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RAIL COSTS AND CAPITAL ADJUSTMENTS IN A QUASI-REGULATED ENVIRONMENT

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ABSTRACT

This paper reports on results obtained from the estimation of a rail cost function using a pooled-time series, cross section of Class I railroads for the period 1974-1986. An analysis is performed of short-run and long-run returns to scale, the extent of capital disequilibrium, and adjustments to way and structures capital in the heavily regulated and quasi-regulated environments before and after the passage of the Staggers Act in 1980. 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 provided by the Staggers Act.

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1. Introduction and Overview

With the passage of the Staggers Act in 1980, the US railroads obtained substantial regulatory freedom to adjust their rates and their capital structure through changes in their 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 structure by permitting them to abandon unprofitable traffic and branch lines and by establishing as a legislative goal that the 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 provision was important since it provided the marketplace with a signal that there was a legislative intent for the railroads to become "profitable," or 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 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. 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.[4]

This paper addresses these issues by reporting results from the estimation of a short-run variable cost function using a pooled cross-section/time series of a sample of Class I railroads for the period 1974-1986. This not only presents an updated railroad cost function,[5] but it also provides sufficient information to determine the extent capital disequilibrium 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 presents evidence on the degree of scale economies in the short and the long run, the efficiency of the utilization of the capital stock, and the movement toward a capital equilibrium during the sample period. Section 4 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:

$$C^V = C^V(y, w, t, x_F, F, T) \tag{1}$$

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 is the fixed way and structures capital (ws), F is a vector of indicator variables to reflect firm-specific effects, and T represents a vector of time counters to capture the effect of productivity growth, mergers, and deregulation. 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. Variable cost (C^V) is primarily derived from conventional "operating costs" as defined in standard railroad accounting. Way and structures' maintenance costs are removed from operating costs and treated as investment. In addition, equipment depreciation is removed from operating costs and is replaced by a "user cost" of equipment. The resulting variable cost measure, therefore, has four components: fuel, labor, equipment, and materials and supplies.[6] Note that to abstract from the effects of inflation, all variables are measured in real (1974) dollars.

Since rail traffic is very heterogeneous, one would ideally like to have an output measure that reflects 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, an output vector that fully captured the heterogeneity of rail output 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 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 based on internal capital stock data provided by Nelson (1974). The approach is relatively straightforward and is based on the perpetual inventory identity

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

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).

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 (T) was included to capture any unexplained productivity growth. In addition, to capture the effects of deregulation and mergers, additional time trends were added to reflect the number of years since the latest merger for the affected firms (T^m) and the number of years since deregulation (T^r).[11] Table 1 provides data on the means and standard deviation of the variables used in the sample.

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 structure and geographic configuration of each railroad -- functions that remain relatively unchanged over the sample period. Consequently we introduced firm-specific indicator variables (F) 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 56 railroads that had Class I status in 1974 only 21 reported data in 1986. From these systems, 27 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 the sample (1974-1986). Since certain roads ceased to exist upon consolidation into other new systems, the data panel is not balanced.[13] The names of the firms used in the sample and their abbreviations are given in Table 2.

Table 1

Mean and Standard Deviation of Variables used in Analysis of Railroad Costs

	Units	Mean	Std Dev.	Min	Max
Variable Cost	\$ bil[a]	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	0.396	0.131	0.190	0.674
Price of Fuel	Index	1.637	0.742	0.684	2.844
Price of M+S	Index	1.728	0.260	0.652	1.495
Ton Miles	bil	45.245	41.876	1.910	203.000
Pct Agriculture	% points	19.117	9.025	6.298	69.175
Pct Coal	% points	26.403	17.816	0.291	79.378
WS Capital	\$ bil	1.906	1.923	0.118	8.303
ALH	1,000 mi	0.392	0.145	0.173	0.780
Track Miles	1,000 mi	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
Labor 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] All costs and prices are in constant 1974 dollars.

Table 2

US CLASS I RAILROADS, 1974-86

Railraod System	Abbreviation	Years in Sample
Atchison, Topeka & Santa Fe	ATSF	74-86
Burlington Northern	BN	74-79
Chicago, Northwest Transit	CNWT	74-86
Colorado Southern	CS	74-81
Denver, Rio Grande Western	DRGW	74-85
Fort Worth, Denver	FWD	74-81
Grand Trunk Western	GTW	75-86
Illinois Central Gulf	ICG	74-86
Kansas City Southern	KCS	74-86
Missouri-Kansas-Texas	MKT	74-86
Missouri Pacific	MP	74-82
Norfolk & Western	NW	74-81
St. Louis, San Francisco	SLSF	74-79
Soo Line	SOO	74-86
Southern Pacific	SP	74-86
Southern Railway System	SOU	74-81
Union Pacific Railway	UP	74-82
Western Pacific	WP	74-82
Consolidated Rail Corp.	CRC	77-86
Chessie System	CHESSIE	74-80
Seaboard System	SBD	74-80
CSX Corporation (1981-82)	CSX1	81-82
CSX Corporation (1983-86)	CSX2	83-86
Burlington Northern - St. Louis System	BNSL	80-81
Burlington Northern System	BNSYS	82-86
Union Pacific System	UPSYS	83-86
Norfolk-Southern Corporation	NSC	82-86

2.3 Econometric 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]

$$
\begin{aligned}
\ln(C^{v}) = A_0 &+ \sum_{i=1}^{n} A_i \ln(w_i) + B_1 \ln(y) + \sum_{j=1}^{m} C_j \ln(t_j) + D_1(T) + M_1(T^{m}) \\
&+ R_1(T^{r}) + .5 \sum_{i=1}^{n} \sum_{c=1}^{n} AA_{ic} \ln(w_i) \ln(w_c) + .5 BB_{11}(\ln(y))^2 \\
&+ \sum_{i=1}^{n} AB_{i1} \ln(w_i) \ln(y) + \sum_{i=1}^{n} \sum_{j=1}^{m} AC_{ij} \ln(w_i) \ln(t_j) \\
&+ \sum_{j=1}^{m} BC_{j1} \ln(t_j) \ln(y) + .5 \sum_{j=1}^{m} \sum_{h=1}^{m} CC_{jh} \ln(t_j) \ln(t_h) \\
&+ BD_{11} \ln(y)(T) + \sum_{i=1}^{n} AD_{i1} \ln(w_i)(T) \\
&+ \sum_{i=1}^{n} AD_{i2} \ln(w_i)(T^{m}) + \sum_{i=1}^{n} AD_{i2} \ln(w_i)(T^{r}) + AD_4 MDUM \\
&+ .5 D_{11}(T)^2 + .5 M_{11}(T^{m})^2 + .5 R_{11}(T^{r})^2
\end{aligned}
\tag{2}
$$

$$
\begin{aligned}
\frac{\partial \ln C^{v}}{\partial \ln w_i} = \frac{\sum_{i}^{n} w_i x_i}{C^{v}} = A_i &+ \sum_{c=1}^{n} AA_{ic} \ln(w_c) + AB_{i1} \ln(y) \\
&+ \sum_{j=1}^{m} AC_{ij} \ln(t_j) + AD_{i1} T \\
&+ AD_{i2} T^{m} + AD_{i3} T^{r}
\end{aligned}
\tag{3}
$$

