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Regulation, Barriers to Exit, and the Investment Behavior of Railroads

Richard C. Levin

Evidence abounds that the railroad industry is in decline. Since World War II industry profits have remained chronically low, lower than those of any manufacturing industry in the United States.[1] In the past decade there have been eight bankruptcies of class I railroads. Although measured productivity gains have been relatively high, there is good reason to believe that conventional productivity measures are biased upward in the case of railroads.[2] More important is the widespread feeling that railroad productivity performance has been especially poor relative to latent technological opportunities. In addition, there are persistent complaints from customers of the railroads about poor service and maintenance.

For the past two decades most economists have presumed that the major source of troubles for the railroads has been the regulation of freight rates by the Interstate Commerce Commission. The familiar story, given emphasis in the work of Meyer et al. (1959) and retold most recently by Moore (1975), is that the persistence of value of service pricing—a legacy of an earlier era of railroad monopoly—induced the shift of high-valued manufactured traffic from rail to truck, reducing the volume of railroad traffic and weighting its composition heavily toward less remunerative traffic in agriculatural and mineral products. Rate deregulation, it was held, in addition to eliminating the dead-weight loss from misallocation, would restore the financial viability of the railroads via increased volume. This conventional wisdom has been challenged by more recent econometric studies (Boyer 1977; Levin 1978) which suggest that the direct allocative effects of rate deregulation are likely to be minimal. The low estimated price elasticity for rail transport implies that both the welfare gains and the traffic shifts attendant upon deregulation would be small.

This recent work on rate regulation suggests that the major causes of the railroad problem may be elsewhere. The most plausible candidate, which occupies a parallel (if not so widely emphasized) strand in the literature on transport economics, is the burden of excess capacity. The problem here, long recognized by farsighted railroad executives such as John Barriger (1956), is that the existing railroad network was designed and built in response to the technological imperatives and locational patterns of the nineteenth-century economy. The advent of alternative technologies (trucking and intermodal) and dramatic shifts in the location of industry and the consuming population have rendered much of the existing rail plant obsolete, despite traffic growth on other portions of the rail network.

The longevity of railroad capital alone would be sufficient to create subnormal profits under such conditions, but the problem has been exacerbated by regulatory control over the exit of capital. Apart from the recent abandonments authorized by congressional action in the restructuring of the northeast rail system, line abandonments require the approval of the Interstate Commerce Commission. Past abandonment proceedings have been lengthy and expensive, and the probability of success before the ICC, though difficult to assess from available data, may be sufficiently low to deter substantially the efforts of railroad firms to rationalize their operations.

The problem of excess capacity is exacerbated by rate regulation as well as by abandonment regulation. The issue here more closely parallels an aspect of airline rate regulation than the problems usually discussed in the rail-rate-regulation literature. One of the oldest principles of ICC rate regulation is that shipments of comparable goods over comparable distances should be comparably priced.[3] Since the cost of providing rail service over low-density lines is substantially higher than over high-density lines, application of this principle has entailed cross-subsidization of low-density traffic by high-density traffic. It is possible that some low-density lines would remain viable if rates were allowed to rise to cover the variable costs of providing service, although in a great many cases remunerative rail rates would surely induce a shift to alternative modes.

The combination of barriers to exit and cross-subsidization has adverse static and dynamic consequences. Statically, the requirement that firms operate low-density lines (LDLs) lowers industry profits at existing prices and alters the distribution of profits and losses across firms; to the extent that LDL traffic could be carried intermodally or by alternative modes at costs below rail costs, pure waste or productive inefficiency is induced. Moreover, cross-subsidization entails a dead-weight loss from misallocation of resources between high- and low-density rail lines, which is unmeasured by conventional welfare-loss calculations based on the average discrepancy of rates from marginal costs within commodity groups and/or distance blocks. Dynamically, the formation of new road capital on the viable portions of the rail network is constrained, thus retarding the diffusion of superior technology embodied in capital goods, such as centralized traffic control, automated switching yards, continuous welded rail, and improved signaling equipment. New investment is retarded through two distinct mechanisms. First, to offset the losses on LDLs, rates on HDLs exceed marginal cost, which restricts output and consequently reduces the desired stock of capital on viable portions of the rail network. Second, the lower profitability and associated higher risks of bankruptcy entailed by exit barriers raise the cost of capital to railroad firms and thus reduce investment.

The object of this investigation is to assess the available evidence for the existence and magnitude of these effects. The economic literature on excess rail capacity has focused heretofore on two aspects of the problem: measuring the extent of excess capacity and estimating the social cost (in the sense of productive rather than allocative inefficiency) of operating the rail network at suboptimal traffic density. This study will present new evidence that bears on the first point, but the static social costs will be measured only partially and indirectly. Instead, the focus here will be upon the consequences of abandonment regulation and cross-subsidization for the profitability, and especially the investment behavior, of firms in the railroad industry. While the redistributive consequences of regulation across railroad firms will be emphasized, the distributive effects of rail abandonments on shippers and local communities (a serious and important issue) will not be discussed.

The Simple Economics of Rail Freight Density

In prior attempts to measure the extent of excess line capacity, Friedlaender (1971) and Keeler (1974, 1976) estimated short- and long-run rail cost functions from data supplied by rail firms. Despite important differences in methodology and functional specification, these authors reached broadly similar conclusions. Both found that the actual cost of operating at existing traffic levels substantially exceeds the cost of providing the same level of service along the long-run cost envelope. In light of the methods employed by these authors, the latter statement is equivalent to a finding of excess line capacity, since each author identifies miles of track as the fixed factor of production in the short run. Keeler finds that minimum cost provision of rail service at 1969 levels would have required only 20–25 percent of the existing miles of road.

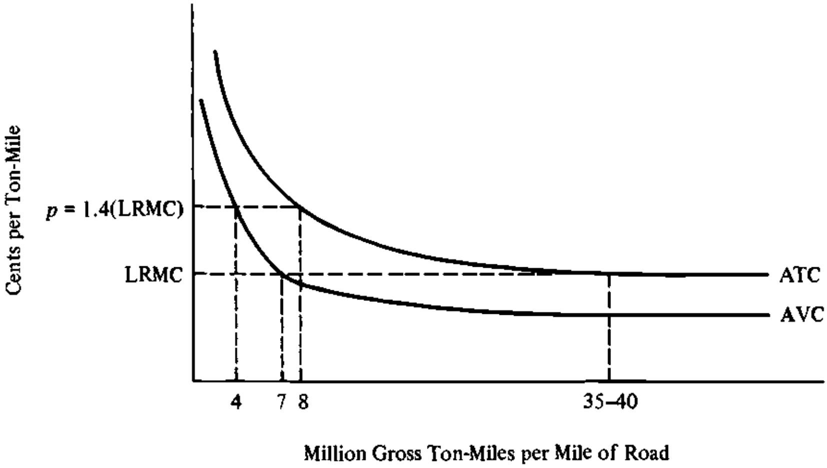

Figure 4.1 Unit total costs, operating costs, and traffic density.

In other words, if all lines operated at efficient levels of traffic density, 75–80 percent of rail route mileage would have been redundant.[4]

Harris (1977) focused directly on the relation of unit rail costs and traffic density, and despite a different specification of the cost function his findings are virtually identical to those of Keeler.[5] Figure 4.1 is a schematic picture of the relation of unit costs and traffic density.[6] Unit costs decline sharply with density, but they become constant once density reaches approximately 35–40 million annual gross ton-miles per mile of road.[7] This represents the level of minimum efficient density, and (roughly speaking) one can think of this as the capacity of a single track between two points, the fundamental indivisibility in the rail cost structure. Higher traffic density can be served at approximately constant cost by adding segments of parallel track and signaling devices. This picture of economies to traffic density is consistent with the findings of Borts (1960), Friedlaender (1971), Keeler (1974), and Caves and Christensen (1976) that the long-run production function for railroad services is linearly homogeneous.[8]

By plotting average rail rates on figure 4.1 it is possible to estimate the break-even level of traffic density.[9] For Harris's cost function (evaluated at the mean average length of haul for firms in his sample) the break-even density was 7.93 million gross ton-miles per mile of road in 1973. Keeler's cost function yields an estimate of break-even density of 8.12 million gross ton-miles per mile of road. Since rates do not vary with traffic density in principle (though they may vary slightly in practice), with commodity type and length of haul held constant, it seems reasonable to infer that profits on traffic carried over lines with density in excess of roughly 10 million gross ton-miles per mile of road subsidize losses on traffic carried on lower-density lines. This proposition will be put to a crude test in the next section.

The observation that rail rates do not cover average total cost on a particular rail line does not necessarily make that line a candidate for abandonment. A firm will presumably offer service if rates cover average variable cost. Economists unfamiliar with railroad costs are inclined to wonder why this criterion would not be satisfied, since they assume that decreasing unit costs of rail service are associated strictly with the fixed cost of road and track, which is sunk. But, as figure 4.1 illustrates, unit operating costs decline sharply with traffic density. Decreasing average variable costs are thought to be primarily attributable to two factors: the fact that low traffic density necessitates shorter trains, which in conjunction with locomotive requirements and especially labor requirements implies higher unit operating cost; and the fact that maintenance costs are largely independent of traffic density. Harris's estimate of average operating costs suggests that, at actual 1973 rates, lines with traffic density below 4.15 million gross ton-miles per mile of road fail to earn revenues in excess of variable cost. If rates were permitted to fall to long-run marginal cost, many lines which cover variable cost at inefficient prices would become candidates for abandonment, at least from the point of a view of a private, profit-maximizing enterprise. Figure 4.1 shows that efficient prices (actual prices divided by 1.4) would cover operating costs where traffic density exceeds 7.03 million gross ton-miles per mile of road. This figure is close to the level of break-even density at existing rates.

New Evidence on the Extent of Excess Capacity

Until recently, econometric work on the excess-capacity problem has been limited to the use of cross-sectional firm data, in which the only indicator of a firm's freight density characteristics is the quotient of its total output and its route mileage. A considerably more detailed picture can now be obtained from data collected by the Department of Transportation in a study mandated by the Railroad Revitalization and Regulatory Reform Act of 1976. The DOT data classify each line segment in the U.S. rail network by the density of its traffic in 1975.[10] Although the DOT is unwilling to release exact density information by line segment, it does place each segment within one of six density categories.[11] When combined with data from the Federal Railroad Administration's network model, the line-segment-density data permit a tabulation of the distribution of each railroad's route mileage by density class. The exact traffic density for each line segment is unknown, but a good approximation to the distribution of each railroad's output by density class may be calculated on the assumption that each line segment has a traffic density equal to the cell mean. Table 4.1 presents this information for class I railroads in 1975.

The percentage of each railroad's route mileage and output in the lowest three density categories are reported in the LDL columns of table 4.1. These density categories account for all segments below 10 million gross ton-miles per mile of road, and correspond closely to the break-even level of density implicit in the estimates of Keeler and Harris. Ten million gross ton-miles per mile of road is also the closest approximation, though perhaps a modest overstatement, of the density level below which efficient rail rates would fail to cover variable costs. These LDLs account for nearly two-thirds of the route mileage of class I railroads yet they carry only 18 percent of the traffic. Only five of the sixty railroads tabulated have less than 20 percent of their route mileage in LDLs; twelve railroads have networks consisting entirely of LDLs. Three of these twelve are bankrupt, and none of the rest are in good financial health.

The HDL columns of table 4.1 report the share of each railroad's mileage and output in the highest of the six DOT density categories. These line segments, which operate at approximately minimum efficient density, represent only 10.9 percent of class I railroad mileage, yet they carry over one-third of the nation's freight. It is remarkable that thirty-two class I railroads have no HDL segments in their networks, and only one (the small but highly profitable Richmond, Fredericksburg, and Potomac) has a system composed entirely of HDLs.

It follows by combining the information reported in columns 4 and 6 that the remaining 25.9 percent of the nation's rail network operates at traffic densities that are remunerative at existing rates but would not be profitable if rates fell to the level of long-run marginal cost. These lines of intermediate density carry nearly half (48.2 percent) of the nation's freight.

Low-Density Lines and Profitability

Before examining the impact of barriers to abandonment and cross-subsidization on railroad investment behavior, it seems worthwhile to

Table 4.1 Line density of Class I railroads, 1975.

