	-5.034 *
41	CRC	-0.1993	0.0373	-5.341 *
43	CHES1	0.0744	0.0312	2.381 *
44	SBDSYS	0.1395	0.0265	5.266 *
46	BNSL	-0.0206	0.0306	-0.673
51	BNSYS	0.0107	0.0269	0.398
45	CSX1	0.1909	0.0421	4.535 *
52	CSX2	0.1406	0.0374	3.760 *
50	NS	0.2013	0.0278	7.245 *
49	UPSYS	0.1262	0.0246	5.122 *

FUEL TERM

COEFFICIENT		ESTIMATE	STANDARD ERROR	T-STAT
Base road:				
2	ATSF	-0.0311	0.1603	-0.194
Other Roads:				
6	BN	-0.0543	0.0213	-2.552 *
9	CNWT	0.1260	0.0263	4.794 *
11	CS	0.4322	0.0874	4.946 *
13	DRGW	0.2734	0.0605	4.522 *
20	FWD	0.4432	0.0814	5.446 *
21	GTW	0.2606	0.0722	3.610 *
22	ICG	0.0716	0.0224	3.192 *
23	KCS	0.2633	0.0683	3.856 *
26	MKT	0.2559	0.0625	4.097 *
27	MP	0.0605	0.0187	3.236 *
28	NW	0.0230	0.0252	0.912
32	SLSF	0.1698	0.0374	4.535 *
35	SOO	0.1642	0.0431	3.807 *
36	SPTC	-0.0625	0.0140	-4.466 *
37	SOU	0.0364	0.0242	1.505
38	UP	0.0132	0.0141	0.939
40	WP	0.2269	0.0629	3.606 *
41	CRC	-0.0837	0.0363	-2.303 *
43	CHES1	-0.0139	0.0302	-0.460
44	SBDSYS	0.0012	0.0255	0.047
46	BNSL	-0.0355	0.0302	-1.176
51	BNSYS	-0.0543	0.0264	-2.060 *
45	CSX1	-0.0963	0.0414	-2.327 *
52	CSX2	-0.0894	0.0365	-2.449 *
50	NS	-0.0558	0.0271	-2.060 *
49	UPSYS	-0.0547	0.0242	-2.257 *

Notes: Railroads 46 and 51 represent the Burlington Northern System over two phases:
1979-80, before the aquisition of FWD and CS;
1981-86, after the aquisition.

Railroads 45 and 52 represent the two phases of the CSX merger:
1981-82 and 1983-86.

3. Returns to Scale in the Short and Long Run

Because of the importance of size-related economies in determining the viability of a non-regulated rail industry, it is important to understand the nature of economies of scale in the rail industry as well as their magnitudes. In this section, we first discuss the nature of size related economies in an environment in which technological variables affect costs, and then present evidence concerning size related economies in the rail industry in both the short and the long run.

3.1 The Measurement of Size Related Economies

In most industries, the concept of economies of scale is relatively straightforward and relates the change in the firm's level of costs to changes in its level of output. Intuitively, the elasticity of cost (Ey) reflects the percentage change in cost relative to the percentage change in output (dC/C)/(dY/Y), and diseconomies or economies of scale exist at Ey greater or less than one with constant returns to scale occurring if Ey = 1. The accepted measure of economies of scale (Sy) is simply given by the reciprocal of the firm's elasticity of cost and is thus measured by the ratio of average cost to marginal cost. Thus a firm is said to be subject to increasing, constant, or decreasing returns to scale as Sy is greater than, equal to, or less than one.

In considering size-related economies of scale in the railroad industry, it is important to distinquish between output-related economies (which arise from changes in the different components of output) and size related economies (which arise from changes in the technological environment in which the railroad operates). In each case, however, it is important to note that these are conditional on the structure of the capital stock. We therefore analyze short run scale economies as conditional on the existing capital stock and long-run scale economies as conditional on the cost-minimizing capital stock. In addition each of these measures is conditional on the existing output levels.[27]

In this paper, we follow most analyses of transport cost functions and define output as ton-miles so that $y \equiv T \cdot H$, where $y \equiv$ ton-miles; $T \equiv$ tons shipped; and $H \equiv$ average length of haul. Although a given percentage increase in tons or average length of haul will have an identical impact on ton-miles, it will not have the same impact upon costs, since average length of haul also enters as a technological characteristic in the cost function.

The importance of this can be seem by considering the specified cost function, where the other arguments are suppressed for convenience. Thus if $C = C(y(H \cdot T), H)$, then

$$\frac{\partial \ln C}{\partial \ln T} = \frac{\partial \ln C}{\partial \ln y} \equiv E_{Cy}$$

$$\frac{\partial \ln C}{\partial \ln H} = \frac{\partial \ln C}{\partial \ln y} + \frac{\partial \ln C}{\partial \ln H} \equiv E_{CH}$$

Hence the elasticity of scale with respect to output (y) with average length of haul held constant, is given by

$$S_{yT} \equiv 1 \;/\; E_{Cy} \tag{6}$$

We refer to this as tonnage-related scale economies. This corresponds to the usual notion of economies of scale and can also be thought of as economies of density.[28] If, however, we consider economies of scale where tonnage is held constant, then the relevant definition is

$$S_{yH} \equiv 1/E_{CH}, \tag{7}$$

which we refer to as ALH-related scale economies. Since costs typically drop with average length of haul ($E_{CH} < 0$), S_{yH} should generally be greater than S_{yT}. This also makes intuitive sense; hauling a given ton an extra mile should be less costly than hauling an extra ton for a given average length of haul, since no additional handling should be needed to ship a ton an extra mile.

Of course, it is unlikely that either tons or average length of haul would change, while the other components of ton-miles or traffic mix remained constant. Thus it is useful to consider a more general measure of scale economies that permits all of the components of ton-miles to change: average length of haul, total tons shipped, and the traffic mix with respect to of coal, agricultural, and other commodities. In this connection, it is useful to express the cost functions as

$$C = C(y(H \cdot T),\ H,\ t_c, t_A)$$

where $t_c \equiv T_c/T$, $t_A \equiv T_A/T$, and T_C and T_A respectively represent coal and agricultural tonnage, and where the other arguments of the cost function are suppressed for notational convenience. Taking the total differential of costs and rewriting the resulting expression in terms of elasticity of costs with respect to output (ton-miles) yields the following expression:

$$\frac{dC}{dy} \cdot \frac{y}{C} = \alpha_T \tilde{E}_{CT} + \alpha_H E_{CH} + \alpha_C E_{CPC} + \alpha_A E_{CPA} \qquad (8)$$

where E_{CPA} and E_{CPC} respectively represent the elasticity of cost with respect to the percentage of agriculture and coal traffic and α_T, α_H, α_c and α_A respectively represent the percentage change of the output component relative to the percentage change in total ton-miles (e.g., $\alpha_T \equiv (dT/T)/(dY/Y)$). In addition, E_{CH} is defined as above and $\tilde{E}_{CT} \equiv E_{Cy} - E_{CPC} - E_{CPA}$.

With these definitions in mind, the full expression for the measure of scale economies that reflects all of the different output components is given by

$$S_{yw} \equiv \frac{1}{\alpha_T \tilde{E}_{CT} + \alpha_H E_{CH} + \alpha_C E_{CPC} + \alpha_A E_{CPA}}, \qquad (9)$$

which we refer to as weighted scale economies. Finally, it is useful to note that if all output components move proportionately, then all of the α's are equal. In this case the general expression for scale economies reduces to[29]

$$S_{yp} \equiv 1/[E_{CY} + E_{CH}], \qquad (10)$$

which we refer to as proportional scale economies.

Thus there is a range of measures of economies of scale that differs with the way output changes. Consequently in evaluating the economies of scale facing railroads, it is important to consider the relative change in the composition of output as well as the returns to scale with respect to the various output components.