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

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

In estimating this equation system, we encountered a number of econometric issues. Of these, the most significant are 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 factor share equations have an additive error structure of the following form:

$$\begin{aligned} C^{v}_{rt} &= F(w, y, t, T, x_F; \beta)\big|_{rt} + \epsilon_{rt}, \quad r = 1,\ldots,R;\ t = 1,\ldots,T \\ S_{irt} &= G(w, y, t, T, x_F ;\beta)\big|_{rt} + \mu_{irt}, \quad i = 1,\ldots n \end{aligned} \tag{4}$$

where the variables have their previous definitions, β represents the vector of parameters associated with the estimated equations, and r and t represent an index over the observations. 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

$$\begin{aligned} \epsilon_{rt} &= \alpha_r + b_t + c_{rt}; \quad r = 1,\ldots,R;\ t = 1,\ldots,T \\ \mu_{irt} &= \alpha_{ir} + \sigma_{it} + \omega_{irt}; \quad i = 1,\ldots,n \end{aligned} \tag{5}$$

To motivate this stochastic specification, we begin by considering the origin of the firm specific error terms (α_r and α_{ir}). We interpret these firm-specific disturbances as reflecting unobserved fundamental network differences among Class I railroads (e.g., the spatial configurations of their routes, whether networks are primarily hub-and-spoke, end-to-end, etc.). Since it is reasonable to assume that this network configuration effect is fixed over time for a given railroad, we can eliminate this firm-specific error component by introducing indicator variables for each firm. We also assume that the underlying network configuration influences input utilization by firms, that these network attributes are known to each railroad, and therefore that they enter in its cost-minimizing decisions.[15] We implement these assumptions by introducing dummy variables into the linear terms of the input share equations and, for consistency, as interactive slope dummy variables on the linear price terms in the cost equation, constraining their coefficient values to equal those in the input share equations.[16] [17]

Intra-equation intertemporal effects are introduced by permitting the b_t and γ_{it} terms to follow first-order autoregressive processes. Although equal across firms, we specify that the first order autoregresssive parameter in the cost function disturbance term b_t differs from that in the share equation disturbance terms γ_{it}. To ensure adding-up consistency, we also specify that the autoregressive parameter for each share equation is equal across shares.[18]

Third, cross-equation contemporaneous correlation of the c_{rt} and the ω_{irt} terms is expected, due to the adding up of the share equations. Therefore, we specify that the n-element disturbance vector consisting of the c_{rt} and n-1 ω_{irt} terms is independent and multivariate normally distributed, with mean vector zero and covariance matrix Ω_{rt}. Finally, on the basis of an examination of residuals, we determined that heteroskedasticity occurred in both the share and cost function equations, with the variance of the residuals being positively related to the $\ln(y_{ht})$. To transform the model so that the disturbance terms became homoskedastic, we therefore divided all variables by the square root of $\ln(y_{ht})$.

In the context of stochastic specification, one final matter deserves particular attention: the endogeneity or exogeneity of output, y, ALOH, and the composition of output variables, %AG and %COAL. Because of the rate setting freedom introduced by the Staggers Act, it is important to determine whether output and its composition should be treated as being endogenous, particularly after 1978, when the railroads began to obtain substantial rate-setting flexibility. To test for the validity of the exogeneity assumption, we utilized Hausman's specification procedure (1978) and decisively rejected the null hypothesis of exogeneity of output.[19]

Insofar as output and its components are determined endogenously through the profit-maximizing behavior of railroads, they should be related to demand variables that do not enter the cost function. Consequently we utilized as instruments appropriate firm-specific demand-related variables, including coal production, mine-mouth prices, oil rates, farm income, and value of shipments from manufacturing.[20]

2.4 The Estimated Cost Function. We estimate the system of equations consisting of the cost function and the n-1 cost share equations (eq (2) and (3)), omitting the linearly dependent M&S cost share equation, and using 3SLS and the previously described instrumental variables for the endogenous variables and their transforms (y, ALOH, %AG, %COAL). Based on the residuals of the 3SLS model, we estimated a common autoregressive parameter for the three share equations, and another autoregressive parameter for the cost function. Since the null hypothesis that these two autoregressive parameters were simultaneously equal to zero was not rejected at usual significance levels,[21] we consequently set these autocorrelation coefficients to zero.

The 3SLS estimated model had one additional drawback, in that curvature restrictions involving ws capital were frequently violated.[22] To deal with this problem we constrained the coefficient on the squared ws term (CC_{11}) to equal zero.[23] Once this restriction was imposed, curvature restrictions were satisfied for 195 of the 229 observations. Parameter estimates and t-statistics (based on heteroskedasticity-robust standard errors) for the common parameters are given in Table 3, with the firm-specific effects given in Table 4.[24] 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.[25] For the most part the signs of the coefficients are as expected,

Table 3

3SLS PARAMETER ESTIMATES FOR RESTRICTED TRANSLOG SHORT-RUN COST FUNCTION

("t-stat" is the Ratio of Parameter Estimate to its Asymptotic Standard Error)