	Route Miles Classified	Gross Ton-Miles (Millions)	Mean Density, GTM/MR	LDL Miles/ Route Miles	LDL Output ÷ GTM	HDL Miles/ Route Miles	HDL Output ÷ GTM
Ann Arbor[a]	342.0	171.00	0.500	1.000	1.000	0.000	0.000
Atchison, Topeka & Santa Fe	12,209.1	156,948.30	12.855	0.576	0.119	0.203	0.553
Baltimore & Ohio	4,732.8	63,531.72	13.424	0.515	0.143	0.179	0.467
Bangor & Aroostook	503.0	2,144.00	4.262	0.950	0.708	0.000	0.000
Bessemer & Lake Erie	170.0	3,597.00	21.159	0.247	0.041	0.171	0.282
Boston & Maine	1,098.5	8,653.35	7.877	0.751	0.208	0.000	0.000
Burlington Northern	20,859.1	204,218.80	9.790	0.651	0.162	0.081	0.289
Canadian Pacific Lines in Maine	305.1	3,480.50	11.393	0.350	0.145	0.000	0.000
Central Railroad of New Jersey[a]	252.4	328.70	1.302	1.000	1.000	0.000	0.000
Central Vermont	363.0	1,779.50	4.902	1.000	1.000	0.000	0.000
Chesapeake & Ohio	4,158.1	53,346.29	12.829	0.637	0.167	0.209	0.570
Chicago & Eastern Illinois[b]	384.5	5,017.50	13.049	0.429	0.095	0.044	0.119
Chicago & Northwestern	9,567.4	64,979.22	6.792	0.791	0.281	0.055	0.282
Chicago, Milwaukee, St. Paul & Pacific	8,889.5	52,894.02	5.950	0.772	0.371	0.002	0.014
Chicago, Rock Island & Pacific	6,220.6	46,218.29	7.430	0.719	0.369	0.001	0.005
Clinchfield	289.0	6,171.00	21.353	0.076	0.011	0.000	0.000
Colorado & Southern	586.4	3,709.50	6.326	1.000	1.000	0.000	0.000
Delaware & Hudson	624.1	8,261.55	13.238	0.479	0.178	0.000	0.000
Denver & Rio Grande Western	1,740.2	21,287.00	12.223	0.496	0.154	0.000	0.000
Detroit & Toledo Shore	61.6	924.00	15.000	0.000	0.000	0.000	0.000
Detroit, Toledo & Ironton	343.8	3,515.50	10.225	0.573	0.232	0.000	0.000
Duluth, Mesabe & Iron Range	319.0	4,004.50	12.553	0.564	0.115	0.197	0.551

Table 4.1 (continued)

	Route Miles Classified	Gross Ton-Miles (Millions)	Mean Density, GTM/MR	LDL Miles/ Route Miles	LDL Output ÷ GTM	HDL Miles/ Route Miles	HDL Output ÷ GTM
Duluth, Winnepeg & Pacific	78.0	1,170.00	15.000	0.000	0.000	0.000	0.000
Elgin, Joliet & Eastern	178.4	1,784.00	10.000	0.583	0.226	0.000	0.000
Erie Lackawanna[a]	2,261.2	15,488.14	6.850	0.713	0.215	0.000	0.000
Florida East Coast	512.6	5,856.50	11.425	0.283	0.058	0.000	0.000
Fort Worth & Denver	1,094.4	5,476.00	5.004	1.000	1.000	0.000	0.000
Georgia, Lessee Organization	309.0	2,759.00	8.929	0.586	0.304	0.000	0.000
Grand Trunk Western	892.7	9,314.90	10.435	0.586	0.123	0.000	0.000
Green Bay & Western[c]	253.0	759.00	3.000	1.000	1.000	0.000	0.000
Illinois Central Gulf	8,919.1	77,861.38	8.730	0.736	0.349	0.040	0.162
Illinois Terminal	167.0	830.00	4.970	1.000	1.000	0.000	0.000
Kansas City Southern	1,442.9	14,331.20	9.932	0.565	0.293	0.000	0.000
Lehigh Valley[a]	632.0	3,499.25	5.537	0.835	0.483	0.016	0.100
Long Island	298.5	759.00	1.358	1.000	1.000	0.000	0.000
Louisville & Nashville	5,995.5	84,604.00	14.111	0.491	0.111	0.147	0.364
Maine Central	757.0	2,853.75	3.770	0.998	0.987	0.000	0.000
Missouri-Illinois[c]	120.0	345.0	2,875	1.000	1.000	0.000	0.000
Missouri-Kansas-Texas	1,797.7	16,402.04	9.124	0.587	0.237	0.013	0.049
Missouri Pacific	7,536.8	78,752.00	10.449	0.611	0.193	0.071	0.237
Norfolk & Western	6,665.4	93,045.88	13.960	0.522	0.126	0.176	0.441
Norfolk Southern	860.0	2,841.75	3.304	1.000	1.000	0.000	0.000
Northwestern Pacific	305.0	1,421.00	4.659	1.000	1.000	0.000	0.000
Penn Central[a]	14,716.0	174,329.30	11.846	0.647	0.158	0.171	0.505

Pennsylvania-Reading Seashore[a]	295.6	406.30	1.374	1.000	1.000	0.000	0.000
Pittsburgh & Lake Erie	177.2	4,705.00	26.552	0.011	0.000	0.524	0.690
Reading[a]	931.0	6,853.70	7.362	0.786	0.153	0.096	0.454
Richmond, Fredericksburg & Potomac	122.5	4,287.50	35.000	0.000	0.000	1.000	1.000
St. Louis–San Francisco	4,480.5	40,518.79	9.043	0.630	0.194	0.000	0.000
St. Louis–Southwestern	1,198.6	22,934.00	19.134	0.388	0.055	0.359	0.656
Seaboard Coast Line	8,716.3	100,022.30	11.475	0.534	0.152	0.081	0.247
Soo Line	4,158.3	27,148.94	6.529	0.759	0.323	0.000	0.000
Southern Pacific	10,551.4	169,603.10	16.074	0.486	0.084	0.300	0.653
Southern[d]	9,334.0	105,501.50	11.303	0.607	0.174	0.075	0.233
Texas-Mexican	177.0	1,893.50	10.698	0.322	0.049	0.000	0.000
Texas & Pacific[b]	1,789.6	21,086.00	11.783	0.536	0.166	0.050	0.149
Toledo, Peoria & Western	271.0	2,021.00	7.458	0.849	0.696	0.000	0.000
Union Pacific	8,356.5	114,870.40	13.746	0.587	0.116	0.250	0.636
Western Maryland	427.1	3,454.50	8.088	0.679	0.255	0.035	0.152
Western Pacific	1,046.1	18,669.50	17.847	0.215	0.057	0.179	0.351
Totals	181,844.1	1,953,640.1	10.743	0.632	0.180	0.109	0.338

a. Merged into Conrail in 1976.
b. Merged into Missouri Pacific in 1976.
c. Class II railroads in 1975; subsequently class I.
d. Includes density data on four Southern Railway subsidaries: Alabama Great Southern; Central of Georgia; Cincinnati, New Orleans & Texas; and Georgia Southern & Florida.

attempt to gauge the impact of these regulatory policies on profitability. If output prices for comparable commodities do not differ substantially across firms, and if the commodity mix of traffic and other factors determining revenues and costs are accounted for, one would expect that the share of a railroad's traffic carried on LDLs would be an important determinant of interfirm differences in profitability. Indeed, the results of estimating a cross-section profit equation may be used to provide an indirect test of the hypothesis that LDLs are cross-subsidized.

Estimating cross-section profit functions is a tricky business. Many of the well-known pitfalls stemming from systematic differences in the tax treatment, capital structure, riskiness, or accounting practices across industries are not relevant when the firms compared are in the same industry and are governed by a common set of accounting rules. Nevertheless, specification of a profit equation is rendered quite difficult by the presence of a large number of highly collinear variables that affect the revenue or cost structure of railroad firms. The results reported in table 4.2 should therefore be regarded as merely suggestive, since the parameter estimates are somewhat sensitive to which variables are in-

Table 4.2 Regression results: railroad profitability in 1975. The dependent variable is the Rate of return on total assets (= [net income plus net interest payments ÷ the book value of assets] × 100). Sample mean = 3.59.

Independent Variables	Estimated Coefficient	Standard Error
Constant	10.9226	9.8984
PCTLDL[a]	−0.3551[b]	0.1771
$\text{PCTLDL}^2 \times 100$	0.2521[b]	0.1341
Mean[c]	0.0827	1.0082
Mean^2	−0.0253	0.0321
PCTAG[d]	−0.2759[b]	0.1439
PCTMIN[e]	−0.0399	0.0311
ALH[f]	0.5345	0.5000
EFF[g]	6.9817	7.2815

Note: Number of observations = 31; $R^2 = 0.4209$

a. Percentage of traffic carried on LDLs = (Output on LDLs ÷ Total output) × 100.

b. Significant at the 0.05 level.

c. Mean = Mean density of firm's network = Gross ton-miles ÷ Route miles.

d. Percentage of agricultural traffic = (Revenue tons of agricultural commodities ÷ Total revenue tons) × 100.

e. Percentage of mineral traffic = (Revenue tons of mineral commodities ÷ Total revenue tons) × 100.

f. Average length of haul, in hundreds of miles.

g. Revenue ton-miles ÷ Gross ton-miles.

cluded in or omitted from the equation. The pattern of signs and significance, however, is less sensitive to the specification.[12]

The explanatory variable of major interest is the percentage of traffic carried on low-density lines (PCTLDL), where low-density lines are those segments below the approximate break-even density of 10 million gross ton-miles per mile of road. While this variable is significant at the 10 percent level when entered linearly, its significance increases when a squared term is added to account for a nonlinearity which is readily apparent from a simple plot of profit rate against PCTLDL. The sign on the squared term is somewhat surprising, since the shape of the average cost curve suggests the opposite sign. Nevertheless, it is clear that the combined effect of the light density line terms is to reduce the level of profits.

The mean density of the firm's network is included in order to explain the cost structure more fully. One expects that, given the LDL percentage, higher average density will be associated with higher profits, at least over some range. Collinearity between mean density and PCTLDL is less severe than one might expect (the simple correlation is 0.61), but the coefficients on mean and mean^2 are insignificantly different from zero despite having the expected signs.[13]

Since both rates and costs depend on commodity type, measures of each firm's commodity mix are included. PCTAG is the share of agricultural and forest products in a firm's total freight tonnage. Since rates on agricultural products are distinctly lower than on manufactured products (the omitted variable), the negative sign conforms to expectations. There is no clear expectation regarding the effect on profitability of mineral products; while rates are lower than on manufactures, high-volume operation (especially on coal traffic) suggests lower costs as well. A similar ambiguity is involved with average length of haul. Rates and unit costs clearly both decline with increases in ALH, and it is widely believed the net effect on profit is positive. The expected sign results in each estimated specification, but the variable is never significant.

Regional dummy variables were consistently insignificant in a wide variety of specifications, despite the expectation that firms operating in the eastern region—with its higher costs and allegedly unfavorable rate divisions—would prove less profitable than those in the west and south. The regional dummies are excluded here because of their high collinearity with ALH and the commodity-mix variables. The final included variable, EFF, is meant to be a measure of efficient equipment utilization, the ratio of revenue ton-miles to gross ton-miles. It has the expected sign, but it is statistically insignificant.

The estimated parameters of the profit function may be used to predict the impact of abandoning low-density lines. The first column of table 4.3 reports the predicted rate of return in 1975 given the existing route structure of each firm in the sample. The second column indicates the predicted rate of return when PCTLDL is set equal to zero. The effect is dramatic. The average rate of return would rise from 3.88 percent to 8.85 percent, with eleven firms earning returns in excess of 10 percent. In dollar terms, returns to capital of the thirty-one railroads would increase by $1.4 billion. This figure almost certainly overstates the avoidable losses recoverable by abandonment. The exercise reported in table 4.3 involves predicting the profitability of each firm on the assumption that its route structure contains no LDLs. It is implicitly assumed in performing this calculation that firms will save the full cost of LDL service, but abandonment will in fact only permit firms to save operating costs. It is not possible to ascertain the precise magnitude of capital costs associated with LDLs, but Harris's figures suggest they are unlikely to be more than one-third of total costs. Thus, each firm's predicted gains should be scaled down by about one-third, and a more plausible estimate of the profit increase resulting from abandonment would be just under $1 billion for the thirty-one sample firms. Since the sample firms own about two-thirds of the industry's capital stock, an extrapolation of this estimate to the industry as a whole yield a predicted increase in profits of $1.4 billion. However, private gains of this magnitude would not be fully realized by abandonment if rates on high-density traffic fell towards marginal costs through intensified competition or regulatory action. The profit increases predicted here implicitly assume that rates would remain constant.