In assessing size related changes in the scale of operations of the enterprise, it is natural to consider simultaneous changes in the output of the firm and the physical environment in which it operates, conditional upon the level of the fixed factor (either actual or optimal). In this case, we treat mile of track (N) as a proxy for the rail network and other characteristics of the physical environment and analyze elasticities of cost and economies of scale when output and miles of track expand simultaneously.[30]

In this case, the extension of the previous analysis is straightforward, and we includes miles of track (N) in our analysis of size-related economies. We write the cost function as $C = C(y(H \cdot T), H, t_C, t_A, N)$ (suppressing the arguments that do not enter into the measures of size-related economies). Following our previous analysis, we take the total differential of the cost function and express the resulting percentage changes with respect to output to obtain an expression for total economies of scale:

$$\tilde{S}_{ytotw} \equiv [\ \alpha_T \tilde{E}_{CT} + \alpha_H E_{CH} + \alpha_c E_{CpC} + \alpha_A E_{CpA} + \alpha_N E_{CN}\ ]^{-1} \qquad (11)$$

which we refer to as total weighted scale economies.

Similarly, if all components move proportionately, expression (11) reduces to [31]

$$\tilde{S}_{ytotp} \equiv [\ E_{Cy} + E_{CH} + E_{CN}\ ]^{-1} \qquad (12)$$

which we refer to as total proportional scale economies.

To date, we have not differentiated between short-run and long-run economies of scale. Because of the large amounts of fixed capital embodied in the railroads' way and structure, it is important to consider the relationship between the opportunity cost of capital and the firm's shadow value of capital. The formal relationships between short-run scale economies, the shadow value of capital, and long-run returns to scale can be seen by considering the following total cost function :

$$C^T = C^s\ (y,\ w,\ t,\ x_F\ ) + \rho^*\ x_F \qquad (13)$$

where C^T represents total costs, ρ^* represents the opportunity cost of capital, and the other variables have their previous meaning.

The shadow value of capital represents the savings that would accrue to variable costs if the stock of WS capital is raised by one unit. Thus we define

$$w \equiv -\frac{\partial C^s(.)}{\partial x_F} \qquad (14)$$

It is straightforward to show that the equilibrium capital stock is obtained when the opportunity cost of capital equals the firm's shadow value of capital. Thus

$$\frac{\partial C^s}{\partial x_F^*} = -\rho^* . \qquad (15)$$

The relationship between short-run and long-run cost elasticities can be obtained by recognizing that in equilibrium, long-run and short-run marginal costs are the same, i.e.,

$$\frac{\partial C^s}{\partial y} = \frac{\partial C^L}{\partial y} \tag{16}$$

By substituting equation (15) into equation (13), it is then a matter of direct calculation to show that the relationship between the short-run and long-run elasticities of cost is given by

$$\frac{\partial \ln C^L}{\partial \ln y} = \frac{\partial \ln C^s\ (y,\ w,\ x_F^*,\ t)\ /\ \partial \ln y}{1 - \partial \ln C^s(y,\ w, x^*_F, t)/\partial \ln x_F^*} \tag{17}$$

where x_F^* represents WS capital at the point of long-term equilibrium.

To calculate long-run returns to scale, we must use a point of long-run equilibrium where equation (17) holds. The previous discussion indicated, however, that railroads are not typically at a point of long-run equilibrium with optimal amounts of WS capital. Nevertheless, by using equation (15) it is possible to calculate x_F^*, which can then be substituted into equation (13) to yield estimates of the long-run cost elasticities. Returns to scale are then given by the reciprocal of the relevant long-run elasticity of cost with respect to output. In this connection, it should be noted that the long-run returns to scale are defined in the same way as the short-run returns to scale, with the optimal capital stock being substituted for the actual capital stock in calculating costs and long-run scale economies.

3.2 Empirical Evidence

Because of the importance of rail rates on captive coal shippers in the current policy debate and the relationship between revenue adequacy and returns to scale, we analyze the behavior of the five railroads that are heavy coal carriers (Burlington Northern, Conrail, CSX System, Norfolk Southern System, and the Denver Rio Grande, which is a relatively small railroad). In addition, because of the number of significant mergers that have taken place during the past decade, it is useful to focus on the merged rail systems (the four large coal systems, plus the Union Pacific System) to see if they have behaved differently from other railroads. Finally, for purposes of comparison we will consider the behavior of the aggregates of non-coal, non-merged railroads, which we denote as East, South, West, Big and Small.[32]

Table 3 presents data on short-run and long-run output-related economies conditional on the network. This indicates that there is substantially more variation in the measures of output-related returns to scale than in the short-run and long-run relationships or in the between-railroad relationships. We focus first on the coal roads and then discuss these relationships for the non-coal roads.

If we look at the conventional measure of returns to scale or returns to density, it is clear that all of the coal roads experience substantial returns to scale. Moreover, this measure of returns to scale has been relatively stable over the sample period, for both the short-run and the long-run, indicating that regulatory changes have not had a significant impact on the railroads' scale economies. In all cases, the estimated short-run returns to scale for the railroads in 1986 are substantial. The long-run returns to scale are generally quite similar to the short-run returns. While both Conrail and the Burlington Northern have somewhat reduced scale economies under optimal capital adjustments, in the case of the Burlington Northern the differences do not seem to be sufficiently great to indicate that the long-run equilibrium provides a different guide for policy than the current short-run equilibrium. In contrast, the long-run returns to scale for Conrail are quite modest.

The situation with respect to the non-coal railroads is essentially similar to that of the coal roads. In all cases the conventionally measured economies of scale or economies of density are substantial, relatively stable over the sample period, and exhibit relative constancy between the short and long-run.

As we have discussed previously, the notion and measure of economies of scale are not conceptually invariant, but can vary with the way in which output changes. To this end, we also utilize another measure of scale economies that assumes that output changes through average length of haul alone, with total tons and output shares being held constant; this is reported in Table 3 Column 2. In this case, the size related economies rise substantially. This is to be expected, since an increase in ton-miles arising solely from an increase in average length of haul does not require any commensurate increase in switching or yard activities.

Table 3

Short Run and Long Run Output-Related
Economies of Scale,
by Rail Road, Selected Years 1974-1986

		Short-Run Returns to Scale				Long-Run Returns to Scale			
RR	Year	Tons[a]	ALH[b]	Wghted[c]	Prop[d]	Tons[a]	ALH[b]	Wghted[c]	Prop[d]
BNS									
	mean	2.40	4.46	4.82	1.56	1.94	2.05	1.80	1.00
	1974	2.44	6.55	5.32	1.78	1.51	1.01	0.57	0.60
	1979	2.25	3.92	3.34	1.43	2.04	3.13	2.98	1.24
	1984	2.33	4.13	2.01	1.49	1.83	1.67	1.38	0.87
	1986	2.30	4.65	1.97	1.54	1.80	2.05	1.35	0.96
DRG									
	mean	2.56	3.88	4.12	1.54	3.32	na	na	4.29
	1974	2.61	5.24	3.10	1.74	2.81	na	6.54	2.93
	1979	2.40	3.83	4.29	1.48	3.13	na	na	4.54
	1984	2.78	3.09	1.85	1.47	3.93	na	na	3.96
CONRAIL									
	mean	1.72	6.78	1.30	1.37	1.20	3.23	0.96	0.87
	1979	1.49	6.20	0.99	1.20	1.12	3.37	0.80	0.84
	1984	1.96	7.19	3.15	1.54	1.24	2.69	1.29	0.85
	1986	1.68	6.87	2.59	1.35	1.23	5.12	1.46	0.99
SEABRD									
	mean	1.97	4.61	1.62	1.38	1.87	4.81	1.10	1.35
	1974	2.07	4.95	1.75	1.46	1.81	3.08	0.85	1.14
	1979	1.91	4.46	1.67	1.34	1.81	4.63	1.16	1.30
CHESSIE									
	mean	1.52	5.21	11.44	1.17	1.59	na	na	1.99
	1974	1.55	5.35	9.90	1.20	1.53	na	na	1.71
	1979	1.46	5.02	11.43	1.13	1.53	na	na	1.88
CSX									
	mean	1.71	4.57	na	1.24	1.57	4.66	5.12	1.17
	1984	1.75	4.09	na	1.22	1.68	6.40	na	1.33
	1986	1.65	5.13	na	1.25	1.51	6.55	na	1.23
NW									
	mean	1.30	9.29	na	1.14	1.26	145.32	na	1.25
	1974	1.27	6.21	na	1.05	1.15	7.56	na	1.00
	1979	1.26	5.34	na	1.02	1.23	152.14	na	1.22
NSS									
	mean	1.55	4.94	na	1.17	1.43	4.86	na	1.11
	1984	1.46	5.15	na	1.14	1.27	3.50	na	0.93
	1986	1.72	4.80	na	1.27	1.73	17.88	na	1.58