US Class I Railroads, 1974-1986

Parameter	Variable	Estimate	t-Stat	Parameter	Variable	Estimate	t-Stat
B_1	y	5.5726	3.09	AA_{11}	$P_L \cdot P_L$	0.1654	2.89
C_1	K	1.3454	1.26	AA_{22}	$P_E \cdot P_E$	0.1530	3.26
C_2	ALOH	-3.1596	-1.20	AA_{33}	$P_F \cdot P_F$	0.0791	8.04
C_3	MILES	-7.1830	-3.00	AA_{44}	$P_{M+S} \cdot P_{M+S}$	0.1253	2.10
C_4	% AG	4.6114	2.88	AA_{12}	$P_L \cdot P_E$	-0.1298	-4.52
C_5	% Coal	-2.0086	-3.39	AA_{13}	$P_L \cdot P_F$	-0.0128	-0.80
AB_{11}	$y \cdot P_L$	0.0442	1.68	AA_{14}	$P_L \cdot P_{M+S}$	-0.0228	-0.40
AB_{21}	$y \cdot P_E$	-0.2042	-10.00	AA_{23}	$P_E \cdot P_F$	0.0064	0.35
AB_{31}	$y \cdot P_F$	0.0766	3.69	AA_{24}	$P_E \cdot P_{M+S}$	-0.0296	-0.80
AB_{41}	$y \cdot P_{M+S}$	0.0835	2.12	AA_{34}	$P_F \cdot P_{M+S}$	-0.0728	-3.39
AC_{11}	$P_L \cdot K$	0.0860	1.26	BC_{11}	$K \cdot y$	0.6115	3.01
AC_{21}	$P_E \cdot K$	0.0567	0.90	BC_{12}	ALOH·y	0.0375	0.11
AC_{31}	$P_F \cdot K$	0.0519	1.89	BC_{13}	MILES·y	-0.5425	1.95
AC_{41}	$P_{M+S} \cdot K$	-0.1945	-3.20	BC_{14}	%AG·y	0.1882	0.98
AC_{12}	$P_L \cdot$ ALOH	-0.0032	0.07	BC_{15}	%COAL·y	0.0130	0.21
AC_{22}	$P_E \cdot$ ALOH	0.1228	3.11	BB_{11}	$y \cdot y$	0.0899	0.25
AC_{32}	$P_F \cdot$ ALOH	0.0219	0.61	CC_{11}	$K \cdot K$	0.0000	
AC_{42}	$P_{M+S} \cdot$ ALOH	-0.1415	-1.90	CC_{12}	ALOH·K	-0.5618	-2.25
AC_{13}	$P_L \cdot$ MILES	0.0437	1.24	CC_{13}	MILES·K	-0.4126	-2.27
AC_{23}	$P_E \cdot$ MILES	0.0095	0.31	CC_{14}	%AG·K	0.5892	3.47
AC_{33}	$P_F \cdot$ MILES	-0.0226	-1.53	CC_{15}	%COAL·K	-0.1630	-3.85
AC_{43}	$P_{M+S} \cdot$ MILES	-0.0306	-0.72	CC_{22}	ALOH·ALOH	1.0303	2.27
AC_{14}	$P_L \cdot$ %AG	0.0487	1.87	CC_{23}	ALOH·MILES	0.2689	0.65
AC_{24}	$P_E \cdot$ %AG	-0.0404	-2.02	CC_{24}	ALOH·%AG	-0.5902	-2.92
AC_{34}	$P_F \cdot$ %AG	0.0023	0.85	CC_{25}	ALOH·%COAL	-0.1494	-1.37
AC_{44}	$P_{M+S} \cdot$ %AG	-0.0106	-0.23	CC_{33}	MILES·MILES	1.0130	2.86
AC_{15}	$P_L \cdot$ %COAL	-0.0144	-2.11	CC_{34}	MILES·%AG	-0.6779	-3.13
AC_{25}	$P_E \cdot$ %COAL	0.0161	3.16	CC_{35}	MILES·%COAL	0.1947	2.52
AC_{35}	$P_F \cdot$ %COAL	-0.0205	-3.63	CC_{44}	%AG·%AG	0.1160	0.58
AC_{45}	$P_{M+S} \cdot$ %COAL	0.0188	2.00	CC_{45}	%AG·%COAL	-0.0759	-1.17
AD_{T1}	$P_L \cdot$ TIME	0.0009	0.27	CC_{55}	%COAL·%COAL	-0.0199	-1.30
AD_{T2}	$P_E \cdot$ TIME	0.0009	0.27	DT	TIME	-0.1284	-4.10
AD_{T3}	$P_F \cdot$ TIME	-0.0125	-5.13	DTT	TIME·TIME	0.0509	5.37
AD_{T4}	$P_{M+S} \cdot$ TIME	0.0107	2.50	M_1	t^m	-0.0718	-2.40
R_1	t^r	-0.0909	-2.96	M_{11}	t^{m2}	0.0097	2.29
R_{11}	t^{r2}	-0.0537	-6.25	AD_4	MDUM	-0.0724	-3.14
AD_{12}	$P_L \cdot t^r$	-0.0064	-1.35	AD_{13}	$P_L \cdot t^m$	-0.0029	-0.83
AD_{22}	$P_E \cdot t^r$	0.0009	0.20	AD_{23}	$P_E \cdot t^m$	0.0009	0.20
AD_{32}	$P_F \cdot t^r$	0.0108	3.52	AD_{33}	$P_F \cdot t^m$	0.0108	3.52
AD_{42}	$P_{M+S} \cdot t^r$	-0.0053	-0.94	AD_{43}	$P_{M+S} \cdot t^m$	-0.0053	0.94

NOTES: Prices, output quantity, K, ALOH, MILES, %AG, %COAL are all logarithmically transformed. TIME, t^m (years since last merger) and t^r (years since deregulation) are all in natural units. Standard error estimates employ the Halbert White [1980] heteroskedasticity-robust computation.

Table 4

3SLS PARAMETER ESTIMATES FOR FIRM-SPECIFIC COST AND FACTOR SHARE TERMS TRANSLOG SHORT-RUN COST FUNCTION, US CLASS I RAILROADS, 1974-1986
(Asymptotic t-statistic based on robust standard errors)

	Cost Function		Labor Term		Equipment Term		Fuel Term	
Firm	Estimate	t-Stat	Estimate	t-Stat	Estimate	t-Stat	Estimate	t-Stat
Base Firm:								
ATSF	21.027	2.43	-0.708	1.92	1.500	5.57	0.003	0.02
Other Firms:								
BN	-0.095	-0.47	-0.033	-0.73	-0.027	-0.68	-0.038	-2.04
CNWT	-1.724	-6.17	0.238	3.70	-0.130	-2.63	0.128	3.05
CS	-2.906	-3.62	0.266	1.19	-0.268	-1.33	0.404	3.59
DRGW	-1.964	-3.50	0.357	2.25	-0.220	-1.47	0.256	2.96
FWD	-4.152	-5.41	0.594	2.85	-0.485	-2.52	0.413	4.50
GTW	-2.062	-3.26	0.498	2.73	-0.241	-1.49	0.249	2.41
ICG	-0.828	-3.69	0.107	1.88	-0.023	-0.74	0.081	1.86
KCS	-2.213	-3.56	0.355	2.00	-0.114	-0.71	0.229	2.56
MKT	-1.994	-3.45	0.312	1.92	-0.093	-0.64	0.237	3.07
MP	-0.734	-4.46	0.090	2.30	-0.008	-0.25	0.054	1.91
NW	-0.020	-0.09	0.073	1.52	0.081	2.09	0.026	0.64
SLSF	-1.473	-4.18	0.236	2.53	-0.158	-1.90	0.163	3.35
SOO	-1.933	-4.73	0.259	2.29	-0.165	-1.61	0.150	2.65
SPTC	0.152	1.52	-0.044	-2.10	0.072	4.01	-0.068	-3.79
SOU	-0.022	-0.10	0.016	0.32	0.097	2.70	0.038	0.85
UP	0.054	0.55	0.005	0.24	0.007	0.40	0.011	0.96
WP	-2.459	-3.81	0.323	2.11	-0.350	-2.42	0.204	3.07
CRC	0.025	0.06	0.068	0.66	-0.190	-2.11	-0.054	-0.99
CHES1	0.116	0.34	0.073	1.10	0.069	1.52	0.003	0.05
SBD	-0.347	-1.29	0.009	0.17	0.138	4.06	0.009	0.16
BNSL	-0.147	-0.57	-0.039	-0.74	-0.011	-0.22	-0.024	-1.09
BNSYS	-0.014	-0.05	-0.070	-1.22	0.018	0.32	-0.052	-2.20
CSX1	0.194	0.44	-0.068	-0.74	0.202	2.65	-0.073	-1.18
CSX2	0.292	0.71	-0.052	-0.59	0.147	2.00	-0.077	-1.32
NS	0.502	1.74	-0.055	-0.89	0.203	3.95	-0.049	-1.08
UPSYS	0.305	1.46	-0.067	-1.40	0.131	2.94	-0.057	-2.34

Notes: BNSL and BNSYS represent the Burlington Northern System over two phases, 1979-80 (before the acquisition of FWD and CX), and 1981-86 (after the acquisition). CSX1 and CSX2 represent the two phases of the CSX merger, 1981-82 and 1983-86.

