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POST-STAGGERS PRODUCTIVITY FOR CLASS I RAILROADS

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16. Abstract

The goal of this research is to estimate productivity gains and cost savings in the railroad industry since 1978. Further, prior work was extended by separating output and size variables into measures of high and low density output and miles of track. For purposes of comparison, a translog cost function employing traditional variables was also estimated. This work also uses a more complete and more up-to-date data set than previous analyses. Three conclusions can be drawn. First, deregulation has resulted in a dramatic downward shift in the average variable cost function. By 1989, the effects of deregulation had lowered costs between 31 to 45 percent. Second, productivity gains increased dramatically with deregulation, to annual cost reductions ranging from about 5 to 7 percent. However, since 1987 these values have fallen and are currently about the same levels as in 1978 (about 1 percent). Finally, the results of the two cost specifications are not entirely consistent. The level of cost savings from deregulation is more than 20 percent higher for the traditional rail cost model. Further, the multiple output cost model suggests that economies of density have largely been realized. This suggests that additional work needs to be done to reconcile and understand these differences.

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PREFACE

Since 1980, the class I rail industry has been restructured as the carriers adapted and changed in response to new regulatory freedoms. Ultimately, these changes are reflected in the cost structure and in productivity gains. The goal of this research is to estimate productivity gains and cost savings in the railroad industry since 1978. Further, prior work was extended by separating output and size variables into measures of high and low density output and miles of track. For purposes of comparision, a translog cost function employing traditional variables was also estimated. This work also uses a more complete and more up-to-date data set than previous analyses. Three conclusions can be drawn.

First, deregulation has resulted in a dramatic downward shift in the average variable cost function. By 1989, the effects of deregulation had lowered costs between 31 to 45 percent. Second, productivity gains increased dramatically with deregulation, to annual cost reductions ranging from about 5 to 7 percent. However, since 1987 these values have fallen and are currently about the same levels as in 1978 (about 1 percent). Finally, the results of the two cost specifications are not entirely consistent. The level of cost savings from deregulation is more than 20 percent higher for the traditional rail cost model. Further, the multiple output cost model suggests that economies of density have largely been realized. This suggests that additional work needs to be done to reconcile and understand these differences.

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I. PROBLEM STATEMENT

Culminating with the Staggers Rail Act of 1980, rail deregulation led to increased rail pricing flexibility and liberalized abandonment and merger procedures. The premise for this significant change in rail policy was that the rail industry is no longer a monopoly requiring extensive ICC regulation. Rather, "most transportation is competitive and much ICC regulation has had an adverse effect on economic efficiency..." (Keeler, 1983). Keeler adds that ICC regulation forced "the railroad industry to accept a return on investment far below the level adequate to maintain financial viability and finance future growth." Thus, Staggers provided the means for improving the financial health of the rail industry.

Deregulation has both direct and indirect effects upon rail costs. A direct effect is defined to be a shift in the transformation function. Regulation thwarted investment by creating barriers to innovation. For example, ICC "power to control railroad rates profoundly influenced the pace and direction of technological change with respect to rolling stock" (Gellman, 1986). Regulation also stymied normal management prerogatives for strategic issues such as abandonment, mergers, labor relations, and financial decisions. "The long-term effect of such intensive regulatory control has been to

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discourage innovative progress and to blunt management incentives and initiative" (McCabe, 1977).

Deregulation also affected rail productivity through its interaction with right-hand-side variables. The indirect effects of deregulation are measured through its effect on arguments of the transformation function. There are many examples. Since deregulation, railroads have altered their traffic mix by increasing the proportion of high density traffic, the proportion of unit train traffic, and reduced the degree that shipments are interlined with other carriers. Railroads have also abandoned or sold more than 38,000 miles of track since 1980. Finally, the average length of haul per shipment has increased since 1980.. Each of these actions is considered to have a reducing effect on average costs. However, there is little research available documenting the degree that these factors have reduced costs since deregulation.

A. Research Objectives

The goal of this research is to estimate productivity gains and cost savings in the railroad industry since 1978. In estimating productivity gains, both the impact of deregulation on productivity and related cost savings from deregulation are considered. The critical difference between a productivity gain and a related cost saving is the manner through which the effect enters the cost function. A productivity effect is the direct influence of regulation on the transformation function. A cost savings effect is the influence of regulation operating through the arguments of the cost function. A two-stage process is used to make this distinction. First, a cost minimization framework that nests input choices under a regulated and a partially regulated state is developed and estimated. Then the explicit technological change and regulation effects in the railroad industry are made.

B. Report Organization

The remainder of the report is organized as follows. A brief literature review is found in the Section II. The conceptual framework is presented in the following section. The empirical model and variables and the data sources are detailed Sections IV and V, respectively. The empirical results are presented in Section VI. Finally, the report ends with a summary and conclusions in Section VII.