[a] defined as S_{YT} from equation (6)
[b] defined as S_{YH} from equation (7)
[c] defined as S_{YW} from equation (9)
[d] defined as S_{YP} from equation (10)

Table 3 (continued)

Short Run and Long Run Output-Related
Economies of Scale,
by Rail Road, Selected Years 1974-1986

RR	Year	Short-Run Returns to Scale Tons[a]	ALH[b]	Wghted[c]	Prop[d]	Long-Run Returns to Scale Tons[a]	ALH[b]	Wghted[c]	Prop[d]
MOPAC									
	mean	2.24	4.44	2.70	1.48	1.89	1.35	0.78	0.79
	1974	2.12	6.45	3.90	1.59	1.31	0.41	0.25	0.31
	1979	2.22	3.92	2.43	1.42	1.98	1.99	3.05	0.98
UP									
	mean	1.66	4.18	2.91	1.18	1.43	1.77	1.19	0.79
	1974	1.71	4.71	2.93	1.26	1.29	0.94	2.11	0.54
	1979	1.52	3.96	2.89	1.10	1.28	1.48	2.24	0.69
UPS									
	mean	1.90	4.10	1.74	1.30	1.60	1.80	0.52	0.85
	1984	1.73	3.82	1.61	1.19	1.51	1.37	0.41	0.72
	1986	1.91	4.01	2.06	1.29	1.73	2.96	0.93	1.09
EAST									
	mean	1.50	5.83	na	1.19	1.72	na	na	2.77
	1974	na	na	na	na	na	na	na	na
	1979	1.48	5.41	3.41	1.16	1.65	na	na	2.36
	1984	1.55	4.54	0.91	1.16	1.87	na	0.45	3.67
	1986	1.66	4.90	1.07	1.24	2.29	na	0.43	30.08
SOUTH									
	mean	1.86	5.61	1.72	1.38	1.64	4.49	1.45	1.20
	1974	1.93	5.74	6.02	1.44	1.65	3.84	3.92	1.16
	1979	1.74	4.80	1.95	1.26	1.61	4.94	1.75	1.21
	1984	2.10	5.88	2.66	1.55	1.79	3.68	2.01	1.21
	1986	1.63	na	na	na	1.23	3.71	1.57	0.92
WEST									
	mean	2.24	4.81	5.75	1.46	2.15	1.91	1.08	1.01
	1974	2.21	5.38	4.72	1.48	2.01	1.27	0.25	0.77
	1979	2.12	4.74	2.92	1.43	1.96	1.84	1.88	0.95
	1984	2.26	4.22	11.09	1.44	2.07	1.26	0.91	0.78
	1986	2.63	4.61	14.83	1.54	2.58	2.29	1.96	1.21
BIG									
	mean	1.93	4.85	na	1.34	1.69	1.63	0.86	0.83
	1974	2.09	4.99	4.90	1.37	2.01	2.25	1.48	1.06
	1979	1.85	4.41	na	1.27	1.68	2.01	na	0.91
	1984	1.90	4.61	1.89	1.34	1.53	0.95	1.22	0.59
	1986	1.73	5.61	1.75	1.31	1.39	1.23	1.21	0.65
SMALL									
	mean	2.30	5.21	3.55	1.53	2.22	3.85	1.02	1.41
	1974	2.40	6.33	2.80	1.68	1.83	1.28	0.23	0.75
	1979	2.18	5.21	2.20	1.50	1.98	2.57	0.97	1.12
	1984	2.40	4.27	2.50	1.51	2.49	4.86	2.61	1.65
	1986	2.90	4.42	2.78	1.63	3.36	na	4.71	4.40

The story changes significantly, however, if one envisions an increase in output caused by proportional increases in all types of traffic. In this case, since distance shipped and tons shipped increase proportionately, the network is not being used more intensively, and the measured economies of scale are reduced accordingly. Moreover, in this case the differences between short-run and long-run measures are substantial, with most railroads exhibiting constant or decreasing long-run returns to scale. Thus, the measured proportional economies of scale suggest that workable competition might be viable in the railroad industry.

Clearly, however, the various components of output do not move proportionately, and the measure of weighted economies of scale is highly variable, indicating that returns to scale actually experienced by the railroads are quite sensitive to relative changes in output. For the Western coal roads the short-run weighted scale economies are substantial, although they are somewhat lower for the Eastern coal roads.[33] Unfortunately, the variability in the relative output shares, the magnitude of the negative cost elasticities with respect to average length of haul, and the percentage of coal traffic were sufficiently large for the CSX and Norfolk-Southern systems that is it impossible to obtain reasonable estimates of their weighted economies of scale.

The short-run weighted economies of scale for the non-coal roads are quite similar to those of the coal roads, generally exhibiting a relatively high degree of returns to scale. The long-term weighted economies of scale are substantially less than their short-run counterparts and in the case of the Union Pacific System and the "Eastern" railroads, exhibiting decreasing returns to scale in the deregulated period. Moreover, the observed weighted scale economies of a number of other railroads in the current quasi-regulated period (Conrail, Burlington Northern, and the "Big" railroads) are sufficiently low to indicate that workable competition may be possible. Nevertheless, it is important to note that the estimated weighted elasticities of scale are sufficiently volatile and sensitive to differential changes in the output components to permit an extrapolation of their behavior into the future.

Table 4 presents the short-run and long-run size related scale economies that were given in equations (11) and (12), which incorporatess changes in output and the network, conditional on the amount of WS capital. With the exception of the weighted short-run size-related scale economies, these measures indicate that railroads would generally operate under marked decreasing returns to scale.[34] This is in clear contrast to the measures of output related economies of scale, which typically indicate a fairly high degree of scale economies.

Upon reflection, these differential measures make sense. In the first case, the existing network and stock of WS capital are being utilized more intensively so that the incremental costs rise less than output. In the case when track mileage (the network) increases proportionaly with output, both service standards and the cost of maintaining the track also rise. Hence in this case we observe that incremental costs rise proportionately more than output. This phenomenom is doubtless exacerbated by the existence of

TABLE 4

Short run and long run size-related economies of scale with network effects, by railroad; selected years 1974-1986.