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                         SUMMARY ESTIMATION STATISTICS


EQUATION:       VARIABLE COSTS

                   DEPENDENT VARIABLE:  NLVARC

                       SUM OF SQUARED RESIDUALS  -     0.259146
               STANDARD ERROR OF THE REGRESSION  -     0.336399E-01
                     MEAN OF DEPENDENT VARIABLE  -    -0.686188
                             STANDARD DEVIATION  -     0.960150
                                      R-SQUARED  -     0.998767
                             ADJUSTED R-SQUARED  -     0.998772
       DURBIN-WATSON STATISTIC (ADJ. FOR 5 GAPS)  -     1.8370

EQUATION:       LABOR SHARE

                   DEPENDENT VARIABLE:  NSHLAB

                       SUM OF SQUARED RESIDUALS  -     0.768320E-01
               STANDARD ERROR OF THE REGRESSION  -     0.183170E-01
                     MEAN OF DEPENDENT VARIABLE  -     0.233328
                             STANDARD DEVIATION  -     0.746357E-01
                                      R-SQUARED  -     0.939519
                             ADJUSTED R-SQUARED  -     0.939783
       DURBIN-WATSON STATISTIC (ADJ. FOR 5 GAPS)  -     1.3988

EQUATION:        EQUIPMENT SHARE

                     DEPENDENT VARIABLE:NSHEQU

                       SUM OF SQUARED RESIDUALS  -     0.421776E-01
               STANDARD ERROR OF THE REGRESSION  -     0.135714E-01
                     MEAN OF DEPENDENT VARIABLE  -     0.199096
                             STANDARD DEVIATION  -     0.814680E-01
                                      R-SQUARED  -     0.972142
                             ADJUSTED R-SQUARED  -     0.972263
       DURBIN-WATSON STATISTIC (ADJ. FOR 5 GAPS)  -     1.7569