Despite the crudeness of the estimated equation, it seems reasonable to conclude that the low-density lines are a significant drain on railroad profitability. The evidence discussed thus far clearly supports the hypothesis that high-density lines are more profitable. To determine whether LDLs are in fact cross-subsidized, predicted values of the rate of return were calculated on the assumption that PCTLDL = 1. Under these circumstances, twenty-four of the thirty-one sample firms would earn negative rates on return on total capital, which indicates that revenues would fail to cover variable costs (that is, net income before interest charges would be negative). All but two of the remaining firms, while covering variable costs, would nevertheless fail to recover fixed costs.

Table 4.3 Effect of low-density-line abandonment on profitability.

	Predicted 1975 Rate of Return With LDLs	Predicted 1975 Rate of Return Without LDLs	Predicted Increase in Profits (in millions)
Alabama Great Southern	5.82	11.24	$ 9.21
Atchison, Topeka & Santa Fe	3.17	7.04	87.02
Baltimore & Ohio	4.39	8.96	63.86
Burlington Northern	3.84	8.92	163.16
Central of Georgia	4.69	10.11	13.01
Cheasapeake & Ohio	4.62	9.85	73.80
Chicago & Eastern Illinois	5.54	8.68	4.53
Chicago & Northwestern	1.86	9.84	35.68
Chicago, Rock Island & Pacific	−2.51	7.16	42.29
Clinchfield	1.89	2.27	0.30
Cincinnati, New Orleans & Texas	3.14	8.56	10.60
Colorado & Southern	4.81	15.11	15.60
Delaware & Hudson	4.52	10.04	5.44
Detroit & Toledo Shore	5.94	5.94	0.00
Duluth, Mesabe & Iron Range	5.94	9.69	4.18
Illinois Central Gulf	0.62	9.94	121.16
Illinois Terminal	3.21	13.51	4.06
Kansas City Southern	2.74	10.98	20.67
Louisville & Nashville	4.76	8.39	48.59
Maine Central	2.49	12.99	8.28
Missouri-Kansas-Texas	1.69	8.69	14.01
Missouri Pacific	3.00	8.92	80.95
Norfolk & Western	4.46	8.53	99.31
St. Louis–San Francisco	4.59	10.53	31.62
Seaboard Coast Line	5.34	10.16	91.21
Soo Line	2.76	11.60	28.65
Southern Pacific	5.20	8.00	83.33
Southern	4.83	10.24	114.36
Texas & Pacific	2.50	7.70	16.47
Union Pacific	3.31	7.09	93.11
Western Maryland	2.33	9.75	14.48
31 firms	3.88	8.85	$1,398.94

These results seem to support overwhelmingly the hypothesis that LDLs are unprofitable, and to support strongly the presence of cross-subsidization in the strict sense.

A Model of Railroad Investment Behavior

To estimate the effects of regulatory constraint on railroad investment behavior, I shall work within the general framework of the neoclassical model of investment developed by Dale Jorgenson (1965, 1967, and others too numerous to mention).[14] Though the Jorgenson model has been subjected to several well-known criticisms,[15] it has proved serviceable in a variety of applications and it seems a reasonable starting point. The novelty in the present application of the neoclassical investment model is the attempt to take proper account of the institutional peculiarities of the railroad industry. To do so requires specific incorporation of the regulatory constraint on prices and of the requirement to maintain service on low-density lines. Moreover, investment in rolling stock should be separated from investment in road and structures, since both the cost of funds and the impact of regulatory constraints are different for these two types of capital.

The results of prior attempts to estimate neoclassical investment functions from railroad data have been poor, possibly because of a failure to take account of these special characteristics. Jorgenson and Handel (1971) estimated a railroad investment function from time-series industry data. They incorporate price regulation but assumed that prices are set equal to marginal cost. They failed to disaggregate road and equipment investment, and did not take account of abandonment regulation and cross-subsidization. Jorgenson and Handel seemed reasonably satisfied with their results, but they failed to observe that the magnitude of the theoretically unjustified constant term in their estimated equation strongly suggests specification error. In the only other attempt to estimate a neoclassical investment function with railroad data that I know of, Swanson (1968) disaggregated road and equipment investment. However, he failed to include any type of regulatory constraint. He claimed only mixed success for his time-series estimates on individual firms.

The newly available DOT data on line-segment density and the convenient separation of road and equipment accounts required by the ICC make possible the estimation of a model that accounts for the special features of railroad investment behavior. Using 10 million gross ton-miles per mile of road as the dividing point, and denoting high- and low-density lines by the subscripts 1 and 2 respectively, we can write the objective function for a firm that seeks to maximize the present discounted value of its stream of revenues minus expenditures as

$$\text{Max} \int_0^\infty e^{-rt}[p(Q_1 + Q_2) - w(L_1 + L_2) - q(I_1 + I_2) - s(J_1 + J_2)]dt, \tag{1}$$

where Q, L, I, and J denote output, labor, gross road investment, and gross equipment investment respectively; p, w, q, and s are the prices associated with output, labor, road investment goods, and equipment investment goods respectively; and r is the discount rate. All variables are functions of time, but this notation is suppressed. (The objective function already incorporates one aspect of regulatory behavior: Output prices are constrained to be equal on high- and low-density lines. Factor prices, of course, do not depend upon the use to which the factors are put.)

The regulated railroad firm maximizes equation (1) subject to a set of constraints. First, output on high- and low-density lines is constrained by the production functions

$$\begin{aligned} F_1(L_1,K_1,E_1) - Q_1 &= 0, \\ F_2(L_2,K_2,E_2) - Q_2 &= 0, \end{aligned} \tag{2}$$

where K and E denote road capital and rolling stock, respectively.[16]

Rate regulation takes the form of requiring the firm to serve all shippers at the regulated price. Since each railroad firm faces downward-sloping demand curves for high- and low-density output in the absence of regulation, we can think of p, a parameter set by the ICC, as determining the levels of output along the demand curves.[17] Thus, the firm's constraint may be written in terms of output as

$$\begin{aligned} \bar{Q}_1 - Q_1 &= 0, \\ \bar{Q}_2 - Q_2 &= 0. \end{aligned} \tag{3}$$

This form of writing the regulatory constraint makes clear that two of the most widely noted objections to the neoclassical investment model are irrelevant to the present formulation. First, since the firm is constrained by demand, it is unnecessary to assume that the production function is strictly convex. Second, the fact that output is indeed exogenous here disarms the criticism that output and investment are determined simultaneously.

A third set of constraints are the growth equations for equipment capital, in which the change in the capital stock must be equal to gross investment minus depreciation:

$$\begin{aligned} &\dot{E}_1 - J_1 + \theta E_1 = 0, \\ &\dot{E}_2 - J_2 + \theta E_2 = 0, \end{aligned} \tag{4}$$

where θ is assumed to be the proportional rate of depreciation of the stock of equipment capital.

Finally, abandonment regulation enters in conjunction with the growth constraints on road capital. It is assumed that the exit of road capital is constrained. That is, $\dot{K}_1$ and $\dot{K}_2$ are constrained to be greater than or equal to zero. If it is further assumed that exit barriers are a binding constraint only on low-density lines, then $\dot{K}_2 = 0$. Thus, the growth equations for road capital may be written as

$$\begin{aligned} &\dot{K}_1 - I_1 + \delta K_1 = 0, \\ &- I_2 + \delta K_2 = 0, \end{aligned} \tag{5}$$

where δ is the proportional rate of depreciation on road capital.

The constraints (5), as written, imply that road capital on low-density lines must be replaced as it depreciates. This seems unduly stringent. It is perhaps more reasonable to assume that barriers to exit are interpreted as a requirement that gross investment be non-negative. In other words, the rate of net disinvestment is constrained by the rate of depreciation. If exit barriers in this sense are a binding constraint for low-density lines, the growth equations for road capital become

$$\begin{aligned} &\dot{K}_1 - I_1 + \delta K_1 = 0, \\ &\dot{K}_2 + \delta K_2 = 0. \end{aligned} \tag{5'}$$

The form of our data makes it possible to estimate with some confidence the model with the constraints (5) imposed, but the alternative specification involving (5′) requires certain *ad hoc* assumptions, which will be discussed below. Both versions of the model were estimated.

If we tie together the firm's objective function, (1), with its set of constraints, (2)–(5), the Lagrangian expression for a maximum of the firm's present value may be written as

$$\int_0^\infty \{e^{-rt}[p(Q_1 + Q_2) - w(L_1 + L_2) - q(I_1 + I_2) - s(J_1 + J_2)]$$

$$
\begin{aligned}
&+ \lambda_1[F_1(L_1,K_1,E_1) - Q_1] + \lambda_2[F_2(L_2,K_2,E_2) - Q_2] \\
&+ e^{-rt}\pi_1(\bar{Q}_1 - Q_1) + e^{-rt}\pi_2(\bar{Q}_2 - Q_2) \\
&+ \phi_1(\dot{K}_1 - I_1 + \delta K_1) + \phi_2(-I_2 + \delta K_2) \\
&+ \psi_1(\dot{E}_1 - J_1 + \theta E_1) + \psi_2(\dot{E}_2 - J_2 + \theta E_2)\}dt \\
&= \int_0^\infty f(t)dt. \qquad (6)
\end{aligned}
$$

The Euler necessary conditions for a maximum of present value subject to the eight constraints involve ten pairs of equations ($i = 1,2$ for all pairs):

$$\frac{\partial f}{\partial Q_i} = e^{-rt}p - \lambda_i - e^{-rt}\pi_i = 0, \qquad (7a)$$

$$\frac{\partial f}{\partial L_i} = -e^{-rt}w + \lambda_i\frac{\partial F_i}{\partial L_i} = 0, \qquad (7b)$$

$$\frac{\partial f}{\partial I_i} = -e^{-rt}q - \phi_i = 0, \qquad (7c)$$

$$\frac{\partial f}{\partial J_i} = -e^{-rt}s - \psi_i = 0, \qquad (7d)$$

$$
\left.
\begin{aligned}
&\frac{\partial f}{\partial K_1} - \frac{d}{dt}\frac{\partial f}{\partial \dot{K}_1} = \lambda_1\frac{\partial F_1}{\partial K_1} + \phi_1\delta - \frac{d}{dt}\phi_1 = 0, \\
&\frac{\partial f}{\partial K_2} - \frac{d}{dt}\frac{\partial f}{\partial \dot{K}_2} = \lambda_2\frac{\partial F_2}{\partial K_2} + \phi_2\delta = 0,
\end{aligned}
\right. \qquad (7e)
$$

$$\frac{\partial f}{\partial E_i} - \frac{d}{dt}\frac{\partial f}{\partial \dot{E}_i} = \lambda_i\frac{\partial F_i}{\partial E_i} + \psi_i\theta - \frac{d}{dt}\psi_i = 0, \qquad (7f)$$

$$\frac{\partial f}{\partial \lambda_i} = F_i(L_i,K_i,E_i) - Q_i = 0, \qquad (7g)$$

$$\frac{\partial f}{\partial \pi_i} = e^{-rt}(\bar{Q}_i - Q_i) = 0, \qquad (7h)$$

$$
\left.
\begin{aligned}
&\frac{\partial f}{\partial \phi_1} = \dot{K}_1 - I_1 + \delta K_1 = 0, \\
&\frac{\partial f}{\partial \phi_2} = -I_2 + \delta K_2 = 0,
\end{aligned}
\right. \qquad (7i)
$$

$$\frac{\partial f}{\partial \psi_i} = \dot{E}_i - J_i + \theta E_i = 0. \tag{7j}$$

To interpret these first-order conditions, note that the π_i, the Lagrange multipliers associated with the regulatory constraint on output, may be regarded as the profit on a marginal unit of output, price minus marginal cost. Thus, we may presume that π_1 is greater than zero, reflecting the excess of price over marginal cost on high-density lines, while π_2 is less than zero, reflecting the unprofitability of low-density traffic. This interpretation leads to the natural conclusion that the shadow prices of output (λ_1 and λ_2), which from (7a) are equal to $e^{-rt}(p - \pi_i)$, may be understood as the discounted marginal cost of high- and low-density output, respectively.