RAILROAD	SHORT RUN WEIGHTED[a]	SHORT RUN PROPORT[b]	LONG RUN WEIGHTED[a]	LONG RUN PROPORT[b]
BNS				
mean	4.38	0.91	0.67	0.53
1974	5.54	1.23	0.38	0.39
1979	2.24	0.82	0.68	0.60
1984	0.94	0.89	0.34	0.47
1986	0.97	0.93	0.35	0.52
DRG				
mean	5.26	0.82	2.52	0.98
1974	3.19	1.04	1.36	1.06
1979	9.66	0.82	na	1.08
1984	2.74	0.70	3.79	0.80
CONRAIL				
mean	1.00	1.05	0.37	0.57
1979	0.83	0.97	0.37	0.58
1984	1.63	1.16	0.35	0.54
1986	1.43	1.04	0.38	0.64
SEABRD				
mean	2.95	0.88	1.13	0.72
1974	3.10	0.94	0.85	0.65
1979	3.07	0.86	1.22	0.72
CHESSIE				
mean	3.31	0.81	1.11	0.94
1974	3.34	0.84	1.03	0.87
1979	3.41	0.80	1.16	0.95
CSX				
mean	4.05	0.79	0.67	0.63
1984	3.42	0.75	0.81	0.65
1986	5.90	0.82	0.85	0.67
NW				
mean	na	0.99	na	0.99
1974	na	0.99	na	0.86
1979	na	0.90	na	1.00
NSS				
mean	na	0.84	na	0.69
1984	na	0.88	na	0.64
1986	na	0.80	na	0.78

[a] defined as $\tilde{S}_{ytotw}$ from equation (11)

[b] defined as $\tilde{S}_{ytotp}$ from equation (12)

TABLE 4 (continued)

Short run and long run size-related economies of scale with network effects, by railroad; selected years 1974-1986.

	SHORT RUN		LONG RUN	
RAILROAD	WEIGHTED[a]	PROPORT[b]	WEIGHTED[a]	PROPORT[b]
MOPAC				
mean	1.91	1.05	0.40	0.52
1974	3.61	1.51	0.18	0.23
1979	1.69	0.97	0.68	0.62
UP				
mean	2.99	0.97	0.80	0.58
1974	2.97	1.12	1.02	0.42
1979	2.94	0.95	1.23	0.54
UPS				
mean	1.92	0.86	0.40	0.52
1984	1.76	0.82	0.33	0.47
1986	2.36	0.83	0.61	0.62
EAST				
mean	na	1.16	na	3.23
1974	na	na	na	na
1979	2.96	1.18	2.67	3.01
1984	0.91	1.01	0.41	3.47
1986	1.06	0.89	0.43	3.98
SOUTH				
mean	1.02	1.03	0.37	0.77
1974	7.17	1.05	1.53	0.73
1979	1.65	0.95	0.77	0.79
1984	2.35	1.07	0.38	0.72
1986	na	na	0.42	0.76
WEST				
mean	6.39	1.29	0.64	0.70
1974	7.14	1.67	0.29	0.58
1979	1.93	1.28	0.62	0.71
1984	9.45	1.07	0.55	0.52
1986	3.31	1.04	0.84	0.69
BIG				
mean	na	1.09	na	0.55
1974	6.57	1.22	0.99	0.64
1979	na	1.02	na	0.61
1984	1.52	1.04	0.40	0.41
1986	1.75	1.11	0.43	0.48
SMALL				
mean	3.83	1.38	0.70	1.03
1974	3.08	1.99	0.25	0.60
1979	1.43	1.40	0.44	0.90
1984	1.16	1.09	0.53	1.00
1986	2.78	0.96	1.30	1.38

significant excess capacity on the part of the railroads[35].

Because of the large amount of excess capacity that exists in the rail industry it is unlikely that we would observe simultaneous increases in output and track mileage.[36] Indeed since the Staggers Act, most railroads have acted to shrink their track miles rather than to expand them. Thus to assess economies of scale, the measures in Table 3 (which assume that only output changes) are probably more relevant than those in Table 4 (which assume that output and track mileage change together).[37]

4. Capital Adjustments and Excess Capacity

In the situation where a firm is in a disequilibrium with respect to its capital stock, it is intuitively obvious that the shadow value of capital will be greater than the opportunity cost of capital if the firm is undercapitalized, and conversely if it is overcapitalized. Moreover, if the firm is overcapitalized, short-run returns to scale will be greater than the long-run returns to scale. However, if the firm is undercapitalized, no inferences can be made about the relationship between short-run and long-run scale economies.[38]

Table 5 presents the shadow price of capital,[39] the opportunity cost,[40] the marginal q and the rate of return to capital for the coal roads and the different aggregates of the non-coal railroads. Since the marginal q represents the absolute value of the ratio of the return of a marginal dollar of investment in way and structure capital (the shadow price of capital) to the opportunity cost of capital, its value indicates whether a firm is overcapitalized or undercapitalized.[41] In the case of overcapitalization, the value of the marginal product of capital is less than its opportunity cost and the marginal q is less than one; in the case of undercapitalization, the converse is true.

In a regulated environment, the extent of overcapitalization or undercapitalization within the rail industry depends on two contradictory forces: (i) the regulatory pressures to maintain common carrier obligations may require a capital structure that is excessive for existing output levels, causing the marginal q to be less than one; (ii) the inability to earn a fair rate of return should prevent the railroads from maintaining an adequate capital base, causing the marginal q to exceed one. In a deregulated environment, however, railroads should have the ability to reduce their capital stock to reflect their traffic needs, thus reducing pressure to remain overcapitalized. At the same time, railroads have only been moderately successful in achieving a fair rate of return. Thus one would expect the marginal q to rise during the sample period, other things being equal. In addition, in so far as mergers have enabled railroads to facilitate their capital adjustments, we would expect to see the marginal q to equilibrate faster for the merged than the unmerged roads.

An examination of Table 5 indicates that this has not generally been the case. Most railroads that started the sample period overcapitalized (marginal $q < 1$) have continued to exhibit overcapitalization (Conrail, BN, UPS and its component parts, South, Big). Similarly, those railroads that started the

TABLE 5

Opportunity Cost and Measures of Returns to Capital by Railroad. Selected Years, 1974 - 1986

RR	SHADP	OPPCST	MARGQ	RORCAP
BNS				
mean	-0.0765	0.1463	0.5229	0.1270
1974	-0.0236	0.1323	0.1784	0.0706
1979	-0.1014	0.1383	0.7332	0.0866
1984	-0.0716	0.1640	0.4366	0.2621
1986	-0.0645	0.1366	0.4722	0.2288
DRG				
mean	-0.2843	0.1511	1.8815	0.0394
1974	-0.1623	0.1362	1.1916	0.0788
1979	-0.2765	0.1415	1.9541	0.0685
1984	-0.3802	0.1693	2.2457	0.0196
CONRAIL				
mean	-0.0556	0.1388	0.4006	0.0791
1979	-0.0576	0.1293	0.4455	0.0517
1984	-0.0539	0.1574	0.3424	0.1317
1986	-0.0556	0.1201	0.4629	0.1364
SEABRD				
mean	-0.1115	0.1370	0.8139	0.0427
1974	-0.0832	0.1341	0.6204	0.0930
1979	-0.1139	0.1398	0.8147	0.0183
CHESSIE				
mean	-0.1537	0.1371	1.1211	0.0351
1974	-0.1269	0.1311	0.9680	0.1031
1979	-0.1603	0.1400	1.1450	0.0087
CSX				
mean	-0.1192	0.1602	0.7441	-0.0130
1984	-0.1463	0.1655	0.8840	0.0375
1986	-0.1028	0.1366	0.7526	-0.2560
NW				
mean	-0.1194	0.1323	0.9025	0.0738
1974	-0.0867	0.1256	0.6903	0.1257
1979	-0.1209	0.1302	0.9286	0.0635
NSS				
mean	-0.1117	0.1543	0.7239	-0.0626
1984	-0.0975	0.1640	0.5945	-0.0642
1986	-0.1392	0.1366	1.0190	-0.0419

TABLE 5 (continued)

Opportunity Cost and Measures of Returns to Capital
by Railroad. Selected Years, 1974 - 1986