EQUATION:        FUEL SHARE

                   DEPENDENT VARIABLE:  NSHFUE

                       SUM OF SQUARED RESIDUALS  -     0.355162E-01
               STANDARD ERROR OR THE REGRESSION  -     0.124536E-01
                     MEAN OF DEPENDENT VARIABLE  -     0.631667E-01
                             STANDARD DEVIATION  -     0.348041E-01
                                      R-SQUARED  -     0.871410
                             ADJUSTED R-SQUARED  -     0.871971
       DURBIN-WATSON STATISTIC (ADJ. FOR 5 GAPS)  -     1.2696
```

and the parameters are generally significant.[26]

3. Size, Scale, and Capital Adjustments

We now turn to the question of the technological structure of the rail industry and the nature of its capital adjustments in response to the Staggers Act. We begin by discussing the nature and extent of scale economies in the industry and then evaluate the amount and costs of the capital disequilibrium that exists within the industry.

3.1 Returns to Scale and to Size. In most industries, the concept of economies of scale is 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 as Ey is 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 differentiate 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 useful to note that these are conditional on the level of output and ws capital, and thus only present a partial equilibrium view of the adjustment process.[27]

Following most analyses of output related measures of returns to scale in the rail industry (e.g., Keeler (1983), Caves et al. (1985)), we focus on returns to scale associated with a given increase in tonnage, which is typically referred to as economies of density.[28] This is simply given as

$$S_y = [\partial \ln C / \partial \ln y\}^{-1} \tag{6}$$

In addition to measuring output elated economies, it is also useful to measure size-related economies that incorporate changes in the physical environment in which the firm operates. In this case it is natural to consider simultaneous changes in the output of the firm and its network,[29] conditional upon the level of the fixed factor (either actual or optimal).[30] In this case, the extension of the previous analysis is straightforward, and we include miles of track (N) in our analysis of size-related economies, given by

$$S_{yn} = [\partial \ln C / \partial \ln y + \partial \ln C / \partial \ln N]^{-1} \tag{7}$$

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:

$$C^T = C^V(y,\ w,\ t,\ x_F) + \rho^* \, x_F \tag{8}$$

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

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, which represents the savings in variable cost if the stock of capital were raised by one unit, i.e.,

$$\frac{\partial C^{V}(y,w,t,T,x_F)}{\partial x_F^*} = -\rho^* \qquad (9)$$

By using equation (9) it is possible to calculate x^*_F, which can then be substituted into equation (8) 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.

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). 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 the other railroads. Finally, for purposes of comparison we will consider the behavior of a number of representative non-coal, non-merged rail systems: the Atchison, Topeka and Santa Fe (a large Western road), the Illinois, Central Gulf (a large Southern road), the Grand Trunk Western (small Eastern Road), the Missouri Kansas Southern (a small Western road), and the Soo (a small Western Road).

Table 5 presents data on the short-run and long-run ton-related economies of scale and their associated standard errors. Although some of the standard errors are large relative to the point estimates, the scale economies are

TABLE 5

ECONOMIES OF SCALE, BY RAILROAD, SELECTED YEARS

	NO NETWORK EFFECTS				NETWORK EFFECTS			
	SHORT RUN		LONG RUN		SHORT RUN		LONG RUN	
	VALUE	ST ERR	VALUE	ST ERR	VALUE	ST ERR	VALUE	ST ERR
bn								
mean	2.343	0.691	3.966	4.239	1.214	0.764	1.063	0.260
74	2.155	0.472	na	na	1.370	0.267	1.295	0.407
79	2.203	0.622	2.558	0.985	1.103	0.197	1.066	0.199
84	2.439	0.839	na	na	1.325	0.319	1.255	0.430
86	2.347	0.715	30.303	281.252	1.391	0.330	1.261	0.402
drg								
mean	2.433	0.642	2.237	0.510	1.038	0.170	1.309	0.217
74	2.415	0.454	2.247	0.415	1.211	0.184	1.351	0.207
79	2.421	0.561	2.105	0.451	1.021	0.164	1.292	0.209
84	2.410	0.940	2.304	0.691	0.984	0.189	1.325	0.257
crc								
mean	1.567	0.260	1.848	0.312	1.193	0.136	0.978	0.119
79	1.414	0.227	1.783	0.339	1.086	0.139	0.964	0.138
84	1.812	0.312	2.203	0.426	1.383	0.156	1.027	0.124
86	1.553	0.249	1.721	0.240	1.235	0.139	1.001	0.115
sbd								
mean	3.125	1.375	3.968	2.520	1.056	0.163	1.042	0.171
74	3.236	1.406	6.757	8.413	1.121	0.177	1.076	0.198
79	3.049	0.386	3.597	2.149	1.036	0.167	1.024	0.173
chessie								
mean	1.715	0.358	1.658	0.332	0.947	0.116	0.983	0.119
74	1.783	0.386	1.795	0.395	1.000	0.133	0.992	0.133
79	1.637	0.337	1.553	0.303	0.931	0.117	0.974	0.120
csx								
mean	2.219	0.664	3.083	5.889	0.974	0.147	0.929	0.151
84	2.331	0.711	2.770	1.162	0.964	0.149	0.926	0.151
86	2.096	0.549	2.994	1.497	1.015	0.160	0.955	0.168
nw								
mean	1.447	0.276	1.969	0.681	1.242	0.238	1.250	0.274
74	1.462	0.339	6.452	13.182	1.366	0.315	1.508	0.538
79	1.403	0.282	1.832	0.617	1.225	0.247	1.232	0.281
sou								
mean	1.832	0.319	2.066	4.630	1.206	0.182	1.193	0.190
74	2.024	0.407	2.545	0.798	1.232	0.179	1.205	0.192
79	1.767	0.345	2.028	0.532	1.222	0.214	1.212	0.225
nsc								
mean	1.802	0.314	3.968	2.993	1.073	0.160	1.076	0.208
84	1.733	0.343	5.376	6.802	1.160	0.193	1.130	0.260
86	2.137	0.493	2.278	0.599	0.982	0.133	0.971	0.135

TABLE 5, CONT

ECONOMIES OF SCALE, BY RAILROAD, SELECTED YEARS

	NO NETWORK EFFECTS				NETWORK EFFECTS			
	SHORT RUN		LONG RUN		SHORT RUN		LONG RUN	
	VALUE	ST ERR	VALUE	ST ERR	VALUE	ST ERR	VALUE	ST ERR
mp								
mean	3.030	0.842	5.747	4.614	1.412	0.240	1.109	0.392
75	2.545	0.415	na	na	1.664	0.273	1.175	0.793
79	3.165	1.167	na	na	1.397	0.271	1.462	0.000
up								
mean	1.712	0.333	3.984	3.322	1.493	0.364	1.488	0.528
75	1.825	0.322	5.917	7.498	1.555	0.358	1.645	0.522
79	1.698	0.356	3.333	2.356	1.468	0.376	1.550	0.494
ups								
mean	2.222	0.548	13.699	46.102	1.239	0.258	1.006	0.438
84	2.203	0.554	na	na	1.290	0.288	1.610	0.812
86	2.381	0.617	6.993	10.397	1.215	0.241	1.179	0.290
atsf								
mean	1.866	0.388	3.690	2.601	1.395	0.313	1.010	0.622
79	1.838	0.375	na	na	1.504	0.396	2.688	2.282
84	1.905	0.421	na	na	1.427	0.332	1.550	0.540
86	1.835	0.422	2.398	0.905	1.318	0.269	1.272	0.282
gtw								
mean	1.681	0.427	1.437	0.361	1.305	0.300	1.403	0.315
75	1.502	0.420	1.437	0.398	1.517	0.410	1.555	0.415
79	1.715	0.489	1.462	0.397	1.397	0.364	1.475	0.371
84	1.866	0.406	1.453	0.307	1.300	0.289	1.374	0.293
86	1.972	0.522	1.541	0.377	1.034	0.208	1.248	0.245
icg								
mean	2.146	0.293	3.096	0.804	1.266	0.112	1.192	0.126
74	2.387	0.415	3.484	1.206	1.241	0.115	1.142	0.126
79	2.247	0.395	3.077	8.530	1.256	0.128	1.196	0.141
84	2.203	0.293	2.882	0.607	1.248	0.102	1.168	0.107
86	1.592	0.233	2.732	0.863	1.481	0.182	1.362	0.210
mkt								
mean	2.703	0.398	3.390	0.695	1.815	0.353	1.845	0.380
74	2.865	0.710	10.989	12.820	2.439	0.626	2.506	0.816
79	2.457	0.364	2.433	0.358	1.754	0.363	1.754	0.363
84	2.740	0.474	3.876	1.488	1.739	0.338	1.742	0.371
86	3.300	0.633	2.681	0.414	1.460	0.232	1.531	0.240
soo								
mean	4.274	1.800	8.772	10.287	1.859	0.369	1.698	0.413
74	3.831	1.598	11.111	15.595	1.916	0.344	1.757	0.360
79	3.731	1.497	20.408	58.064	1.976	0.417	1.976	0.512
84	3.610	1.467	na	na	2.079	0.465	2.119	0.648
86	7.519	6.913	9.804	12.765	1.437	0.222	1.429	0.229

typically estimated with an acceptable level of precision. When the network is held fixed, the estimates of returns to scale (given under the heading "no network effects") of are uniformly greater than one, and substantially so in many cases. Thus, given the large amounts of fixed track and ws capital, there are substantial returns to density as utilization increases. Moreover, if capital is adjusted in an optimal fashion, the returns to scale are somewhat larger, indicating that increasing returns is not a transitory phenomenon due to excessive capital, but may be an inherent characteristic of rail technology.

The network related measures of economies of scale (given under the heading "network effects") assume proportional increases in tonnage and route miles. These are substantially lower than the measures that assumes a change in tons alone. This is to be expected, since service standards and the cost of maintaining the track rise as the network expands. However, in most cases the point estimate is still greater than one in both the short and the long run, although the standard errors indicate that this difference is not generally statistically significant. Nevertheless, on balance these estimates suggest that economies of scale are an inherent aspect of rail technolgy.[31]