The marginal-productivity conditions for the services of road capital may be derived from (7e) with appropriate substitutions from (7a) and (7c):

$$\frac{\partial F_1}{\partial K_1} = \frac{q(\delta + r - \dot{q}/q)}{p - \pi_1}, \tag{8a}$$

$$\frac{\partial F_2}{\partial K_2} = \frac{q\delta}{p - \pi_2}. \tag{8b}$$

The right-hand sides of these expressions may be understood as the ratio of the shadow price of capital services to the shadow price of output. The numerator of the right-hand side of (8a) may be modified to take account of the effects of the corporate income tax, as shown by Hall and Jorgenson (1967). Under these circumstances, we can write the marginal productivity condition for high density road capital as

$$\frac{\partial F_1}{\partial K_1} = \frac{c}{p - \pi_1}, \tag{8a$'$}$$

where

$$c = (1 - k)q\left[\left(\frac{1 - uv}{1 - u}\right)\delta + \left(\frac{1 - uw}{1 - u}\right)r - \left(\frac{1 - ux}{1 - u}\right)\frac{\dot{q}}{q}\right].$$

The parameters k, u, v, w, and x reflect aspects of the corporate tax structure: k is the investment tax credit, u is the rate of corporate income tax, v is the proportion of economic depreciation charged against income for tax purposes, w is the proportion of the total cost of capital charged against income, and x is the proportion of capital gains charged against income.

The marginal-productivity condition for road capital on low-density lines differs from (8a) as a consequence of the exit constraint. The implicit service price of low-density road capital is just its nominal depreciation $q\delta$, since the exit constraint renders the opportunity cost component of the service price effectively zero.

The marginal-productivity conditions for equipment capital may similarly be derived from (7f), with substitutions from (7a) and (7d) yielding

$$\frac{\partial F_i}{\partial E_i} = \frac{s(\theta + r - \dot{s}/s)}{p - \pi_i}, \qquad i = 1, 2. \tag{9}$$

As above, (9) may be modified to take account of the corporate income tax as follows:

$$\frac{\partial F_i}{\partial E_i} = \frac{d}{p - \pi_i}, \tag{9'}$$

where

$$d = (1 - k)s\left[\left(\frac{1 - uv}{1 - u}\right)\theta + \left(\frac{1 - uw}{1 - u}\right)r - \left(\frac{1 - ux}{1 - u}\right)\frac{\dot{s}}{s}\right].$$

The marginal-productivity conditions (8a′) and (9′) may be solved for the firm's desired stock of high-density road capital, K_1^*, and desired equipment capital, E_1^* and E_2^*. The desired level of road capital on low-density lines, however, is irrelevant to the firm's investment decision, since the exit constraint requires that $\dot{K}_2 = 0$ in the version of the model incorporating constraint (5). When the alternative constraint (5′) is in force, $I_2 = 0$ as long as the actual level of capital, K_2, exceeds its desired level, K_2^*. I assume that this is true on light-density lines over the time horizon under study.

To derive expressions for K_1^*, E_1^*, and E_2^*, assume that the production functions for high- and low-density lines have the identical Cobb-Douglas form:

$$Q_i = L_i^{1-\alpha-\beta} K_i^{\alpha} E_i^{\beta}, \qquad i = 1, 2. \tag{10}$$

The marginal-productivity conditions may now be solved for the levels of desired capital:

$$K_1^* = \alpha \frac{(p - \pi_1)Q_1}{c}, \tag{11a}$$

$$E_1^* = \beta\frac{(p - \pi_1)Q_1}{d}, \tag{11b}$$

$$E_2^* = \beta\frac{(p - \pi_2)Q_2}{d}. \tag{11c}$$

The Jorgenson investment model has two components: Expenditure on replacement investment is assumed to be a constant proportion of the capital stock, and net investment expenditure at time t is a distributed lag of changes in desired capital. In the present application, when regulation requires the replacement of capital on low-density lines, replacement investment for road capital at time t is simply[18]

$$R_t = (\delta K_1)_t + (\delta K_2)_t = \delta K_t. \tag{12}$$

If all road capital is replaced and net investment in low-density-road capital is assumed to be zero, the firm's net investment in all road capital, N_t, is a distributed lag of changes in the desired level of high-density-road capital:

$$N_t = I_t - R_t = \mu_0(\Delta K_1^*)_t + \mu_1(\Delta K_1^*)_{t-1} + \cdots + \mu_n(\Delta K_1^*)_{t-n}, \tag{13}$$

where $\mu_0, \mu_1, \ldots, \mu_n$ is a sequence of non-negative numbers which sum to unity.[19] The expression for net investment in equipment corresponds, except that the distributed lag is expressed in terms of changes in the desired level of all equipment, $\Delta E_1^* + \Delta E_2^* = \Delta E^*$.

Jorgenson derives his analog of equation (13) from the assumption that the firm places new orders each period such that its present capital stock plus outstanding orders equals its current level of desired capital. The parameters μ_i thus represent the distribution of delivery times—the fraction μ_0 of new orders arrive in the current period, μ_1 in the next period, and so forth.[20]

To complete the model, Jorgenson assumes that the sequence $\mu_0, \ldots, \mu_n$ has a rational generating function. Then the model (13) can be written as a rational distributed lag function in net investment and changes in desired capital:

$$\omega_0 N_t + \omega_1 N_{t-1} + \cdots + \omega_m N_{t-m} = \gamma_0(\Delta K_1^*)_t + \gamma_1(\Delta K_1^*)_{t-1} + \cdots + \gamma_k(\Delta K_1^*)_{t-k}. \tag{14}$$

The restrictions that the μ_i be non-negative and sum to unity imply a set of constraints on the ω_i and γ_i, which are thoroughly discussed in Jorgenson 1966. Without loss of generality, ω_0 may be set equal to unity. Recalling that $N_t = I_t - \delta K_t$ and limiting the order of the ω_i sequence to 3 and that of the γ_i sequence to 2,[21] we write the model in its final form:

$$I_t = \gamma_0(\Delta K_1^*)_t + \gamma_1(\Delta K_1^*)_{t-1} - \omega_1 N_{t-1} - \omega_2 N_{t-2} + \delta K_t. \tag{15}$$

Our principal interest is in estimating the parameters of the road-investment equation (15) and using them to predict the impact of LDL abandonment on capital formation on the viable portions of the rail network. Rolling stock is obviously less critically affected by the regulatory constraint on abandonment, but examination of the marginal-productivity conditions (11) shows that cross-subsidization does affect the desired stock of equipment capital. We therefore also estimate an equation for gross equipment investment, J_t, as a function of current and lagged changes in desired capital, $(\Delta E^*)_t$ and $(\Delta E^*)_{t-1}$; lagged net investment, M_{t-1}; and the stock of capital, E_t:[22]

$$J_t = \gamma_0'(\Delta E^*)_t + \gamma_1'(\Delta E^*)_{t-1} - \omega_1' M_{t-1} + \theta E_t. \tag{16}$$

Estimating the Model of Railroad Investment Behavior

The parameters of equations (15) and (16) describing road and equipment investment were estimated on a cross-section sample of annual data on thirty-two class I railroads for the year 1975.[23] Estimation of the model required data on road and equipment capital stocks, gross and net investment, and desired capital. In constructing capital stocks for each firm, book values of net road and equipment capital as of January 1, 1969 were taken as benchmarks. Gross road and gross equipment investment series for each firm taken from *Moody's Transportation Manual* were expressed in real terms using appropriate price deflators.[24] From the benchmark capital stocks and real-gross-investment figures, real capital stocks and real net investment in both road and equipment for each year from 1969 to 1975 were calculated annual depreciation rates of 0.04691 for road capital and 0.06907 for equipment. These depreciation rates were estimated from Department of Commerce (1974) time series on industry aggregates of fixed railroad structures and railroad equipment.[25]

Desired capital stocks can be known only up to a multiplicative constant, since the output elasticities of each type of capital, α and β, are unknown *a priori*. Recall from (11) that the expressions for desired capital are

$$K^* = K_1^* = \alpha\frac{(p - \pi_1)Q_1}{c}, \tag{17a}$$

$$E^* = E_1^* + E_2^* = \beta\left(\frac{(p - \pi_1)Q_1}{d} + \frac{(p - \pi_2)Q_2}{d}\right). \tag{17b}$$

Since α and β are unknown, the model is actually estimated with changes in K^*/α and E^*/β as independent variables. Thus, instead of using equations (15) and (16) as written, the empirical procedure is to estimate

$$\begin{aligned} I_t = {} & \gamma_0\alpha\left(\Delta\frac{(p - \pi_1)Q_1}{c}\right)_t + \gamma_1\alpha\left(\Delta\frac{(p - \pi_1)Q_1}{c}\right)_{t-1} \\ & - \omega_1 N_{t-1} - \omega_2 N_{t-2} + \delta K_t \end{aligned} \tag{18}$$

and

$$\begin{aligned} J_t = {} & \gamma'_0\beta\left[\Delta\left(\frac{(p - \pi_1)Q_1}{d} + \frac{(p - \pi_2)Q_2}{d}\right)\right]_t \\ & + \gamma'_1\beta\left[\Delta\left(\frac{(p - \pi_1)Q_1}{d} + \frac{(p - \pi_2)Q_2}{d}\right)\right]_{t-1} \\ & - \omega'_1 M_{t-1} + \theta E_t. \end{aligned} \tag{19}$$

As Jorgenson (1966) showed, consistent estimates of production function parameters may be obtained by application of the formulas $\alpha = \Sigma\gamma_i\alpha/\Sigma\omega_i$ and $\beta = \Sigma\gamma'_i\beta/\Sigma\omega'_i$.

To measure K^*/α and E^*/β we can use the previously noted empirical finding of Keeler (1976) and Friedlaender (1971) that the ratio of price to marginal cost on high-density lines is 1.4. Since $p - \pi$ may be interpreted as marginal cost, it follows that $p - \pi_1 = 0.71p$. Since we know from the DOT density data the percentage of each firm's output carried on lines above break-even density we can measure $(p - \pi_1)Q_1$ by the product of 0.71, the firm's freight revenue, and the share of its output carried on lines with density greater than 10 million gross ton-miles per mile of road. For the equipment equation we need to know $p - \pi_2$ as well. On the somewhat dubious assumption that price is set such that profits on high-density lines equal losses on low-density lines for the rail system as a whole, $p - \pi_2 = 2.32$.

The prices of capital services are calculated by Jorgenson's standard procedure of assuming that capital gains are regarded by firms as transitory. We thus assume that the capital service prices for road and equipment are

$$c = (1 - k)q\left[\left(\frac{1 - uv}{1 - u}\right)\delta + \left(\frac{1 - uw}{1 - u}\right)r\right], \tag{20}$$

$$d = (1 - k)s\left[\left(\frac{1 - uv'}{1 - u}\right)\theta + \left(\frac{1 - uw}{1 - u}\right)r'\right]. \tag{21}$$

Values of c and d were computed for each firm using the depreciation rates and investment goods prices already discussed and the statutory rates of corporate income tax and investment tax credit. The parameter v, the proportion of economic depreciation charged against incomes, was calculated separately for road and equipment from each firm's income statement as reported in Moody's. The parameter w, the ratio of interest payments to the total dollar cost of capital, could not be computed separately for road and equipment since interest payments are not disaggregated in the income statements.

An important part of the story is that the cost of capital differs for road and equipment. Thus, r is measured using the weighted average yield of the firm's outstanding general purpose bonds (such as mortgage issues and income debentures), and r' is measured using the weighted average yield of the firm's outstanding equipment trust certificates.[26]

One final complication must be discussed before empirical results can be presented: In the railroad industry, direct investment represents only one means of adjusting a firm's capital stock toward its desired level. The firm may also adjust its stock of rented capital. Whereas leased or rented road capital is only a small fraction of the total capital stock, rented equipment represents a considerable fraction of rolling stock. By dividing rental payments reported on income statements by the appropriate service price of capital, we can impute the stocks of rented equipment and rented road capital. Annual changes in the stock of rented capital (ΔKR and ΔER) are added to the dependent variable (and to lagged net investment) in the estimation of equations (18) and (19).

The empirical model of investment behavior is completed by assuming that equations (18) and (19) each contain an additive error term. If the error term is distributed identically and independently over observations and independently of the changes in desired capital stock, and if the estimated equation represents a stable difference equation in net investment, then the ordinary least-squares estimator is best, asymptotically normal, and also asymptotically efficient if the constraints implied by the non-negativity of the sequence $[\mu_i]$ are satisfied. In the present instance, estimating the model on a cross-section of firms suggests that the assumption of identically distributed errors is unwarranted. When the residuals of the ordinary least-squares estimates are ranked by firm size (as measured by freight revenue), the hypothesis of homoscedasticity was decisively

Table 4.4 Regression results: Investment in road and structures in 1975. The dependent variable is gross investment plus change in rented capital. All variables are measured in thousands of 1969 dollars.