RR	SHADP	OPPCST	MARGQ	RORCAP
MOPAC				
mean	-0.0703	0.1454	0.4835	0.1662
1974	-0.0023	0.1419	0.0162	0.1907
1979	-0.0774	0.1383	0.5597	0.1675
UP				
mean	-0.0675	0.1360	0.4963	0.0666
1974	-0.0244	0.1257	0.1941	0.1170
1979	-0.0515	0.1302	0.3955	0.0814
UPS				
mean	-0.0726	0.1515	0.4792	0.0823
1984	-0.0580	0.1640	0.3537	0.0319
1986	-0.0940	0.1366	0.6881	0.1830
EAST				
mean	-0.2390	0.1485	1.6094	-0.2042
1974	NA	NA	NA	NA
1979	-0.2203	0.1517	1.4522	0.2490
1984	-0.3264	0.1546	2.1113	-0.1541
1986	-0.4037	0.1361	2.9662	-0.1716
SOUTH				
mean	-0.0963	0.1451	0.6637	0.0113
1974	-0.0819	0.1323	0.6190	0.0992
1979	-0.1025	0.1359	0.7542	0.0141
1984	-0.1043	0.1724	0.6050	-0.0711
1986	-0.0625	0.1504	0.4156	-0.1853
WEST				
mean	-0.0977	0.1508	0.6479	0.0198
1974	-0.0362	0.1405	0.2577	0.1124
1979	-0.0822	0.1427	0.5760	0.0512
1984	-0.1101	0.1701	0.6473	0.0001
1986	-0.1351	0.1481	0.9122	-0.0048
BIG				
mean	-0.0686	0.1499	0.4576	0.0224
1974	-0.0667	0.1371	0.4865	0.1359
1979	-0.0720	0.1391	0.5176	0.0243
1984	-0.0527	0.1692	0.3115	-0.0184
1986	-0.0500	0.1450	0.3448	-0.0498
SMALL				
mean	-0.1388	0.1497	0.9272	0.0189
1974	-0.0361	0.1406	0.2568	0.0473
1979	-0.1096	0.1444	0.7590	0.0477
1984	-0.2201	0.1677	1.3125	-0.0009
1986	-0.2692	0.1488	1.8091	0.0388

NOTE: SHADP is the shadow price of capital, OPPCST is the opportunity cost of capital, MARGQ is marginal q (SHADP/OPPCST), and RORCAP is the *ex post* average rate of return on capital.

sample period substantially undercapitalized (marginal q > 1) have tended to stay undercapitalized. However, it is important to note that these railroads (DRG, East), are quite small and have concomitantly large economies of scale, making it difficult for them to achieve revenue adequacy on their existing asset base.

The behavior of the remaining railroads is less clear. Prior to merger, the Seaboard exhibited evidence of overcapitalization while the Chessie exhibited evidence of moderate undercapitalization. In contrast, although the Norfolk Southern appears to be relatively close to equilibrium in 1986, for most of the sample period it has exhibited evidence of overcapitalization, as did the N & W. Similarly, while the West aggregate approached equilibrium in 1986, for most of the sample period, it was significantly overcapitalized.

In terms of mergers the evidence is somewhat mixed. The Burlington Northern, Conrail, and the CSX have not shown marked movements toward equilibrium post merger, while the Norfolk Southern and Union Pacific systems have. This suggests that the reasons for the equilibrating behavior of the Norfolk Southern and Union Pacific are probably not due to merger activity per se, but more likely reflect managerial activities and other considerations.[42]

It is somewhat surprising that the majority of the railroads appear to have been overcapitalized throughout most of the sample period. This suggests that the barriers to adjusting capital in an optimal fashion may be greater than is generally believed. Alternatively, it may be possible that the cost savings from increments in WS capital may not fully reflect the benefit of

TABLE 6

Optimal Capital Adjustments, by Railroad, Selected Years, 1974-1986

RR	Capital Stock	($ Millions)	Difference	
BNS	Actual	Optimal	Actaul	Percent
mean	4668.0	2833.4	1834.6	39.30
1974	4293.2	965.0	3328.2	77.52
1979	4201.9	3363.2	838.7	19.96
1984	5238.2	2734.1	2504.1	47.80
1986	5251.9	2987.4	2264.5	43.12
DRG				
mean	385.5	521.8	-136.3	-35.36
1974	368.0	406.1	-38.1	-10.35
1979	373.6	530.0	-156.4	-41.86
1984	412.5	604.4	-191.9	-46.52
CONRAIL				
mean	7723.5	4091.0	3632.5	47.03
1979	7982.2	4394.4	3587.8	44.95
1984	7362.4	3484.8	3877.6	52.67
1986	7041.9	4165.8	2876.1	40.84
SEABRD				
mean	2651.6	2271.5	380.1	14.33
1974	2697.3	1878.2	819.1	30.37
1979	2661.9	2281.6	380.3	14.29
CHESSIE				
mean	3105.0	3327.8	-222.8	-7.18
1974	3304.2	3234.8	69.4	2.10
1979	2295.3	3263.1	-967.8	-42.16
CSX				
mean	5765.2	4632.4	1132.8	19.65
1984	5744.9	5265.8	479.1	8.34
1986	5783.8	4706.1	1077.7	18.63
NW				
mean	1888.7	1745.7	143.0	7.57
1974	1917.5	1437.6	479.9	25.03
1979	1873.1	1771.2	101.9	5.44
NSS				
mean	3948.2	3063.9	884.3	22.40
1984	3952.8	2632.4	1320.4	33.40
1986	3884.0	3935.3	-51.3	-1.32

Table 6 (continued)

Optimal Capital Adjustments, by Railroad, Selected Years, 1974-1986

RR	Capital Stock ($ Millions)		Difference	
BNS	Actual	Optimal	Actaul	Percent
mean	1461.4	774.7	686.7	46.99
1974	1355.2	23.2	1332.0	98.29
1979	1474.0	913.5	560.5	38.03
UP				
mean	1978.5	1086.9	891.6	45.06
1974	1861.0	411.1	1449.9	77.91
1979	2044.4	904.6	1139.8	55.75
UPS				
mean	4142.7	2280.9	1861.8	44.94
1984	4135.5	1684.6	2450.9	59.26
1986	4234.5	3180.1	1054.4	24.90
EAST				
mean	243.4	328.3	-84.9	-34.88
1979	242.6	311.7	-69.1	-28.48
1984	240.7	397.7	-157.0	-65.23
1986	245.4	463.0	-217.6	-88.67
SOUTH				
mean	1676.2	1257.4	418.8	24.99
1974	1748.5	1213.2	535.3	30.61
1979	1730.0	1417.8	312.2	18.05
1984	1486.9	1026.6	460.3	30.96
1986	1396.4	712.2	684.2	49.00
WEST				
mean	778.1	344.0	434.1	55.79
1974	522.9	168.0	354.9	67.87
1979	598.1	276.3	321.8	53.80
1984	1207.3	416.2	791.1	65.53
1986	1242.1	653.9	588.2	47.36
BIG				
mean	1797.4	926.4	871.0	48.46
1974	1492.7	896.9	595.8	39.91
1979	1692.8	1002.6	690.2	40.77
1984	1922.1	684.8	1237.3	64.37
1986	1943.3	850.4	1092.9	56.24
SMALL				
mean	306.2	237.2	69.0	22.53
1974	408.3	143.9	264.4	64.76
1979	289.2	202.9	86.3	29.84
1984	320.8	294.5	26.3	8.20
1986	330.3	424.2	-93.9	-28.43

their investments. If, for example, enhanced track enables service to improve and thus to increase revenues substantially, the measured cost savings would fail to reflect the full benefits of the investments.[43] The persistence of the low value of the marginal q throughout the sample period for many large railroads is certainly a puzzle, since in the period after the passage of the Staggers Act they should have had sufficient freedom to adjust their capital stock in an optimal fashion. This suggests that the transition to equilibrium may be quite long.