3.2. Capital Adjustments and Excess Capacity. Table 6 presents the shadow price of capital, the opportunity cost, and the marginal q for the railroads discussed in this analysis. Since the marginal q represents the ratio of the absolute value of the return of a marginal dollar of investment in way and structures capital (the shadow price of capital) to the opportunity cost of capital, its value indicates whether a firm is overcapitalized or undercapitalized. 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.

TABLE 6

MEASURES OF CAPITAL AND CAPITAL DISEQUILIBRIUM, BY RAILROAD, SELECTED YEARS

Year	SHADOW PRICE	OPPTUNTY COST	MARG Q	ROR CAPITAL	WS CAPITAL ($ BIL)	MILES TRACK	WS CAP/ MI TR ($ MIL)
bn							
mean	0.0737	0.1463	0.5039	0.0769	4.667	23071	0.202
74	0.0266	0.1323	0.2013	0.0706	4.293	21466	0.200
79	0.1067	0.1383	0.7712	0.0595	4.202	21009	0.200
84	0.0437	0.1640	0.2666	0.1315	5.238	24944	0.210
86	0.0405	0.1366	0.2966	0.1086	5.252	22834	0.230
drg							
mean	0.3437	0.1511	2.2742	0.0258	0.386	1752	0.220
74	0.2061	0.1362	1.5141	0.0788	0.368	1840	0.200
79	0.3532	0.1415	2.4955	0.0471	0.374	1779	0.210
84	0.4326	0.1693	2.5545	0.0098	0.413	1719	0.240
crc							
mean	0.0567	0.1388	0.4087	0.0433	7.723	14573	0.530
79	0.0585	0.1293	0.4526	0.0355	7.982	15651	0.510
84	0.0512	0.1574	0.3252	0.0661	7.362	13147	0.560
86	0.0512	0.1201	0.4264	0.0647	7.042	12354	0.570
sbd							
mean	0.1133	0.1370	0.8265	0.0337	2.652	14731	0.180
74	0.0828	0.1341	0.6179	0.0930	2.697	14985	0.180
79	0.1201	0.1398	0.8587	0.0126	2.662	14788	0.180
chessie							
mean	0.1652	0.1371	1.2049	0.0284	3.105	7962	0.390
74	0.1265	0.1311	0.9653	0.1031	3.304	8261	0.400
79	0.1788	0.1400	1.2767	0.0046	2.995	7680	0.390
csx							
mean	0.1056	0.1668	0.6329	-0.0070	5.765	20838	0.277
84	0.1260	0.1655	0.7613	0.0188	5.745	19810	0.290
86	0.0815	0.1366	0.5962	-0.1215	5.784	19279	0.300
nw							
mean	0.0820	0.1323	0.6196	-0.2125	3.948	10671	0.370
74	0.0348	0.1256	0.2773	0.1257	1.918	5046	0.380
79	0.0792	0.1302	0.6079	0.0436	1.873	5062	0.370
sou							
mean	0.1080	0.1332	0.8108	0.0536	1.803	4044	0.446
74	0.0935	0.1323	0.7064	0.1423	1.718	4117	0.417
79	0.1022	0.1302	0.7850	0.0338	1.836	4006	0.458
nsc							
mean	0.0820	0.1543	0.5312	-0.0330	3.948	12736	0.310
84	0.0556	0.1640	0.3388	-0.0322	3.953	10980	0.360
86	0.1230	0.1366	0.9002	-0.0198	3.884	16183	0.240

TABLE 6, CONT

MEASURES OF CAPITAL AND CAPITAL DISEQUILIBRIUM, BY RAILROAD, SELECTED YEARS

Year	SHADOW PRICE	OPPTUNTY COST	MARG Q	ROR CAPITAL	WS CAPITAL ($ BIL)	MILES TRACK	WS CAP/ MI TR ($ MIL)
mp							
mean	0.0709	0.1454	0.4876	0.0791	1.475	9831	0.150
75	0.0271	0.1419	0.1910	0.1541	1.339	7876	0.170
79	0.0621	0.1383	0.4492	0.1150	1.474	10529	0.140
up							
mean	0.0539	0.1360	0.3964	0.0492	1.971	8569	0.230
75	0.0473	0.1257	0.3764	0.0683	1.857	8843	0.210
78	0.0589	0.1302	0.4522	0.1616	2.009	8371	0.240
ups							
mean	0.0416	0.1515	0.2748	0.0401	4.143	19727	0.210
84	0.0208	0.1640	0.1268	0.0160	4.136	19693	0.210
86	0.0629	0.1366	0.4606	0.0868	4.234	19248	0.220
atsf							
mean	0.0500	0.1408	0.3551	-0.0770	2.430	11615	0.209
79	0.0124	0.1302	0.0955	0.0312	2.320	11686	0.199
84	0.0475	0.1640	0.2895	0.0081	2.449	11395	0.215
86	0.0845	0.1366	0.6183	-0.0036	2.538	11146	0.228
gtw							
mean	0.2860	0.1470	1.9456	-0.1147	0.243	959	0.253
75	0.1705	0.1358	1.2554	0.0105	0.250	829	0.301
79	0.2766	0.1517	1.8233	-0.1091	0.243	913	0.266
84	0.3282	0.1546	2.1228	-0.0772	0.241	1060	0.227
86	0.4443	0.1361	3.2643	-0.0815	0.245	1056	0.232
icg							
mean	0.0900	0.1524	0.5906	-0.0179	1.598	7380	0.217
74	0.0759	0.1323	0.5738	0.0575	1.779	8929	0.199
79	0.0897	0.1415	0.6342	-0.0176	1.624	8262	0.197
84	0.1077	0.1724	0.6249	-0.0357	1.487	6486	0.229
86	0.0520	0.1504	0.3455	-0.0879	1.396	3608	0.387
mkt							
mean	0.1480	0.1737	0.8520	0.2804	0.265	1767	0.150
74	0.0708	0.1647	0.4298	0.0064	0.279	1902	0.147
79	0.1598	0.1573	1.0160	-0.0483	0.251	1627	0.154
84	0.1322	0.1846	0.7162	-0.0444	0.276	1920	0.144
86	0.2481	0.1752	1.4162	-0.0797	0.276	1884	0.146
soo							
mean	0.0920	0.1480	0.6216	0.0279	0.502	4467	0.112
74	0.0699	0.1362	0.5133	0.1229	0.545	4353	0.125
79	0.0738	0.1415	0.5215	0.0635	0.486	4376	0.111
84	0.0639	0.1640	0.3895	0.0397	0.488	4198	0.116
86	0.1318	0.1442	0.9140	0.1000	0.512	6263	0.082

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: (1) 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; (2) 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 the pressure to remain overcapitalized. At the same time, railroads have only been moderately successful in achieving a normal 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 the railroads to facilitate their capital adjustments, we would expect the marginal q to equilibrate faster for the merged than the unmerged firms.

With the exception of two small roads (the Denver Rio Grande and the Grand Trunk Western), the railroads have maintained a marginal q well below one, indicating that excess capacity is pervasive in the industry. Moreover, there is no clear movement toward equilibrium in the post Staggers period. While some railroads appear to have moved toward equilibrium under deregulation (Norfolk Southern, Union Pacific System, Atchison Topeka and Santa Fe, Missouri Kansas Texas, and Soo), others have moved away (Burlingron Northern, CSX, Illinois Central Gulf). Furthermore, the performance of the merged firms is quite mixed, with the Norfolk Southern and the Union Pacific System moving toward equilibrium and the Burlington Northern and the CSX moving away.[32] This suggests that the reasons for the equilibrating behavior of these latter two systems are probably not due to merger activity per se, but are more likely to reflect managerial activities and other considerations.

The pervasiveness of the low marginal q throughout the sample period is surprising and suggests that there may be substantial barriers to the optimal adjustment of capital. If railroads treat their ws capital as a sunk cost, as long as they receive some return on the margin, they have little incentive to abandon it. Alternatively, the cost savings from increments in ws capital may not fully reflect the benefit of this investment.[33] In particular, if service quality enters the demand function and service quality depends on the amount of ws capital, it is likely that the shadow value of capital underestimates the true benefits of investment and the marginal q would overestimate the degree of overcapitalization.

Although it is not possible to address this issue fully without developing a demand model, the data given in Table 6 on the amounts of ws capital, miles of track, and ws capital per mile of track are suggestive. If, for example, regulation forced the railroads to maintain a network in excess of optimal levels, we would expect to observe substantial reductions in track in the post Staggers period. Similarly, if the amount of ws capital embodied in the track had a significant demand enhancing effect, we would expect to see the amount of ws capital per mile of track to rise. Although the data in Table 6 are somewhat mixed in this regard, they generally indicate increasing capital intensity of track after deregulation (Burlington Northern, Conrail, Denver Rio Grande, Seabord/CSX, Mopac/Union Pacific System, Atchison Topeka and Sante Fe, and the Illinois Central Gulf), suggesting that there may well be unmeasured returns from enhanced track quality.

It is possible to shed further light on this issue by considering the rate of return to capital earned by the railroads, which we define as [(R - VC) / x_F] where R represents total revenues, and 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 6 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 the years in the sample. 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; Conrail essentially refurbished its capital (which had been allowed to deteriorate during the bankruptcy of its constituent firms) to permit enhanced service. Similarly, 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 7, which indicates that the bulk of the railroads have experienced substantial overcapitalization throughout the sample period. However, the degree of overcapitalization

TABLE 7