	Estimated Coefficients (Standard Errors in Parentheses)	
Independent Variables	Ordinary Least-Squares	Weighted Least-Squares
$(\Delta K^*/\alpha)_{1975}$	0.00946[a] (0.00195)	0.00873[a] (0.00256)
$(\Delta K^*/\alpha)_{1974}$	−0.00109 (0.00354)	0.00080 (0.00351)
$(N + \Delta KR)_{1974}$	0.45936[a] (0.06676)	0.39983[a] (0.07683)
$(N + \Delta KR)_{1973}$	0.17230[b] (.08740)	0.17213[b] (0.08895)
K_{1975}	0.03256[a] (0.00256)	0.03153[a] (0.00314)
No. of observations	32	32
$\bar{R}^2$	0.9384	—
F	82.26	33.86

a. Significant at the 0.01 level.
b. Significant at the 0.05 level.

rejected by nonparametric Goldfeld-Quandt tests on each of the reported specifications. Glejser-type regressions of the residuals on various transformations of revenue consistently suggested weighting the investment regressions by the square root of revenue.

Ordinary and weighted least-squares (OLS and WLS) estimates of the parameters of the road investment equation are presented in table 4.4. It is obvious by inspection that weighting has very little effect on the parameter estimates. It is also reassuring that the estimated parameters satisfy all the inequality constraints required to ensure the non-negativity of each element in the sequence of delivery lag coefficients. Moreover, the stability of the difference equation in net investment and changes in desired capital is ensured.[27]

The parameters of the gross investment equation can be used to calculate α, the elasticity of output with respect to road capital, and the sequence $[\mu_i]$ describing the form of the lagged response of net investment to changes in desired capital. The OLS and WLS estimates of α are 0.0227 and 0.0223 respectively. Though there is no reason (given the divergence of actual and desired capital stocks as well as the output price distortion) for the estimated value of α to approximate the empirically observed share of payments to road capital in the value of output, estimates in the range of 2 percent do seem distinctly low.[28]

Table 4.5 Form of the lagged response of net road investment.

Lag	Parameter	OLS Estimate	WLS Estimate
Current year	μ_0	0.4165	0.3921
1 year	μ_1	0.1432	0.1926
2 years	μ_2	0.1375	0.1444
3 years	μ_3	0.0878	0.0909
4 years	μ_4	0.0640	0.0612
5 years	μ_5	0.0445	0.0401
6 years	μ_6	0.0315	0.0266
Remainder	$\sum_{i=7}^{\infty} \mu_i$	0.0750	0.0521

The sequence of lag coefficients computed from OLS and WLS estimates is reported in table 4.5. Each element μ_i may be interpreted as the proportionate response of net investment to changes in the level of desired capital i periods earlier. In Jorgenson's view, these coefficients reflect the structure of delivery lags; μ_i may also be interpreted as the proportion of orders placed today that will arrive i periods hence. Hall (1977), however, notes that the latter interpretation is not necessary to justify the former; net investment response may reflect a combination of delivery lags and the placement of orders based on expected future levels of desired capital. In any case, the relatively rapid response of investment to changes in desired capital, wherein nearly 60 percent of the total response is effected within one year, seems quite consistent with Healy's (1954) detailed institutional description of the railroad investment process.

Since the estimated parameters of our road investment equation are to be used to predict the impact of altered regulatory policy, it is especially important to check the estimates for sensitivity to specification error. One simple check is the addition of an intercept term to the model. Since the constant term has no theoretical justification, we should be wary of an intercept estimate significantly different from zero, and we should be troubled to find the other parameters significantly altered. In fact we find that the addition of an intercept term produces no significant alternation in the estimated parameters, nor is the constant itself significantly different from zero.

Another check is to examine the estimated coefficient on the capital stock term. If the model of replacement investment is correctly specified, the estimated coefficient $\hat{\delta}$ should not differ significantly from the rate of depreciation used in calculating the capital stock. In this case, however, both the OLS and WLS estimates of the replacement rate are significantly below the depreciation rate of 0.04691. This finding is not surprising in light of our initial skepticism about the assumption that the entire stock of road capital on low-density lines is replaced.

An alternative view of replacement investment is that only capital on high-density lines is replaced, while capital on LDLs is allowed to depreciate. By imposing the constraint (5′), that gross investment on LDLs is zero, an alternative investment equation may be estimated involving the current value of K_1 (high-density-road capital) on the right-hand side. The difficulty in estimating this form of the model is that K_1 is unknown. The DOT line-segment data permit the computation of high-density-route mileage and output, but the stock of capital associated with high-density lines is not known directly. An upper bound may be placed on K_1 by assuming that the proportion of each firm's road capital invested in high-density lines (K_1/K) equals the proportion of its output carried on HDLs (Q_1/Q). Similarly, it seems plausible that the share of HDLs in each firm's route mileage represents a lower bound on K_1/K.[29]

The alternative investment model was estimated using each of these proxy measures for the high-density capital stock. The results were somewhat surprising in that none of the coefficients reported in table 4.4. was significantly altered. The estimated replacement rate remained 0.031, still significantly below the rate of depreciation used in computing the capital stock. These results suggest either that the assumed rate of depreciation is too high or that there is not full replacement of depreciated capital even on high-density lines. To check the sensitivity of the results to the assumed 0.04691 rate of depreciation, the alternative capital stock series was calculated using 0.031 as the rate of depreciation. The model was then reestimated using each of the alternative assumptions about replacement investment. Even in this form, the estimated replacement rate was consistently below the assumed depreciation rate, but once again none of the other parameters of the model differed significantly from the estimates reported in table 4.4. This failure to adequately model replacement investment is troubling, but the stability of the remaining coefficients across alternative specifications is reassuring in that it suggests that using these parameters in predicting the response to changes in regulatory policy is not unreasonable.

A final check on the validity of my specification was to estimate the model with additional terms reflecting changes in desired capital on low-density lines. In other words, this alternative specification assumes that there is no constraint on exit. If the model is correct in assuming that

Table 4.6 Regression results: Investment in equipment in 1975. The dependent variable is gross investment plus change in rented capital. All variables are measured in thousands of 1969 dollars.

	Estimated Coefficients (Standard Errors in Parentheses)			
	Unconstrained estimates		Constrained estimates	
Independent Variables	OLS	WLS	OLS	WLS
$(\Delta E^*/\beta)_{1975}$	0.02271[a] (0.00763)	0.01843[a] (0.00956)	0.02370	0.01963
$(\Delta E^*/\beta)_{1974}$	−0.02124 (0.01289)	−0.01464 (0.01425)	−0.01011	−0.00965
$(M + \Delta ER)_{1974}$	0.46116[a] (0.08861)	0.51140[a] (0.09733)	0.42638	0.49164
E_{1975}	0.06766[a] (0.00713)	0.07635[a] (0.00979)	0.07153	0.07841
No. of observation	32	32	32	32
$\bar{R}$	0.8483	—	—	—
F	39.13	25.81	—	—

a. Significant at the 0.01 level.

only changes in desired capital on high-density lines affect output, then the parameter estimates reported in table 4.4 should be unaffected, while the coefficients on the added terms should be insignificantly different from zero. This is precisely what happens in the WLS case. In the OLS case the only exception is that $(\Delta K_2^*)_t$ has a significant coefficient with the incorrect (negative) sign.

While our primary interest attaches to road investment, the parameters of the equipment investment function were also estimated by both ordinary and weighted least-squares methods. The estimates, which are presented in the "unconstrained estimates" columns of table 4.6, fail to satisfy one of the inequality constraints necessary to ensure the non-negativity of the distributed lag coefficients $[\mu_i]$. In particular, the constraint $\gamma_1' > \gamma_0'\omega_1'$ is violated. Imposition of this nonlinear constraint with equality required an iterative estimation procedure to produce the maximum likelihood estimates reported in the "constrained estimates" columns of table 4.6.[30] The constrained estimates are quite similar to the unconstrained estimates. The hypothesis that replacement investment is proportional to the current capital stock appears to be supported here, since the estimated $\hat{\theta}$ in the OLS and WLS equations is not significantly different from the 0.06907 rate of depreciation used in calculating the capital stock.

One implication of imposing the constraint $\gamma_1' = \gamma_0'\omega_1'$ is that the underlying sequence of distributed lag coefficients takes the form of

[1,0,...,0]. In other words, the results suggest that equipment investment adjusts fully to changes in desired capital within one year. The data provide further support for this claim. If the rational distributed lag structure is replaced by a more straightforward regression of gross investment on the current capital stock and on current and lagged changes in desired capital, only the coefficients associated with current values of independent variables are statistically significant. The finding of full adjustment within one year is not entirely implausible, since the dependent variable includes changes in the stock of rented equipment. While the delivery lag for new rolling stock sometimes exceeds one year, there is an active rental market. On the other hand, the unusual lag structure found here may be an artifact of using data from 1975, a slack year for equipment investment.

Impact of Abandonment of Low-Density Lines on Railroad Investment

There are two distinct mechanisms by which abandonment of LDLs may stimulate the formation of new capital on the economically viable high-density portions of the rail network. First, since abandonment would eliminate the need for cross-subsidization, rates on HDLs could be permitted to fall toward marginal cost. The lower rates would attract additional traffic and thus raise the level of desired capital.[31] Second, LDL abandonment may lower the cost of capital to rail firms by improving long-run profitability and reducing the risk of bankruptcy. The lower cost of funds would bring forth new capital formation.

These two mechanisms can be seen in the context of the algebraic expression for the firm's desired capital stock:

$$K^* = \frac{\alpha(p - \pi_1)Q_1}{c}.$$

The former mechanism operates through the numerator of this expression. With constant returns to scale on HDLs $p - \pi_1$ (which equals marginal cost) remains constant as both p and π_1 fall, but the fall in p induces an increase in Q_1, which depends on the elasticity of demand. The latter mechanism operates primarily through the denominator as a fall in the cost of capital, r, reduces c, the service price of capital, and thus increases K^*.[32] For convenience we will refer to the former mechanism as the *price effect* of abandonment, and to the latter mechanism as the *capital cost effect*.

To predict the magnitude of the price effect on new road investment, we need to know the extent to which prices will fall on HDLs and the elasticity of rail demand. In fact, the magnitude of the price effect on investment is simply proportional to the product of $\Delta p/p$ and the elasticity of demand. Given the divergence of price and marginal cost estimated by Friedlaender and Keeler (which suggests that $\Delta p/p$ would be approximately 0.3), and given the recent demand estimates of Boyer and Levin (which suggest that average demand elasticities are about 0.3 or 0.4), it seems reasonable to expect that LDL abandonment would produce an increase in output (and hence in the desired HDL capital stock) of approximately 10 percent. Under alternative assumptions about demand elasticity and price response, the predicted change in the capital stock would vary proportionately.

Predicting the magnitude of the effect of capital cost on new investment is a more complicated matter. It remains to establish the point that barriers to the abandonment of LDLs do in fact raise the cost of capital to railroad firms. To do so, it is necessary to formulate and test a simple model of the determinants of the cost of capital. The parameters of the capital-cost equation may then be used to predict the effect of LDL abandonment on capital cost, and the predicted capital cost may then be fed into the investment equation in order to predict the short- and long-run investment response.

My argument about the cost of capital concerns the perceived riskiness of various railroad securities and the associated costs of bankruptcy. Equipment trust certificates are perceived as virtually riskless assets, presumably because rolling stock is easily disposed of in the event of bankruptcy. General-purpose bonds secured by road capital or simply by future income are considerably more risky, since the liquidation value of fixed railroad property is usually well below its going-concern value and since the length and outcome of railroad bankruptcy proceedings are highly uncertain. If this argument is correct, then those factors that raise the probability of railroad bankruptcy ought to increase the cost of raising funds to finance road investment through corporate bonds but have negligible effect on the cost of funds for investment in new equipment.

In a strikingly successful attempt to predict railroad bankruptcies using discriminant analysis,[33] Altman (1973) found measures of long-run profitability and current solvency to be the most important determinants of the probability of bankruptcy. His results motivated the specification of the equations reported in table 4.7, where the percentage of low-density lines in a firm's network (PCTLDL) is used as a proxy for long-run profitability and the ratio of net income before fixed charges to fixed

Table 4.7 Regression results: Cost of railroad capital in 1975.