It is possible to shed some insight on this issue by considering the realized rate of return to capital earned by the railroads, which we define as $(R - VC) / x_F$ where R represents total revenues, VC represents variable costs, and x_F represents WS capital. Thus while the shadow value represents the marginal cost savings for an incremental unit of capital, the rate of return represents the average return (including revenues) to the existing stock.

Table 5 indicates that as is true for the marginal q, most railroads exhibit low rates of return, consistent with overcapitalization. In a few cases, however, the two measures are at variance. For example, the marginal q's for the Burlington Northern and Conrail are quite low, indicating overcapitalization. In contrast, the rate of return for the Burlington Northern is well in excess of the opportunity costs for 1984 and 1986, while for Conrail the rate of return and opportunity costs are quite close to each other for 1984 and 1986. In each case, the demand effects of WS investment are substantial: the Burlington Northern invested heavily in new track in the Powder River Basin to permit it to exploit its coal fields; and Conrail essentially refurbished its capital (which had been allowed to deteriorate during the bankruptcy of its constituent firms) to permit enhanced service. Similiarly, prior to its merger with the Union Pacific, the Missouri Pacific had a reputation of delivering high-quality service. Thus the cases in which the rate of return exceed the opportunity costs of capital are consistent with WS investments influencing demand as well as reducing costs.

Nevertheless, on balance, the marginal q's and the rates of return to capital investment indicate that the rail industry is generally overcapitalized and in need of substantial capital reduction, which can only come about through substantial reallocation of its WS capital. This can be seen from Table 6, which indicates that the bulk of the railroads have experienced substantial overcapitalization through the sample period. Nevertheless, the degree of overcapitalization has fallen somewhat in the post-Staggers period for a number of railroads, suggesting that deregulation has modestly hastened capital adjustments in the rail system. For example, relative to 1974 (the base year of comparison), the Burlington Northern, Norfolk Southern, and Union Pacific systems have reduced their degree of excess capacity by about a third to a half. In contrast, Conrail, the CSX system and the aggregates of South, Big, and West have maintained the same percentage degree of excess capacity (or have even increased it somewhat) during the sample period.

Although some of the railroads have reduced their degree of excess capacity, it remains large in absolute amounts. In particular, during the sample period, the amount of aggregate excess capacity ranged from a low of

$6.8 billion (in 1979) to $12.8 billion (in 1984).[44] If we assume an average opportunity cost of capital of 12%, this represents a partial deadweight loss ranging from $816 million (in 1979) to $1.5 billion (in 1984). On average, over the sample period, the annual deadweight loss of excess capacity was approximately $1 billion.[45]

In addition, it is useful to consider the cost differentials created by this excess capacity. This is given in Table 6, which presents data on the actual and optimal total costs for the railroads used in our analysis. While the percentage differences between actual and optimal total costs are much less than the actual and optimal value of the capital stock, the aggregate cost differentials are substantial, ranging from a high of $1.8 billion in 1984 to a low of $1.3 billion in 1986. Although the comparision of the excess costs in 1984 and 1986 indicates a substantial reduction in excess costs during these two years, it is difficult to extrapolate from these figures, since the aggregate cost differential exhibits substantial variation over the selected sample years.[46]

5. Summary and Conclusions

The most striking aspect of this analysis is the apparent inability of the rail industry to adjust its capital stock expeditiously to reach a cost-minimizing equilibrium. This is shown through the consistent differentials between short-run and long-run returns to scale; the consistently low values of the marginal q's; the relatively constant magnitude of the differentials between the actual and the optimal capital stock; and the relative stability

TABLE 7

Cost Adjustments by Railroad
Selected Years

Railroad	Costs ($million) Optimal	Actual	Difference Actual	Percent
BNS				
mean	3632.7	3820.2	187.5	4.908
1974	1310.7	1683.3	372.6	22.135
1979	3411.1	3448.0	36.9	1.070
1984	5183.4	5545.4	362.0	6.528
1986	4420.4	4691.3	270.9	5.775
DRG				
mean	344.7	364.7	20.0	5.484
1974	174.2	175.0	0.8	0.457
1979	328.4	346.9	18.5	5.333
1984	485.3	526.1	40.8	7.755
CONRAIL				
mean	4430.7	4907.6	476.9	9.718
1979	4523.1	4855.9	332.8	6.854
1984	4538.7	5190.2	651.5	12.553
1986	4238.1	4544.1	306.0	6.734
SEABRD				
mean	2161.5	2180.2	18.7	0.858
1974	1430.8	1464.2	33.4	2.281
1979	2673.2	2685.5	12.3	0.458
CHESSIE				
mean	2160.7	2166.7	6.0	0.277
1974	1588.0	1588.9	0.9	0.057
1979	2623.2	2629.9	6.7	0.255
CSX				
mean	6974.6	7061.2	86.6	1.226
1984	7281.1	7296.6	15.5	0.212
1986	6278.9	6335.4	56.5	0.892
NW				
mean	1641.4	1645.2	3.8	0.231
1974	1103.5	1118.4	14.9	1.332
1979	1876.9	1878.9	2.0	0.106
NSS				
mean	5044.8	5142.0	97.2	1.890
1984	4917.0	5046.3	129.3	2.562
1986	5183.4	5186.3	2.9	0.056

TABLE 7 (continued)

Cost Adjustments by Railroad
Selected Years

	Costs ($million)		Difference	
MOPAC				
mean	1309.5	1388.1	78.6	5.662
1974	441.9	684.3	242.4	35.423
1979	1491.9	1534.6	42.7	2.782
UP				
mean	1811.3	1908.1	96.8	5.073
1974	892.6	1043.3	150.7	14.445
1979	2031.2	2152.6	121.4	5.640
UPS				
mean	4959.4	5215.1	255.7	4.903
1984	5075.5	5044.8	-30.7	-0.609
1986	4989.8	5059.8	70.0	1.383
EAST				
mean	334.3	346.9	12.6	3.632
1979	301.8	306.4	4.6	1.501
1984	470.3	497.3	27.0	5.429
1986	409.8	466.8	57.0	12.211
SOUTH				
mean	1375.2	1417.0	41.8	2.950
1974	836.0	863.1	27.1	3.140
1979	1533.0	1556.2	23.2	1.491
1984	1676.1	1721.8	45.7	2.654
1986	1235.5	1338.1	102.6	7.668
WEST				
mean	769.8	961.3	191.5	19.921
1974	216.3	474.8	258.5	54.444
1979	518.2	784.8	266.6	33.970
1984	1484.3	1714.4	230.1	13.422
1986	1437.7	1589.1	151.4	9.527
BIG				
mean	1704.9	1883.2	178.3	9.468
1974	706.2	988.0	281.8	28.522
1979	1488.7	1813.5	324.8	17.910
1984	2327.0	2654.6	327.6	12.341
1986	2072.7	2316.9	244.2	10.540
SMALL				
mean	283.1	289.0	5.9	2.042
1974	158.7	168.3	9.6	5.704
1979	259.5	274.9	15.4	5.602
1984	436.2	471.8	35.6	7.546
1986	495.2	517.9	22.7	4.383

between the levels of actual and optimal costs.

This lack of rationalization of capital stock is particulary puzzling in view of the large adjustments that have been made in rail labor[47], the apparent responsiveness of the railroads to the rate freedom guaranteed to them by the Staggers Act, and the legislative freedom guaranteed in that same Act to rationalize route structures and abandon track.

One explanation for this behavior was alluded to above: namely that the amount of WS capital not only affects costs, but also affects service quality and thus demand. Hence the cost-minimizing amount of WS capital may not be consistent with the profit-maximizing level of WS capital. In view of the higher speeds and better service permitted by high quality rail bed, this is a plausible hypothesis. Unfortunately, however, the requisite data are lacking to substantiate this conjecture.