ACTUAL AND OPTIMAL LEVELS OF CAPITAL AND TOTAL COSTS BY RAILROAD, SELECTED YEARS

	CAPITAL STOCK Bil $74		DIFFERENCE		TOTAL COST Bil $74		DIFFERENCE	
Year	ACTUAL	OPTIMAL	ACTUAL	PERCENT	ACTUAL	OPTIMAL	ACTUAL	PERCENT
bn								
mean	4.667	2.618	2.050	43.919	2.091	1.981	0.110	5.24
74	4.293	1.019	3.274	76.257	1.565	1.310	0.254	16.26
79	4.202	3.440	0.762	18.139	2.084	2.071	0.013	0.62
84	5.238	1.634	3.604	68.808	2.559	2.256	0.302	11.81
86	5.252	1.862	3.390	64.545	1.955	1.733	0.222	11.34
drg								
mean	0.386	0.589	-0.204	-52.787	0.210	0.193	0.017	7.94
74	0.368	0.470	-0.102	-27.791	0.160	0.157	0.003	1.99
79	0.374	0.621	-0.247	-66.113	0.217	0.197	0.020	9.22
84	0.413	0.661	-0.249	-60.255	0.250	0.225	0.025	10.05
crc								
mean	7.723	3.960	3.764	48.728	2.525	2.324	0.201	7.96
79	7.982	4.222	3.760	47.110	2.944	2.779	0.164	5.58
84	7.362	3.175	4.188	56.878	2.282	1.989	0.293	12.83
86	7.042	3.743	3.299	46.849	1.879	1.738	0.141	7.51
sbd								
mean	2.652	2.276	0.376	14.171	1.543	1.534	0.009	0.59
74	2.697	1.822	0.876	32.464	1.348	1.322	0.026	1.90
79	2.662	2.354	0.308	11.584	1.717	1.714	0.003	0.18
chessie								
mean	3.105	3.510	-0.405	-13.042	1.521	1.513	0.008	0.50
74	3.304	3.223	0.081	2.447	1.417	1.417	0.000	0.01
79	2.995	3.552	-0.557	-18.590	1.658	1.648	0.010	0.60
csx								
mean	5.765	4.114	1.651	28.636	3.406	3.308	0.098	2.88
84	5.745	4.655	1.090	18.977	3.394	3.370	0.023	0.69
86	5.784	3.812	1.972	34.092	2.749	2.687	0.063	2.28
nw								
mean	3.948	2.269	1.679	42.525	2.329	2.288	0.041	1.76
74	1.918	0.587	1.330	69.366	1.036	0.952	0.084	8.11
79	1.873	1.217	0.656	35.042	1.208	1.189	0.019	1.60
sou								
mean	1.803	1.528	0.275	15.252	1.043	1.038	0.005	0.49
74	1.718	1.297	0.422	24.535	0.911	0.902	0.009	0.99
79	1.836	1.503	0.333	18.132	1.127	1.122	0.005	0.44
nsc								
mean	3.948	2.269	1.679	42.525	2.416	2.288	0.128	5.29
84	3.953	1.515	2.438	61.671	2.359	2.184	0.176	7.44
86	3.884	3.565	0.319	8.213	2.279	2.276	0.003	0.12

TABLE 7, CONT

ACTUAL AND OPTIMAL LEVELS OF CAPITAL AND TOTAL COSTS BY RAILROAD, SELECTED YEARS

	CAPITAL STOCK Bil $74		DIFFERENCE		TOTAL COST Bil $74		DIFFERENCE	
Year	ACTUAL	OPTIMAL	ACTUAL	PERCENT	ACTUAL	OPTIMAL	ACTUAL	PERCENT
mp								
mean	1.475	0.756	0.719	48.769	0.901	0.857	0.043	4.82
75	1.339	0.294	1.045	78.043	0.633	0.543	0.090	14.22
79	1.474	0.722	0.752	50.994	0.955	0.920	0.036	3.74
up								
mean	1.971	0.863	1.108	56.216	1.184	1.122	0.062	5.21
75	1.857	0.765	1.092	58.805	0.941	0.888	0.053	5.67
78	2.009	1.039	0.970	48.283	1.229	1.176	0.053	4.29
upsys								
mean	4.143	1.314	2.828	68.270	2.416	2.179	0.237	9.81
84	4.136	0.572	3.564	86.178	2.648	2.241	0.407	15.36
86	4.234	2.180	2.055	48.528	2.172	2.078	0.094	4.31
atsf								
mean	2.430	0.902	1.528	62.881	1.500	1.392	0.108	7.21
79	2.320	0.235	2.085	89.887	1.466	1.262	0.203	13.88
84	2.449	0.789	1.660	67.770	1.624	1.491	0.133	8.20
86	2.538	1.720	0.818	32.226	1.253	1.229	0.024	1.94
gtw								
mean	0.243	0.379	-0.136	-55.967	0.195	0.187	0.008	3.97
75	0.250	0.293	-0.044	-17.493	0.137	0.137	0.001	0.51
79	0.243	0.369	-0.127	-52.209	0.193	0.186	0.007	3.41
84	0.241	0.411	-0.171	-70.931	0.233	0.221	0.012	5.01
86	0.245	0.510	-0.264	-107.772	0.210	0.182	0.028	13.43
icg								
mean	1.598	1.055	0.543	33.980	0.754	0.729	0.025	3.26
74	1.779	1.158	0.621	34.909	0.695	0.675	0.020	2.92
79	1.624	1.133	0.492	30.263	0.782	0.768	0.014	1.84
84	1.487	1.036	0.451	30.339	0.789	0.773	0.017	2.10
86	1.396	0.574	0.823	58.922	0.583	0.529	0.053	9.14
mkt								
mean	0.265	0.230	0.035	13.208	0.175	0.172	0.003	1.73
74	0.279	0.140	0.139	49.760	0.133	0.125	0.008	6.12
79	0.251	0.254	-0.003	-1.209	0.162	0.162	0.000	0.01
84	0.276	0.211	0.066	23.747	0.209	0.207	0.002	0.90
86	0.276	0.350	-0.074	-26.719	0.194	0.192	0.002	1.25
soo								
mean	0.502	0.345	0.157	31.275	0.235	0.227	0.008	3.40
74	0.545	0.329	0.215	39.508	0.191	0.182	0.009	4.46
79	0.486	0.286	0.200	41.178	0.226	0.218	0.008	3.57
84	0.488	0.222	0.267	54.608	0.241	0.224	0.017	7.10
86	0.512	0.477	0.035	6.787	0.316	0.316	0.000	0.07

has fallen somewhat in the post-Staggers period for a number of railroads, suggesting that deregulation has hastened capital adjustments in the rail system. For example, relative to 1974 (the base year of comparison), the Burlington Northern System, Norfolk Southern, Union Pacific System, the Atchison, Topeka, and Santa Fe, the Missouri Kansas Texas, and the Soo have reduced their degree of excess capacity, and in some cases substantially. In contrast, Conrail, the CSX System, and the ICG have either maintained the same percentage degree of excess capacity (or have increased it somewhat) during the sample period.

Even though 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 $8.949 billion (in 1974) to a high of $16.908 billion (in 1984).[34] If we assume an average opportunity cost of capital of 12%, this represents a partial deadweight loss ranging from $1.074 billion (in 1974) to $2.038 billion (in 1984). On average, over the sample period, the annual deadweight loss of excess capacity was approximately $1.25 billion.[35]

In addition, it is useful to consider the cost differentials that are created by this excess capacity. This is also given in Table 7, which presents data on the short run fitted and optimal total costs for the railroads used in our analysis. While the percentage difference between the fitted 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 $1.407 billion in 1984 to a low of $0.557 billion in 1979. Although the excess costs fell significantly in 1986, totalling $0.630 billion, it is difficult to extrapolate from these figures, since the aggregate costs differentials exhibits substantial variation over the selected sample years.[36] Nevertheless, the data on costs corroborate the findings that the costs of excess capacity are large and pervasive.

5. Summary and Conclusions

The most striking aspect of this analysis is the apparent inability of the rail industry to adjust its capital stock to reach a cost-minimizing equilibrium. This is manifested by the consistently low values of the marginal q's; the low rates of return; the relatively constant magnitude of the differentials between the actual and the optimal capital stock, and the relative constancy between the levels of actual and optimal costs.

This lack of rationalization of capital stock is particularly puzzling in view of the large adjustments that have been made in rail labor[37], 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 unmeasured 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, where the latter includes service quality attributes. In view of the higher speeds and better service permitted by high quality rail bed, this is a plausible hypothesis. Nevertheless, given the magnitude of this disequilibrium, it is unlikely that it can be explained by demand effects alone.

Another explanation may be related to the lumpiness of capital and the need of the railroads to maintain a minimum service level to be competitive with trucks. Thus the railroads may not be faced with a decision about investing a given amount of ws capital at the margin, but may, in fact, be faced with the need to maintain a critical amount of capital if they are to maintain an acceptable service level. This suggests that once this critical level is reached, the railroads may have an incentive to invest their cash flow in non-rail activities or in capital restructuring. While there is some evidence of this behavior,[38] it does not appear to be pervasive.

Thus we are led back to the conclusion that the institutional barriers to capital adjustment may substantial. The rate of capital adjustment is extremely slow, and 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 incentives 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.

NOTES

1. For a discussion of the impact of the Staggers Act upon coal and related rates see Moore (1983), Rose (1988) and Friedlaender (1991).

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 argue that the 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 (1991) 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), who 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 in 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.

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 geometric depreciation (δ) 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 and Berndt *et al.* (1991) for a discussion of the impact of mergers on productivity growth.

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