	Estimated Coefficients (Standard Errors in Parentheses)	
Independent Variables	Bonds[a]	Certificates[b]
Constant	9.4218[c] (0.2414)	9.0010[c] (0.1939)
PCTLDL (= Output on LDLs ÷ Total output) × 100	0.0289[c] (0.0158)	0.0138 (0.0127)
$\text{PCTLDL}^2 \times 100$	0.0226[d] (0.0148)	0.0141 (0.0119)
Assets (in hundred million $)	−0.0083 (0.0117)	−0.0229[c] (0.0094)
Coverage LE 1 (Net income before fixed charges ÷ Fixed charges, if $\leqslant 1$; zero otherwise)	−0.1967[c] (0.0456)	−0.0065 (0.0366)
Coverage GT 1 (Net income before fixed charges ÷ Fixed charges, if > 1; zero otherwise)	−0.0005 (0.0005)	0.0000 (0.0004)
No. of observations	44	44
R^2	0.4699	0.1690

a. In this column the dependent variable is weighted average yield on outstanding long-term corporate bonds. Sample mean = 9.8529.

b. The dependent variable is weighted average yield on outstanding equipment trust certificates. Sample mean = 9.0072.

c. Significant at the 0.05 level.

d. Significant at the 0.01 level.

charges is employed as a measure of solvency. Separate coefficients were estimated for high and low values of the solvency measure, since it was felt that investors would be more responsive to changes in the coverage ratio when a firm was showing losses than otherwise. A firm-size measure was added to the equation to explore the possibility that smaller firms have somewhat greater difficulty in marketing their securities. Finally, the PCTLDL term is squared to account for a nonlinearity that was apparent in a simple plot of the data.

The results seem strongly supportive of my hypotheses. The percentage of low-density lines in a firm's network, which appears from the cross-section profit estimates to be the most important determinant of long-run profitability, has a significant positive impact on the cost of capital to finance road investment. Solvency, another important indicator of the probability of bankruptcy, has a strong impact over the range where firms are failing to cover fixed charges. As expected, neither the density nor the solvency measure has a significant impact on the cost of equipment capital. Firm size, however, does have a small but significant role in reducing the cost of equipment capital. The presence of LDLs significantly raises a firm's cost of road capital, but the magnitude of the effect is rather small. If firms of equal size and solvency are compared, the cost of capital for a firm with 50 percent of its output carried on LDLs will be less than one percentage point (0.88 percent) higher than that for a firm with no LDLs at all.[34]

Table 4.8 shows the predicted effect of LDL abandonment on the cost of road capital for each of the thirty-two firms in the investment sample. The first column shows the fitted value of each firm's corporate bond rate, given its current route structure. The second column indicates the predicted bond rate if PCTLDL were set equal to zero. The final column multiplies the reduction in the bond rate by each firm's stock of road capital to obtain its implicit capital cost savings from abandonment. The average reduction in the bond rate is a little under half a percentage point, but there is good reason to believe this an understatement of the impact of abandonment. Since abandonment would improve cash flow, the coverage ratio would improve, producing a further decrease in the bond rate for those firms currently unable to meet fixed charges out of current income.

The ultimate effect of LDL abandonment on investment in road capital is reported in table 4.9. The predictions are based on the WLS estimates of the parameters of the investment equation, and the OLS predictions are virtually identical. The short-run-price, capital-cost, and combined effects reported in the first three columns represent the first-year impact on investment on the remaining portions of the rail network in the event of LDL abandonment. The final three columns show the long-run response, which is 2.5 times as great if the lags implied by the investment equation are taken into account. The estimates are of course sensitive to the assumption of a 10 percent increase in output, and as noted the full extent of the capital cost effect is likely to be larger than that reported.

The firms in the sample own approximately two-thirds of the road-capital stock in the industry. If they are assumed to be representative, the predicted $106 million in new capital formation produced by LDL abandonment should be inflated to approximately $160 million for the industry as a whole. This represents about one-third of the average annual level of gross road investment undertaken by class I railroads in the United States over the past decade. By this standard, $160 million would seem a hefty influx of new investment. On the other hand, it represents only a little more than 1 percent of the existing stock of road capital, and it is considerably less, for example, than estimates of the cost of upgrading the

Table 4.8 Effect of LDL abandonment on cost of capital.

	Predicted 1975 Bond Rate		Predicted Cost Savings (in millions $)
	With LDL	Without LDL	
Alabama Great Southern	9.84	9.41	0.74
Atchison, Topeka & Santa Fe	9.54	9.23	7.01
Baltimore & Ohio	9.67	9.30	5.13
Burlington Northern	9.56	9.15	13.08
Central of Georgia	9.83	9.40	1.04
Chesapeake & Ohio	9.72	9.30	5.92
Chicago & Eastern Illinois	9.66	9.41	0.37
Chicago & Northwestern	9.96	9.33	2.83
Chicago, Rock Island & Pacific	12.58	11.82	3.31
Cincinnati, New Orleans & Texas	9.84	9.40	0.85
Colorado & Southern	10.04	9.41	0.95
Delaware & Hudson	9.84	9.40	0.44
Detroit & Toledo Shore	9.42	9.42	0.00
Detroit, Toledo & Ironton	11.71	11.17	0.46
Elgin, Joliet & Eastern	9.93	9.39	0.64
Fort Worth & Denver	10.04	9.41	0.47
Grand Trunk Western	10.08	9.75	0.56
Kansas City Southern	10.05	9.40	1.63
Louisville & Nashville	9.60	9.31	3.91
Maine Central	10.06	9.41	0.51
Missouri Pacific	9.78	9.30	6.47
Norfolk & Western	9.55	9.22	7.99
Pittsburgh & Lake Erie	9.40	9.40	0.00
St. Louis–San Francisco	9.85	9.38	2.53
St. Louis–Southwestern	9.53	9.38	0.78
Seaboard Coast Line	9.65	9.26	7.32
Soo Line	10.09	9.39	2.26
Southern Pacific	9.40	9.17	6.73
Southern	9.68	9.24	9.16
Texas & Pacific	9.81	9.39	1.32
Union Pacific	9.52	9.22	7.50
Western Maryland	9.99	9.40	1.15
32 firms	9.91	9.49	103.07

roadbed and track along the Boston-Washington corridor to a standard sufficient to accommodate current best-practice technology in high-speed passenger transport.

Summary and Conclusions

The evidence presented herein lends considerable support to the hypothesis that the burden of excess capacity is a primary source of the unprofitability and the sluggish performance of the U.S. railroad industry. Analysis of recently compiled DOT line-segment data revealed that nearly two-thirds of the nation's class I railroad mileage is below or barely above the break-even level of traffic density at current rail rates, and a substantial fraction of these lines fail to produce revenues sufficient to cover variable costs. Interfirm profitability differences were found to depend upon the proportion of low-density lines in a firm's network, and our profitability model provided strong support for the hypothesis that losses on low-density lines are cross-subsidized by profits on lines of higher density. It was predicted that abandonment of uneconomic lines would increase railroad industry profits by at least $1.4 billion (in 1975 dollars). Although clearly of the same order of magnitude, this figure is somewhat smaller than the savings from abandonment predicted with the cost function estimated by Friedlaender (1971) and Keeler (1974).

The dynamic impact of the burden of excess capacity is somewhat less dramatic but nevertheless significant. Investment in roadway and structures was found to be explained well by a model of investment behavior that specifically incorporated cross-subsidization and a constraint on the exit of LDL capital. The cost of capital used to finance road investment, in contrast to the cost of funds raised with equipment trust certificates, was found to depend on the extent of excess line capacity. LDL abandonment, by lowering the cost of capital and by permitting lower rates on the remaining rail network, would bring forth approximately $160 million in new capital formation, presumably enhancing the growth of productivity since many of the opportunities for technical change in railroad operations are embodied in capital goods. Nevertheless, the $160 million capital shortfall produced by regulatory constraint on exit and cross-subsidization may appear small in contrast to the static losses from excess capacity.

Thus, my results generally support the view that low-density lines constitute a serious impediment to the attainment of static and dynamic efficiency in the railroad industry. The potential improvement in railroad

Table 4.9 Effect of LDL abandonment on new investment in road and structures, 1975. (Figures in millions of 1975 dollars.)

	Short-Run Response to Lower Price	Short-Run Response to Lower Capital Cost	Total Short-Run Increase in Investment	Cumulative Response to Lower Prices	Cumulative Response to Lower Capital Cost	Total Cumulative Increase in Investment
Alabama Great Southern	0.14	0.04	0.18	0.34	0.11	0.47
Atchison, Topeka & Santa Fe	2.50	0.59	3.15	6.38	1.50	8.04
Baltimore & Ohio	1.34	0.33	1.71	3.42	0.85	4.36
Burlington Northern	2.94	0.84	3.87	7.50	2.16	9.88
Central of Georgia	0.33	0.10	0.44	0.84	0.25	1.12
Chesapeake & Ohio	1.24	0.36	1.64	3.16	0.94	4.19
Chicago & Eastern Illinois	0.13	0.02	0.15	0.32	0.05	0.38
Chicago & Northwestern	1.64	0.78	2.50	4.18	1.98	6.37
Chicago, Rock Island & Pacific	0.73	0.30	1.06	1.86	0.76	2.70
Cincinnati, New Orleans & Texas	0.21	0.07	0.28	0.53	0.18	0.72
Colorado & Southern	0.00	0.00	0.00	0.00	0.00	0.00
Delaware & Hudson	0.19	0.06	0.25	0.48	0.15	0.65
Detroit & Toledo Shore	0.03	0.00	0.03	0.07	0.00	0.07
Detroit, Toledo & Ironton	0.16	0.07	0.23	0.42	0.17	0.60
Elgin, Joliet & Eastern	0.30	0.12	0.44	0.77	0.30	1.10
Fort Worth & Denver	0.00	0.00	0.00	0.00	0.00	0.00
Grand Trunk Western	0.49	0.11	0.61	1.23	0.27	1.56
Kansas City Southern	0.43	0.20	0.65	1.10	0.51	1.66
Louisville & Nashville	2.40	0.48	2.93	6.13	1.21	7.47
Maine Central	0.00	0.00	0.00	0.01	0.00	0.01
Missouri Pacific	1.25	0.39	1.67	3.18	0.99	4.27
Norfolk & Western	2.35	0.56	2.97	6.00	1.42	7.57

Pittsburgh & Lake Erie	0.22	0.00	0.22	0.56	0.00	0.56
St. Louis–San Francisco	1.01	0.32	1.36	2.57	0.83	3.48
St. Louis–Southwestern	0.54	0.06	0.60	1.38	0.14	1.54
Seaboard Coast Line	2.54	0.68	3.29	6.47	1.74	8.39
Soo Line	0.26	0.13	0.40	0.67	0.31	1.02
Southern Pacific	3.01	0.47	3.53	7.66	1.20	8.99
Southern	1.19	0.36	1.59	3.03	0.93	4.05
Texas & Pacific	0.32	0.09	0.42	0.81	0.22	1.06
Union Pacific	4.32	0.96	5.37	11.01	2.43	13.69
Western Maryland	0.13	0.06	0.19	0.34	0.14	0.50
32 firms	32.34	8.55	41.76	82.48	21.76	106.46

performance strongly recommends lifting the exit constraints on private, for-profit railroad firms. If for reasons of distributional equity some form of subsidy to affected shippers and local communities is desired, a variety of solutions appears less costly than requiring railroad firms to pay to the subsidy out of their meager profits. The Railroad Revitalization and Regulatory Reform Act of 1976 has already lain groundwork to facilitate the purchase of abandoned lines by state and/or local government with generous federal subsidies. While this form of subsidization may be superior to requiring cross-subsidization it would behoove legislators and rail planners to recognize that subsidizing an inefficient transport mode (low-density rail movements) is in many (perhaps most) cases distinctly inferior on efficiency grounds to scrapping the line and subsidizing shippers all or part of the difference between truck or intermodal rates and rail rates.

One puzzle remains to be explained. Given the burden imposed on railroads by low-density lines, one might expect that there would be persistent efforts to abandon large portions of the rail network, and that such efforts would be repeatedly rebuffed by the Interstate Commerce Commission. Instead, over the past decade an average of considerably less than 1 percent per year of the nation's route mileage has been proposed for abandonment (aside from the petitions of firms already in bankruptcy). Moreover, from 1968 through 1976, 97.5 percent of the abandonment petitions acted upon by the ICC were approved, with the denials involving only 3.1 percent of the route mileage proposed for abandonment.[36] On first consideration these figures suggest that regulatory barriers to exit are minimal, and that the railroad themselves are to blame for the persistence of excess capacity.