In terms of policy, it is difficult to draw inferences. Clearly the rate of capital adjustment is extremely slow, which indicates that the transition from the existing inefficient equilibrium to an efficient cost-minimizing is a long one. This, in turn, suggests that it might make sense to provide railroads with further incentive to rationalize their route structure. While the rail industry has certainly become more efficient in the period since the Staggers Act, the evidence of this paper suggests that, at least with respect to their capital stock, they still have a long way to go.

FOOTNOTES

1. For a discussion of the impact of the Staggers Act upon coal and related rates see Moore (1983), Rose (1988) and Friedlaender (1989).

2. Because of the apparent high returns to scale associated with rail operations, there is a potential conflict between the shippers' needs for stable and equitable rates and the railroads' needs to earn a fair rate of return. This issue has become particularly important with respect to "captive" shippers of coal and other non-competitive commodities who feel that railroads are charging them excessive and inequitable rates. Although these shippers have introduced legislation to limit the railroads' ability to charge rates substantially in excess of variable costs, as of this writing, this legislation has not left committee. Friedlaender (1989) has recently undertaken an analysis indicating that the apparent contradiction between rail profitability and equitable coal rates may not exist.

3. See Caves, et. al. (1985) and Friedlaender and Spady (1981).

4. Meyer and Tye (1985) provide a useful discussion of these transitional adjustments. In addition, it is important to note that output levels will change as the rail and related transportation markets adjust to a quasi-regulated environment. Thus the adjustments discussed in this paper represent a partial-equilibrium analysis instead of a full general-equilibrium analysis.

5. The most recent rail cost function was estimated by Caves and his associates (1985), which used panel data on a sample of Class I railroads for the period 1951-1975.

6. Fuel expenditures include fuel and other energy and power costs, while labor expenditures include direct wage payments plus fringe benefit payments. Equipment expenditures are calculated as the opportunity cost of capital times the current year reproduction value of the equipment capital stock. Expenditures on materials and supplies are defined as a residual after the other expenditures have been subtracted from variable costs. See Vellturo (1989) for a full description of these and other variables.

7. Although data are available for tons carried by commodity type, length of haul is a sufficiently important dimension of output that it was felt that it should also be incorporated into the measure of output.

8. During our sample period, Amtrak had taken over rail passenger service, so that none of the carriers in our sample had any passenger traffic. While it would have been desirable to disaggregate the output vector further than coal, agriculture, and "other" commodities (primarily manufacturing), the increase in the number of parameters to be estimated made this infeasible.

9. Specifically, the user cost of equipment (P_{it}) was estimated to be equal to the effective after-tax cost of equipment debt issued by each railroad i in year t (r_{it}), plus a measure of after-tax depreciation (δ) assumed to be 5%, representing a 20 year life straight-line depreciation, multiplied by a price index of rail equipment (P_t). Thus $P_{it} = P_t(r_{it} + \delta)$. As such there is a railroad specific measure of the price of equipment capital for each year of the sample.

10. See Wang Chiang and Friedlaender (1985) for an example of the use of these variables in estimating trucking costs.

11. During our sample period a number of major consolidations took place in which the Burlington Northern merged with the Colorado Southern, the Fort Worth Denver and the Saint Louis and San Francisco Railroads; the Chessie and the Seaboard Systems merged to create the CSX system; the Norfolk and Western and Southern Railroads merged to form the Norfolk Southern system; The Union Pacific, Missouri Pacific, and Western Pacific Merged to form the Union Pacific system, and Conrail was formed out of the merger of the Penn-Central System with the New Haven, Reading, Central of New Jersey, and Erie Lackawana Railroads. See Vellturo (1989) for a full discussion of rail merger history during this period.

12. See Mundlak (1978), Caves et. al. (1985) and Vellturo (1989) for a full discussion of these issues.

13. See Hausman and Taylor (1981) and Judge et. al (1985) for a full discussion of the use of unbalanced panel data.

14. The homogeneity restrictions associated with this equation are:

$$\sum_{i=1}^{n} A_i = 1 \qquad \sum_{i=1}^{n} AB_{i1} = 0$$

$$\sum_{i=1}^{n} AA_{ic} = 0 \quad \text{(for all c)}$$

$$\sum_{i=1}^{n} AC_{ij} = 0 \quad \text{(for all j)}$$

$$\sum_{i=1}^{n} AD_{i1} = 0$$

15. In estimating rail costs, Caves and his associates (1985) assume that fixed effects enter the cost function but not the input share equations. By contrast, introducing fixed effects into the input share equations, permits unobserved network and related effects to influence input utilization.

16. Thus the coefficients given in the cost and input share equations, (2) and (3), should be interpreted as follows:

$$A_o = A_o' + F_K \qquad K = 1,\ldots,R-1$$

$$A_i = A_i' + F_{iK} \qquad i = 1,\ldots,,,,, n-1;\ K = 1,\ldots,R-1$$

where A_0' and A_i' respectively represent the intercept and linear coefficients on the input price variable for the base railroad (R). Therefore F_K represents a zero-one intercept dummy of railroad K and F_{iK} represents a zero-one intercept dummy for railroad K in input share equation i. See Vellturo (1989) for a detailed discussion.

17. In this case the homogeneity restrictions are given by:

$$F_{no} = 1 - \sum_{i=1}^{n-1} F_{io}$$

$$F_{nr} = - \sum_{i=1}^{n-1} F_{ir} \qquad \text{for all} \quad \begin{matrix} r = 1, \ldots R-1 \\ i = 1, \ldots n-1 \end{matrix}$$

For a full discussion see Vellturo (1989).

18. We implicitly assume that ρ is equal across firms. We also assume that ρ may differ between the cost function and the factor share equations, but is equal across factor shares. This latter assumption preserves the additive nature of

the share error term. For a full discussion of this issue, see Berndt and Savin (1975).

19. The results are invariant to the share equation chosen to be dropped. To ensure this, we utilize the restrictions on the first-order out correlation terms set forth by Berndt and Savin (1978).

20. See, for example, Caves, et.al. (1987) Friedlaender and Spady (1981), Caves, Christensen, and Swanson (1980).

21. These data were obtained at the state level and aggregated for each railroad according to the states through which each firm operates. Although this method does not account for demand affects arising from interline traffic, any attempt to incorporate interlining would be ad hoc and would reduce the heterogeneity of the instruments. See Vellturo (1989) for a full discussion of the use of these variables and their construction.

22. Under the hypothesis of no endogeniety in output, Three Stage Least Squares (3SLS) will be consistent but not efficient while the LSQ estimator will be consistent and efficient. We want to test the null hypothesis, using the specification test outlined in Hausman et. al. (1988):

$$(\hat{b}_{3sls}-\hat{b}_{lsq})\ (V(\hat{b})_{3sls}-V(\hat{b})_{lsq})^{-1}(\hat{b}_{3sls}-\hat{b}_{lsq}) \sim \chi^2_{\text{no. of Parameters being tested}}$$

The χ^2 test statistic = 43.8, is just equal to the .05 critical value with 30 degrees of freedom, but is less than the .025 critical value of 47.0; therefore the hypothesis that there is exogeneity cannot be rejected at any confidence level less than 5 percent.

23. Whether to estimate the variables as deviations from the grand sample mean or not is really a matter of computational convenience. Using variables measured as deviations from the mean permits an interpretation of the first-order coefficients of the cost function as representing the relevant elasticity or input share at the grand sample mean, but fails to provide a direct estimate of the fixed effects dummy variables. The approach followed here provides direct estimates of the fixed effects dummy variables, but does not provide an intuitive interpretation of the coefficients on the linear terms.