13. A large number of railroads lost Class I status, some went bankrupt, and others had incomplete bond histories (which made it impossible to generate correct capital equipment costs). See Hausman and Taylor (1981) and Judge *et al.* (1985) for a full discussion of the use of unbalanced panel data.

14. Note that this specification assumes that mergers have a one time positive "adjustment cost" effect on costs as measured by AD_4 (the coefficient on the MDUM variable), but that costs can diminish subsequently over time depending on the value of the M_1 and M_{11} parameters. By permitting the time counters to interact with input prices we follow the usual practice of introducing differential productivity effects with respect to inputs but not with respect to output or capital. The homogeneity restrictions associated with this equation are:

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

$$\sum_{i=1}^{n} AA_{ic} = 0 \ \forall c; \quad \sum_{i=1}^{n} AC_{ij} = 0 \ \forall j; \quad \sum_{i=1}^{n} AD_{ih} = 0 \ , h = r, m$$

15. This interpretation of the unobserved variables is more general than that of Caves *et al.* (1985), who assume that the fixed effects enter the cost function, but not the input share equations.

16. The coefficients given in the cost and input share equations should be interpreted as follows:

$$A_o = A_o' + F_r, \quad r = 1, \ldots, R-1;$$
$$A_i = A_i' + F_{ir}, \quad i = 1, \ldots, n; \quad r = 1, \ldots, R-1$$

where $A^{o\prime}$ and A_i' respectively represent the intercept and linear coefficients on the input price variable for the base railroad (denoted by R); F_r is a zero-one intercept dummy for railroad r in the cost function, and F_{ir} is both a zero-one intercept dummy for railroad r in the ith share equation and a multiplicitive dummy variable on the ln w_i term in the variable cost function equation.

17. For consistency, we must also impose appropriate adding up conditions on these fixed effects, which are given as follows:

$$F_{nr} = -\sum_{j=1}^{n-1} F_{jr}\ ,\ r = 1,\ldots,R-1$$

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

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. Hence, we assume a diagonal autocovariance matrix, with the diagonal elements for the share equation autoregressive parameters being equal. For further discussion, see Berndt and Savin (1975)

19. To test for endogeneity of output and its components, we implemented a system version of the Hausman specification test by estimating an equation system consisting of the variable cost function and n-1 of the cost share equations (we deleted the linearly dependent M&S cost share equation from this system) under two alternative procedures: first, by using 3SLS assuming that y, ALOH,%AG, and %COAL and their transforms are endogenous; and then by maximum likelihood (ML) under the assumption that all regressors are uncorrelated with the error terms. Note that under the null hypothesis ML estimation is efficient, while 3SLS is consistent; if the alternative hypothesis is true, then only the 3SLS estimates are consistent. The χ^2 test statistic corresponding to the null hypothesis that $\beta_{3SLS} = \beta_{ML}$ is 1252.99, which is much larger than the critical value with 38 degrees of freedom at any reasonable significance level. Thus we conclude that y, ALOH, %COAL, and, %AG are endogenous. All subsequent estimation results that we report are therefore based on the assumption that these output-related variables are endogenous and are based on 3SLS with appropriate instrumental variables.

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

21. The estimated ρ in the cost function was 0.1535 with a t-statistic of 0.1160, while the estimate of the common ρ in the share equation was 0.1956 with a t-statistic of 0.1090.

22. Specifically, point estimates of either the montonicity or concavity conditions were violated at 119 of the 229 observations (52%).

23. The point estimate of the CC_{11} coefficient was 0.6775, with a robust standard error of 0.3252.

24. The Atchison, Topeka and Santa Fe (ATSF) railroad was treated as the "base case" railroad. Hence all the fixed effects estimates given in Table 4 should be interpreted as differences from this base case railroad.

25. 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.

26. 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; specifications were also estimated that employed fixed effects only on the constant term or 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.

27. Short run returns to scale are conditional on the existing capital stock, while long run returns to scale are conditional on the optimal capital stock for the given level of output. Since output would doubtless change with the capital stock, these estimates do not provide a measure of returns to scale at the full equilibrium of the firm.

28. Since ton-miles is the product of tons (T) and average length of haul (ALOH), which not only enter into the cost function as output but as technological variables, the definition of scale economies will differ under different assumptions about changes in output. Within the context of this cost function, which includes ALOH and the composition of output as technological variables, economies of density can be thought of as a measure of ray economies of scale with respect to physical output, holding ALOH fixed. Alternative measures of economies of scale include letting ALOH adjust proportionately with tonnage and incorporating the actual changes in the components of output as weights. See Friedlaender (1991) for a full discussion of these points and estimates of different measures of economies of scale for the railroads in the sample. She concludes that the tonnage related measure of returns to scale is the most reliable.

29. As is true in the output-related measures of returns to scale, we can consider various size related measures that incorporate different changes in output (e.g., tons alone, tons with ALOH, etc.). Because we found the ton-related measure to be the most reliable, we utilize its size-related counterpart. Caves et al. (1985) provide some alternative measures of size-related economies that incorporate changes in the various components of output.

30. Alternatively, one can think of miles 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 was adjusted to reflect service quality and hence incorporated demand as well as cost characteristics; (iii) if miles of track are viewed 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 too 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. Using similar definitions, Caves et al. (1985) found returns to scale to be substantially lower than our estimates (an estimate at mean of 0.98 with a standard error 0.07). Since their sample period covered 1951-1975, their results are not directly comparable to ours.

32. Although Conrail was also the result of a merger, it is a special case since it was publicly operated during this period and received substantial infusions of government funds for its ws capital

33. 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

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

where the other arguments in the demand and cost function have been suppressed for notational convenience. In this case, it is straightforward to show that the optimal amount of capital obtains when $MRK = \partial C^V/\partial K + \rho_K$. Thus in equilibrium the difference between the absolute value of opportunity cost of capital and its shadow price is exactly equal to 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.

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

1974	\$ 8.949 billion
1979	\$ 9.384 billion
1984	\$16.908 billion
1986	\$12.124 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.

35. This is comparable to the estimates of the dead weight loss associated with inefficient pricing reported in Winston (1988).

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

1974	$ 0.557 billion
1979	$ 0.555 billion
1984	$ 1.467 billion
1986	$ 0.630 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. It is interesting to note that these estimates are comparable to those estimated by Winston *et al.* (1990).

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

38. For example, in the early 1980's, the CSX diversified into real estate as well as transportation related investments; Conrail undertook a stock buy back plan in 1990; and the Southern Pacific bought a major interest of SPRINT.

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