The incentives for managers to maintain the size of their firms may partially explain the reluctance of railroads to seek abandonment. This explanation has some plausibility for firms composed entirely or in very large part of low-density lines, where abandonment would actually threaten the jobs of top management; it is a less compelling explanation for the behavior of the roughly thirty firms that carry most of the nation's rail freight. Despite the possible importance of managerial incentives to keep LDLs in operation, there are several reasons for supposing that regulatory barriers to exit are considerably more formidable than the data on abandonment petitions suggest.

First, abandonment proceedings are lengthy and costly, especially when the petition to abandon is contested by shippers, local communities, labor unions, and state governments. In a detailed study, Sloss et al. (1974)

found that 63 percent of all abandonment petitions filed between January 1968 and December 1970 were approved within six months, 78 percent within one year, and 96.5 percent within two years. The picture is quite different, however, when one considers contested cases in which the decision of the hearing officer or administrative law judge was appealed to the Finance Division of the Commission. Of the contested cases between 1970 and 1976, 56.5 percent required more than two years from initial filing to final decision and 34.8 percent required more than three years; only 21.7 percent were resolved within one year, and the average time from filing to resolution was 28.7 months.[37] Second, in the face of strong opposition to abandonment, the probability of a successful petition diminishes. Of the 23 cases carried to final appeal between 1970 and 1976, four petitions were wholly denied and two others denied in part. Third, for a period after 1971 the ICC held that opponents of abandonment bear the burden of proof in cases where it is clearly established that the annual volume of rail traffic is less than 34 carloads per mile. Virtually all proposed abandonments in recent years have met this standard, but the 34-carload standard covers only about 10–15 percent of the nation's remaining route mileage—perhaps no more than one-quarter of the total route mileage that would be uneconomic at rates equal to long-run marginal cost. Finally, in recent years only firms in or near bankruptcy have attempted to abandon large portions of their route network, which is not surprising in view of the ICC's explicit position that the weakness of a carrier's overall financial position weights in its favor in abandonment cases. These attempts, especially that of the Penn Central to abandon one-quarter of its total mileage, leave little doubt that railroad firms are aware of the unprofitability of low-density lines. Nevertheless, bankruptcy only improves the probability of success before the ICC; massive abandonment in the northeast ultimately required legislation.

The foregoing considerations suggest that railroad firms are willing to undertake the costly and time-consuming process of piecemeal abandonment only when the probability of success is high. In view of the costs of litigation (recently increased by the court-imposed requirement that environmental impact be considered in each abandonment case), the incentive to abandon for a still-solvent firm is probably small unless the 34-carload standard is satisfied and opposition is expected to be minimal. The barriers to abandonment are also doubtless increased by the piecemeal nature of the process. The ICC decides cases on a line-by-line basis, and the potential savings from abandoning a given 10- or 20-mile branch line may appear small when weighed against the fixed costs of litigation and the uncertainty of opposition. Yet the benefits from abandoning the sum of many small line segments may be substantial.[38] A simplified regulatory procedure, or, better still, freedom of exit accompanied by transitional subsidies to ease adverse distributional impact, would be likely to improve the performance of the railroad industry significantly. The 4-R Act, in its attempt to speed and simplify the regulatory process when abandonment proposals meet no opposition and in its recognition that direct subsidy is superior to cross-subsidy, has taken at least a few small steps in the right direction.

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Notes

1. Source: First National City Bank *Monthly Letter* (various issues).

2. A strong argument in support of this position is put forth in the report of the Task Force on Railroad Productivity (1973).

3. The issue that has received most attention in the controversy over rate regulation is that shipments of different commodities over comparable distances are not priced comparably despite comparable costs.

4. Friedlaender concludes that 26 percent of rail route mileage was redundant in 1961–1963. Her lower estimate may be in part a consequence of her use of an earlier sample period, but one suspects it is primarily attributable to methodological peculiarities. As Nelson (1971) pointed out, Friedlaender's estimate of the extent of excess capacity in the rail system as a whole is rendered somewhat suspect by her implausible finding that eastern railroads such as the Pennsylvania, the New York Central, Central of New Jersey, Lehigh Valley, and the Maine Central had a deficiency rather than an excess of line capacity in 1961–1963.

5. Friedlaender does not report sufficient information to permit derivation of the relation between unit cost and density implied by her cost and production function estimates.

6. Throughout this article density is measured by gross ton-miles per mile of road. This measure is distinctly inferior to revenue ton-miles per mile of road, since gross ton-miles includes the weight of engines and freight cars. The use of gross ton-miles was unavoidable since it was the measure used in the DOT line-segment data on traffic density discussed below.

7. Strictly, Keeler's average-cost curve becomes flat, but Harris's asymptotically approaches a lower bound at a level that is approximately equal to the flat range of Keeler's function.

8. As Harris aptly notes, there is considerable confusion in the literature between economies of scale and economies of density. Economies of scale are present when—allowing for variation in all inputs, including route mileage—increased output leads to falling unit costs. Economies of density are present when unit costs fall as output increases, with route mileage held constant.

9. Friedlaender and Keeler are in precise agreement about the relation between actual average rail rates and estimated long-run marginal costs (that is, average costs at efficient density). Friedlaender found that the ratio of estimated long-run marginal costs in long-run equilibrium to observed average costs was 0.736 in 1969. If this ratio has remained constant over recent years, it follows that the ratio of observed rates to long-run marginal cost has varied within the range 1.385–1.423 since 1969. Keeler (1976) found the ratio to be 1.42 in 1969.

10. The data are reported in tabular form in *Final Standards, Classification and Designation of Lines of Class I Railroads in the United States*, Volume II. A computer tape containing this information and others indicating the mileage of each line segment were supplied to the author by the Federal Railroad Administration.

11. The density categories are as follow:

Density Class	Gross Ton-Miles per Mile of Road
1	0–1
2	1–5
3	5–10
4	10–20
5	20–30
6	>30

12. Data on the first four independent variables listed in table 4.2 are derived from the DOT line-segment density data presented in table 4.1. Data on the dependent variable and the remaining independent variables were taken from *Moody's Transportation Manual 1976*. The eastern firms under the temporary jurisdiction of the U.S. Railway Association were excluded from the sample, and a number of other firms had to be excluded on grounds of insufficient data.

13. When mean and mean^2 are dropped from the regression, the significance of the PCTLDL terms drops to the 0.10 level but the estimated parameters are virtually unchanged.

14. One might reasonably wonder why an economist trained and employed at Yale would choose to employ a neoclassical investment function instead of the Keynes-Tobin alternative. Rest assured that I am most impressed by the suitability of the so-called "q" theory for my purposes, and indeed I had intented to compare the performance of the two theories when they are modified to take account of the special characteristics of the railroad industry. Unfortunately, the data requirements of the q theory (especially the need to measure the market value of each firm's securities) proved insurmountable, since the equity of many railroads is held either by other railroads or by diversified holding companies.

15. See, for example, Tobin 1967, Gould 1969, and Brainard 1977.

16. The independence of the production functions for output on high- and low-density lines is assumed primarily to simplify analysis. While it is not difficult to imagine interdependence in production, it is not entirely clear how it should be modeled.

17. It should perhaps be noted that, while time notation is supressed, each firm's demand curves may be shifting over time, and the regulated price may also vary over time.

18. When constraint (5′) operates, replacement is simply proportional to the stock of high-density-road capital, not to the entire stock of road capital; that is, $R'_t = (\delta K_1)_t$.

19. Under the alternative constraint (5′), depreciation on low-density-road capital, $(\delta K_2)_t$, must be subtracted from the right-hand side of (13).

20. I cannot resist commenting on certain defects of the Jorgenson model. The assumed behavior is peculiarly myopic. The firm acts as if it is entirely ignorant of delivery lags; it is always adjusting its stock of outstanding *orders* to its current level of desired capital. But if the firm knew anything about delivery lags, even probabilistically, one might expect it to place its orders such that expected deliveries this period (if some orders are filled immediately) or next period (if that is the minimum delivery lag), plus the actual capital stock, would equal the actual or expected level of desired capital. Such a formulation leads to an estimating equation quite similar to Jorgenson's, but with a different interpretation of the parameters. A second peculiarity is that delivery lags exist only on new investment, not on replaced capital.

21. Jorgenson (1966) showed that the sequence $[\mu_i]$ may be approximated to any desired degree of accuracy with a finite number of parameters, ω_i and γ_i. No clear criterion has been established to determine the preferred number of terms in each sequence of parameters. I followed Jorgenson's procedure of experimenting with a wide variety of specifications and choosing that which minimized the adjusted standard error of the regression. Very little seems to have been lost by limiting the sequences ω_i and γ_i to three and two terms respectively; in none of the tested specifications were any higher-order terms statistically significant.

22. In the model of equipment investment the sequence ω_i is limited to two terms ($\omega_0 = 1$ and ω_1) by application of the criterion discussed in note 21.

23. Of the 58 class I line haul railroads in 1975, I excluded the eight bankrupt northeastern roads involved in reorganization on the grounds that the assumed profit-maximizing behavior was implausible. Auto-Train and the Long Island Railroad were also excluded on grounds of noncomparability with ordinary freight-hauling railroads. Sixteen other firms were excluded on grounds of deficient data.

24. The equipment series was deflated by the wholesale price index for railroad equipment. There is no comparable WPI deflator for railroad structures, although the ICC developed an index for road investment that runs from 1914 to 1966. The ICC index has not been updated, but it turns out to be extraordinarily highly correlated ($r = 0.993$) in the period prior to 1966 with the index of purchased materials and supplies (excluding fuel) developed by the Association of American Railroads. The AAR index was therefore used as a deflator for road investment.

25. The Commerce Department series on capital stocks and annual depreciation was constructed using a modified perpetual-inventory method, assuming a distribution of service lifetimes based on IRS Bulletin F estimates, an initial benchmark, and an industry series on gross investment. The Commerce Department annual depreciation figures were regressed on the current capital stock, assuming second-order serial correlation. Experimentation showed that estimated proportionate depreciation rates since World War II were significantly higher than before World War II, so that the rates used in this study were derived from regressions run over the period 1947–1972.

26. Computing the cost of capital was a laborious task. Price data reported by Moody's for many general-purpose bond issues allowed yields to be computed directly. Price data were often unavailable for some of a firm's rated bond issues; in such cases Moody's average yield on railroad bonds of identical rating was used as a proxy. Unrated bond issues were ignored, but they were always a small share of outstanding debt. The directly computed or imputed yield of each issue was then weighted by its share of the firm's outstanding general-purpose debt, and the firm's cost of road capital was obtained by summing over all outstanding rated issues.

For equipment obligations, price data were unavailable. It was therefore necessary to impute the Moody's average yield for the appropriate rating category to each outstanding equipment trust certificate, and compute a weighted average yield for each firm. For some of the few firms in the sample that had no equipment trust certificates, Moody's reported data on the terms of conditional sales agreements which permitted assignment of the firm to a Moody's rating class. A small number of the firms had either no reported equipment obligations or no general-purpose bonds. For these firms, the missing cost of capital was imputed by assuming that the firm's differential between equipment and road capital costs were equivalent to the mean differential of firms issuing both types of obligations.

27. The constraints on γ_i and ω_i, as well as the stability condition, are given in Jorgenson 1966.

28. Implausibly low estimates of output elasticity have been reported in every one of Jorgenson's papers on investment behavior. Jorgenson and Stephenson 1967 suggests that measurement error may be responsible, but there is no reason to believe that measurement error would lead to a clear direction of bias. To my knowledge, no convincing explanation has yet been offered for the apparent downward bias of the output elasticity.

29. In other words, I am asserting that $M_1/M < K_1/K < Q_1/Q$. This seems plausible since one clearly expects K_1/M_1 (capital per route mile on HDLs) to exceed capital per mile on LDLs, because improvements are more likely to have been made on these portions of the route system. On the other hand, the capital-output ratio on HDLs will be lower than that on LDLs if there is excess capacity on LDLs.

30. Constrained estimates were obtained as follows. The initial regression equation is of the form

$$J_t = \gamma_0'\beta(\Delta E^*/\beta)_t + \gamma_1'\beta(\Delta E^*/\beta)_{t-1} - \omega_1' M_{t-1} + \theta E_t + \varepsilon_t.$$

Imposing the constraint $\gamma_1' = \gamma_0'\omega_1'$ and rearranging terms yields

$$J_t - \gamma_0'\beta(\Delta E^*/\beta)_t = \omega_1'[\gamma_0'\beta(\Delta E^*/\beta)_{t-1} - M_{t-1}] + \theta E_t + \varepsilon_t.$$

For any chosen value of $\gamma_0'\beta$, ω_1' and θ may thus be estimated by least squares. The value of $\gamma_0'\beta$ that minimizes the sum of squared residuals produces maximum-likelihood estimates of the parameters given the constraint $\gamma_1' = \gamma_0'\omega_1'$.