24. In view of the large number of parameters generated by the introduction of fixed effects, an analysis of the specification of the fixed effects was also performed, and specifications were also estimated that employed fixed effects only on the constant term and that utilized regional fixed effects instead of firm-specific fixed effects. These implied restrictions were rejected. This implies, of course, that not only should a full range of firm-specific fixed effects be included in estimating rail costs using panel data, but the fixed effects should enter into the input share equations. Intuitively this makes sense, since input utilization should be closely related to the firm's network; the fixed effects are envisaged as capturing unobserved network effects.

25. For these observations either $\partial C^s/\partial x_F > 0$ or $\partial^2 C^s/\partial x^2_F < 0$. In the first case, the estimated marginal productivity of capital is negative; in the second case, estimated marginal productivity of capital rises as the amount of capital rises. In either case, the response of costs to increases of capital violates the conditions required for a well-behaved production function.

26. The likelihood ratio test is used to determine whether there is a significant difference between the restricted cost function ($CC_{11}=0$) and the unrestricted cost function. The log of likelihood function of the unrestricted function is 2440.92 and the restricted function is 2440.88. The likelihood ratio test statistic therefor equals 0.08, which is less than the critical value at any reasonable significance level. Hence, imposition of this restriction does not affect the estimated model significantly.

27. It should be noted, however, that output will probably change as the capital stock and costs adjust. Thus all of these measures of scale economies are of a partial equilibrium nature.

28. For a related discussion of these points and somewhat different measures of scale economies, see Keeler (1985) and Caves <u>et al</u>, (1985).

29. Since all output proportions remain constant in this case, this measure is akin to ray economies of scale in the multiproduct case. See Bailey and Friedlaender (1982) for a discussion of multiproduct measures of size related economies.

30. Alternatively, one can think of a mile of track as a fixed input akin to WS capital and assume that a railroad minimizes costs with respect both these variables. While this has some intuitive appeal, there are a number of difficulties associated with this approach: (i) during the period of regulation, mile of track reflected the common carrier obligation of the railroad; (ii) during the period of deregulation, mile of track (or the network) was adjusted to reflect service quality and hence reflects demand as well as cost characteristics; (iii) if miles of track (N) are treated as an

input, the resulting production function exhibits a peculiar form of separability since N requires inputs of capital and labor, which in turn are independent of N. For these reasons, we follow the usual analysis of rail costs and treat N as a technological variable reflecting the environment in which the railroad operates, and x_f as the fixed factor over which the railroad optimizes.

31. This expression is similar to one utilized by Caves <u>et al</u> (1985).

32. The classification of railroads in these categories is given as follows:

East: Grand Truck Western (a small railroad).

South: Illinois Central Gulf; Southern (prior to merger).

West: Atchinson, Topeka, & Santa Fe; Chicago Northwest Transit; Colorado Southern; Fort Worth Denver; Kansas City Southern; Missouri Kansas Texas; Missouri Pacific (prior to merger); Saint Louis San Francisco (prior to merger); Soo Line; Southern Pacific; Union Pacific (prior to merger); Western Pacific (prior to merger);

Big: Atchinson Topeka Santa Fe; Chicago Northwest; Illinois Central Gulf; Missouri Pacific (prior to merger); Southern (prior to merger); Union Pacific (prior to merger); Southern Pacific.

Small: Colorado Southern; Fort Worth Denver; Grand Truck Western; Kansas City Southern; Missouri Kansas Texas; Saint Louis San Francisco (prior to merger); Soo; Western Pacific (prior to merger).

Note that when a railroad merges with a larger system, it is treated as being part of the merged system. Thus when the Southern Railroad merged with the Norfolk Western in 1981, Southern Railroad left the aggregate of non-coal roads.

33. Because some of the relative output changes are quite large and since certain cost elasticities are typically negative (e.g., average length of haul, percentage of coal), the weighted cost elasticity can be close to zero or even negative. In these cases we have written "na" in Table 3, indicating that reasonable measures of the weighted elasticity of scale are not available.

34. In the context of end-to-end rail mergers, Vellturo (1989) has used a somewhat different measure of scale economies and defined them as economies of expansion, measured by the sum of changes in output, track, and WS capital. In his case, he found that the size related scale economies were virtually constant, indicating that there were few economies related to a proportionate expansion in the scale of the firm per se.

35. This will be discussed in Section 4 below.

36. Of course, in the case of the Powder River Basin, both the Burlington Northern and Chicago Northwest Transit built new rail lines to exploit these coal fields. Nevertheless, in most cases the rail lines have shrunk their network rather than expanded it in the post-Staggers era.

37. Note that in the case of mergers, output, WS capital and the network all expand together. Vellturo (1989) has referred to the resulting economies as

economies of expansion and used this concept to analyze the efficiencies of end-to-end mergers.

38. Let AC and MC measure the short-run average and marginal costs at the firm's actual level of output for a given capital stock and let AC* and MC* measure the long-run average and marginal costs that would occur at the level of output if the firm achieved a cost-minimizing equilibrium with respect to its capital stock. If the firm is overcapitalized, AC > AC* and MC < MC*. Thus in this case it follows that short-run return to scale will be greater than long-run returns to scale since AC/MC > AC*/MC*. If however, the firm is undercapitalized, AC > AC*, and MC > MC*. In this case no inference can be drawn concerning the relationship between long-run and short-run economies of scale since AC/MC >/< AC*/MC*.

39. The shadow price of capital is given by $\partial C^s/\partial x_f$, which represents the reduction in short-run variable costs that results from an incremental unit of the fixed capital.

40. The opportunity cost of each firm (i) at time t is defined as $P_{Kt}(r_{it}+\delta)$, where P_{Kt} represents the price index of railway and structures capital at time t; r_{it} represents the bond rate for railroad i at time t, and δ is the rate of depreciation. See Vellturo (1989) for a full definition of this and related variables.

41. Hayashi (1982) has defined the marginal q as the present discounted value of additional future after-tax profits that are due to an additional unit of investment. If marginal costs are independent of output and the firm is an output price taker, our definition of marginal q and Hayashi's are equivalent.

If, however, either of these conditions do not hold, this equivalence is not exact.

42. See Vullturo (1989) for a full discussion of the impact of mergers on capital utilization.

43. This can be seen by considering the following model in which demand depends on price (p) and service quality (S), which in turn depends on the amount of WS capital (K). In this case profits are given by the following expression

$$\pi = p \,.\, y(p,\ S(K)) - C^s\ (y,\ w,\ K) - \rho_K K$$

where the other argument in the demand and cost function have been supressed for notational convenience. In this case, it is straightforward to show that the optimal amount of capital obtains when MRK = $\partial C^s/\partial K + \rho_K$. Thus in equilibrium the difference between the absolute value of opportunity cost of capital and its shadow price is exactly equal the marginal revenue of capital. While it is unlikely that this equilibrium existed during the sample period, this analysis is suggestive and indicates that the observed difference in the shadow price of capital and its opportunity cost may overestimate the true extent of the actual capital disequilibrium. See Hayashi (1982) for a related discussion of the value of marginal q in the presence of demand effects.

44. The measures of the aggregate excess capacity for the selected sample points is given as follows :

1974 \$ 9.191 billion

1975 $ 6.775 billion

1976 $12.798 billion

1977 $ 9.275 billion

Because of problems associated with the first and second order regularity conditions, it was not always possible to obtain estimates of the optimal capital stock for all railroads for the representative years in the sample. Consequently, the aggregate measure of excess capacity for these years is not comparable.

45. It is interesting to note that this is substantially greater than most estimates of the dead-weight loss due to an inefficient rate structure. Winston (1985) has a good summary of various measures of dead-weight losses in the rail industry.

46. The aggregate cost differentials for each year used in this analysis were as follows:

1974 $ 1.393 billion

1979 $ 1.211 billion

1984 $ 2.834 billion

1986 $ 1.289 billion

As indicated above, it is somewhat difficult to compare these figures, since measures of the optimal costs were not available for all of the railroads at these sample points.

47. See Vellturo (1989) for a full discussion of this point.

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