31. One objection to this line of argument is that the traffic gains from lower rates might be more than offset by the loss of HDL traffic that originated on LDLs. While it is undoubtedly true that some (perhaps a large portion) of LDL traffic is fed on to higher-density routes, it is easy to exaggerate the importance of LDLs as "feeder" lines. In a study of LDLs outside the northeast, Matzzie et al. (1977) showed that 55 percent of carloads originating on LDLs contained agricultural products. Since these products are typically transported by truck to a nearby rail terminal, it is unlikely this traffic would be lost to the railroads if the trucks were required to go a bit farther to a rail line of efficient density. Indeed, intermodal transport is probably the least costly alternative for most of the other commodities originating on LDLs. Moreover, a significant fraction of the potential losses of feeder traffic is likely to be prevented by state or local takeover of branch lines or by subsidy to private short-line operators. In sum, the traffic losses on the remainder of the rail network resulting from LDL abandonment are likely to be small.

32. A reduction in the cost of capital also reduces long-run marginal cost $(p - \pi_1)$, partially offsetting the effect of the declining denominator. It is easily shown that the decrease in the numerator is exactly α times the decrease in the denominator, and since $\alpha < 1$ (in this case it is about 0.02), an increase in K^* is ensured.

33. On the basis of research completed in 1971, Altman proposed ten class I railroads as "probable bankrupts." Five of the ten—Ann Arbor, Erie Lackawanna, Milwaukee, Reading, and Rock Island—subsequently filed bankruptcy petitions. Several of the remaining five are still on or near the brink.

34. Several alternatives to the model estimated in table 4.7 were tested. When a direct measure of current profitability, the rate of return on total assets, was added to the first equation, it was insignificant and PCTLDL remained significant. When the rate of return was substituted for PCTLDL, it was statistically significant at the 0.10 level, but the R^2 dropped substantially. I interpret these results as supporting the rather plausible view that PCTLDL is a better indicator of long-run expected profitability than current level of profits.

35. The cost-of-capital equations were estimated from a larger sample than the investment equations, because capital cost data were available for some firms that reported insufficient investment, depreciation, or tax data to be used in the investment sample.

36. Abandonment data are taken from ICC *Annual Reports* (1969–1976). The percentages cited omit from consideration the roughly 20 percent of petitions filed that were dismissed without decision over the same period. Dismissals are usually based on technical grounds unrelated to the merits of the case.

37. These figures were computed from a survey of all abandonment decisions taken by the full commission or its finance division as reported in the ICC *Reports* (volumes 338–346). I am indebted to Alice P. White for assistance in compiling these data.

38. This line of argument places considerable emphasis on litigation costs. While there is no solid evidence on the magnitude of these costs, one Conrail official reported that the costs in terms of legal fees and especially in terms of the diversion of corporate personnel were indeed substantial. In particular, contested cases involve considerable diversion of effort by top management to the appeasement of politicians and community and shipper groups. These direct and indirect costs probably measure in the tens of thousands of dollars for a relatively minor case. To see that this is not a trivial impediment to seeking abandonment, consider that the average abandonment petition over the past decade involved a line segment of 17 miles. If litigation costs of such petitions were \$50,000–\$100,000, the cost of piecemeal abandonment all LDLs in the system in 17-mile segments would be \$350 million–\$700 million.

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Comment

John J. McGowan

According to Levin's analysis, eliminating regulatory impediments to abandonment of low-density lines might increase railroad profits by about $1.4 billion per year. He suggests that, after such abandonment, rates on high-density lines would fall toward marginal cost because those rates would no longer need to generate the sufficient revenues to subsidize the low-density lines. Lower rates would lead to an increase in output and the desired stock of capital on high-density lines, and, in addition, abandonment would reduce the supply price of capital to railroads. The combined effect of lower rates and lower capital cost would lead to an increase in investment (in the long run) of about 106 million 1975 dollars per year for the railroads in his sample.

Despite the high quality of Levin's economic analysis and econometric work, I remain troubled by some of his conclusions. To begin with, if the railroads really could increase profits by $1.4 billion per year, thus more than doubling their rate of return on total investment, I wonder why they are not actively pursuing abandonment to the fullest extent. Levin's explanation is that the transaction cost of pursuing abandonment proceedings at the ICC and the low probability of success therein reduce the expected return from pursuing abandonment to almost zero. He also suggests that management, in its own interest, may attach some utility to size itself and so does not pursue increased profitability through abandonment with the vigor that profit maximization might imply. He may be right about management's tendency to pursue objectives other than maximum profit, but if so should he not reconsider the theoretical basis of the investment equations he estimates? He may also be right about the expected returns from undertaking abandonment proceedings, but I find his arguments far from persuasive.

First of all, although litigation is expensive, $1.4 billion will buy an awful lot of it. Hearsay suggests that the services of first-rate law firms can be purchased at rates approximating $100 per person-hour. If expenses run at approximately 25 percent of professional services billings, $1.4 billion would buy more than 5,000 person-years of high-quality legal services. Even allowing for some expert economic testimony, the potential annual savings would clearly purchase a massive litigation effort. Of course, this is an oversimplified analysis. One must consider the probability of success in estimating what legal effort is warranted by the estimated savings of $1.4 billion per year. However, one must also consider that the probability of success may be an increasing function of the legal effort, and also that the present value of the savings from abandonment is the relevant benefit measure, not the annual savings. Perhaps more important, one should consider the technology for achieving abandonment approval. Levin's discussion assumes that abandonment must be pursued within the existing ICC procedures for achieving it, and that legal expenses are incurred in that context. However, if the benefits through abandonment are as large as he estimates, would not firms explore alternative technologies for achieving abandonment, such as bypassing ICC procedures through promotion of superseding legislation?

If Levin's explanation for railroads' lack of vigor in pursuing abandonments is faulty, is there any reason to suspect that his estimates are overly optimistic? I am not enough of a railroad buff to offer solid evidence on this score, but one possibility is that Levin's approach assumes that profits on high-density lines would be unaffected by abandoning low-density lines. It seems at least conceivable that, by abandoning low-density lines, railroads would lose business over high-density lines to the competing intra- or intermodal competitors, who would then originate or terminate some shipments.

Levin suggests that his $1.4 billion figure may be an overestimate because regulators might take back some of the increased profits by forcing rate reductions on the high-density lines. Casual inspection of the data presented by Levin suggests that this might not be a likely explanation for the failure of railroads to pursue abandonments more vigorously. Table 4.3 indicates that after abandonment of low-density lines the firms in his sample would have an average rate of return on assets of 8.85 percent, while according to table 4.8 the cost of capital for firms in his sample after low-density-line abandonment would have a cost of capital on the average of 9.49 percent. Since it seems unlikely that regulation would force rate reductions when the rate of return on assets is below the cost of capital, it does not seem from Levin's data that, on average, the fear of regulation-enforced rate reductions reduces the prospective benefits from abandoning low-density lines. Closer inspection of tables 4.3 and 4.8 indicates that twenty-six railroads appear in both tables. For thirteen of them, the rate of return after abandoning low-density lines as shown in table 4.3 would still be below their cost of capital after abandoning low-density lines, which appears in table 4.8.

(They are the following: Atcheson, Topeka & Santa Fe; Baltimore & Ohio; Burlington Northern; Chicago & East Illinois; Chicago, Rock Island & Pacific; Cincinnati, New Orleans & Texas; Detroit & Toledo Shore; Louisville & Nashville; Missouri Pacific; Norfolk & Western; Southern Pacific; Texas & Pacific; and Union Pacific.) According to the last column of table 4.3, these railroads account for $793 million of Levin's estimated $1.4 billion of the increased profits due to low-density-line abandonment. Accepting Levin's overall estimate, it appears that railroad profits could be increased by about at least $800 million through abandonment of low-density lines.

Would there in fact be any incentive for the abandoning railroads to increase investment on their high-density lines? In general, Levin estimates that investment will increase both because rates will fall and because the cost of capital will fall as a result of abandonment of low-density lines. However, if we recall that the thirteen railroads that account for the $800 million increase in profit due to abandonment would, even after abandonment, be earning rates of return on capital lower than their costs of capital, I fail to see why they would have any incentive to reduce prices. Thus, I do not believe that the approximately $55 million cumulative increase in annual investment that Levin estimates would be undertaken by these railroads because of lower prices would ever materialize. In sum, it appears that even if we accept Levin's estimate of the potential for increasing profits through abandonment of low-density lines, the effect of abandonment on investment would be somewhat less than one-half of the approximately $106 million per year he estimates in the long run.

Comment

Almarin Phillips

Professor Levin has provided a stimulating and provocative paper. His attack on the conventional wisdom regarding the source of railroad problems is, indeed, quite persuasive. The argument moves smoothly among facts, theory, and econometrics—so smoothly that just a few critical comments seem in order.

It is not clear, as Levin implies in his discussion and assumes explicitly in equation (1) of his model, that value-of-service pricing, price discrimination, and cross-subsidization are so bad. One would suppose that, in general, the low-density lines have higher demand elasticities than do the high-density lines. It is quite clear that few railroads are currently pressing on a rate-of-return constraint. This brings into question the impact of the "principle" that "shipments of comparable goods over comparable distances should be comparably priced."

If one takes at all seriously the theory of Ramsey-type pricing, there are reasons to suspect that this nondiscrimination regulatory constraint is, along with abandonment, an important source of railroads' problems. In the context of general second-best theory—and with some important limitations involving externalities, cross-elasticities, and a defined set of goods whose prices are regulated—W. J. Baumol and D. P. Bradford have shown that an inverse elasticity rule applies ("Optimal Departures from Marginal Cost Pricing," *American Economic Review* 60 [1970]: 265–283; see also Baumol, "Quasi-Optimality: The Welfare Price of a Nondiscriminatory Price System," in *Pricing in Regulated Industries: Theory and Application*, ed. J. T. Wenders [Denver: Mountain States Telephone and Telegraph Co., 1977]). Until the rate-of-return constraint is satisfied, outputs of the several goods—in this case, transportation of goods among origin and destination pairs—should be reduced proportionately from their respective price-equals-marginal-cost ($P = MC$) points. Prices charged would then vary inversely with demand elasticities. If (as seems to be the case with railroads) the return constraint does not become binding up to the point of profit maximization, we are left with a second-best welfare condition with marginal cost equal to marginal revenue ($MC = MR$) across the goods in question.

Hesitation in the practical application of this theory is obviously necessary, but so is hesitation in pursuing a free abandonment policy when nondiscriminatory pricing is an operational constraint. Whether it is called cross-subsidization or not, there may be genuine welfare reasons for charging different rates for the same goods over comparable distances.

If this is correct, Levin's conclusions about the differences in investment with and without abandonment are questionable. Ramsey-type price discrimination—keeping those lines where $P \geq MC$, even though there is a bookkeeping loss—would improve carrier rates of return and foster the desired capital investment. Lines which might be abandoned with a full and complete linear pricing system might not be abandoned with linear pricing by commodity within origin and destination pairs but price discrimination by commodity across origin and destination pairs.

A related issue concerns sequential abandonments of LDLs and their system effects. If a line between A and B is abandoned, it will reduce traffic between A and C, D, ... Similarly, it will reduce traffic between B and C, D, ... Thus, the first abandonment increases the likelihood that, say, a line between A and C, or A and D, or B and C, or B and D, or indirectly between C and D, etc., will qualify for abandonment in the future. It is an interdependent network system, no single component of which can be judged in isolation. With interdependence, the condition that $P \geq MC$ on each line is no longer necessary for profit maximization, constrained or unconstrained.

None of these comments suggest that Levin's basic conclusion, that excess capacity is a primary source of unprofitability, is wholly erroneous. They do suggest that care should be exercised before fully free abandonment is encouraged. The carriers may, in fact, not have pursued persistent efforts for abandonment for just these reasons, rather than those Levin somewhat tortuously proposes. Managers may recognize varying elasticities and the interdependence of their systems. Rather than pressing for wholesale abandonments, they might rationally seek instead to relieve their problems through more discriminatory (and, perhaps, more welfare-inducing) pricing structures. Neither the theory nor the econometrics of the paper covers these alternatives.