II. PREVIOUS RESEARCH

Numerous studies have considered the effects of deregulation on rates and service quality. A representative view is "the Staggers Act and associated regulatory reform actions have led to more efficient rail pricing and service and have improved the financial status of railroads" (McDonald, 1989). Grimm and Smith (1986) found that shippers perceive a large improvement in rates and service quality. Lower rail costs likely reflect most of the advantages of deregulation. However, there has only been limited analysis about the effects of deregulation on costs and productivity to date.

Historically several studies have evaluated productivity in the railroad industry. Productivity provides an important measure of industry performance. Three types of productivity measures (single-factor, total-factor, and total productivity) have been used to measure rail productivity (Levine, 1985). The different measures vary in their complexity and usages. In evaluating policy and technological advance, accurate measures of productivity are critical.

Single-factor analysis is the most common type of rail productivity measure. It is popular because it is easy to estimate and interpret. However, the results are suspect because single-factor analysis, such as ton-miles per labor hour, fails to consider substitution effects. In addition, single-factor measures of productivity may vary widely, depending upon the output and input variables. Further, as pointed out by Meyer and Morton (1975) and Caves, Christensen, and Swanson (1980, 1981), traditional measures of productivity carry along several assumptions that may not be tenable in the railroad industry. They include: 1) constant returns 2) marginal cost pricing, 3) optimal factor usage, 4) predetermined substitution and transformation elasticities, 5) input homogeneity and/or homotheticity, and 6) Hick's neutral technological change.

Caves, Christensen, and Swanson's model of total productivity overcomes many of the problems arising from the traditional measures and allows measures of total productivity to be defined. Their model determines whether increases in productivity arise from changes in output variables, input variables, or technological characteristics. They used the model to estimate rail productivity growth between 1.5 and 2.0 percent over the period 1951-1974. Their results suggest that productivity growth was much lower than previously estimated.

Extensive data requirements and estimation complexity have limited the use of such models. Work by Tretheway and Waters (1991) updating Caves, Christensen, and Swanson's work on productivity provides estimates for productivity growth between 1982 and 1987. Using similar input and output indices, they define a total factor productivity measure, finding annual productivity gains between 2.9 and 5.1 percent.

Productivity appears to be higher "for the post-Staggers' years than experienced during the regulated era, but this cannot be stated with certainty" (Tretheway and Waters, 1991). Unlike the earlier work, Tretheway and Water's estimates of total factor productivity do not distinguish between gains resulting from scale or density economies and gains from shifts in productive efficiency. Further, given improvements in the output measures, the results are not directly comparable.

A related of study of interest is Ying's (1990) analysis of inefficiencies in the trucking industry. Ying's approach is important to this work for two reasons. First, he develops a model that distinguishes between direct and indirect effects of deregulation. Direct effects are those directly arising from deregulation. The indirect effects are those arising through the interactions of the deregulation variable with the arguments of the right-hand-side. Our approach and results for rail are comparable to Ying's trucking work.

Much of deregulation impacts costs and preferred measures of productivity require estimates of a cost function. The railroad industry has provided a recurrent subject for economic cost analysis. According to Keeler (1983), the Interstate Commerce Commission (ICC) conducted the first statistical rail cost analysis in the late 1920s. Various issues have been addressed in the rail cost studies. These include economies of size and density, productivity, mergers, and the effects of rail line abandonment.

The methodology used to estimate the structure of cost became more sophisticated in the 1970s with the introduction of flexible form cost functions. Work by Brown, Caves, and Christensen (1978); Harmatuck (1979); Caves, Christensen, and Swanson (1980); and Friedlaender and Spady (1981) and others each used a translog. This work improves earlier rail cost specifications by incorporating multiple outputs; testing previously maintained hypotheses concerning the underlying structure of production; and incorporating additional technological variables.

Friedlaender and Spady (1981) introduced measures of traffic mix and the proportion of low-density miles as technological variables. "One would expect traffic mix by commodity type to have some effect on costs and factor intensities" (Friedlaender and Spady, 1981). Low-density miles are hypothesized to have higher costs because of deferred maintenance and lower traffic densities.

Two more recent studies - Lee and Baumel (1987) and Barbera et al. (1987) - also used the translog model. Each of these studies used more recent data. Before their studies, all previous studies were based on data no more recent than 1974. Because of changes in data reporting requirements, the newer data are measurably better. In addition, more recent data are required to analyze the effects of structural change caused by rail deregulation.

The results of Lee and Baumel (1987) and Barbera et al. (1987) are consistent with the findings from the earlier studies. The consistency of results and some limited statistical tests may imply that rail deregulation did not alter the railroad cost structure. For example, Lee and Baumel (1987) found that "deregulation and the massive structural changes from 1950 to 1980 have not exhausted the economies of density." Barbera et al.'s (1987) model included a dummy variable "to obtain separate estimates of scale and density economies for the periods 1979-80 and 1981-1983." The dummy variable was not significantly different between the two periods. This lead them to conclude, "while railroads have reduced costs through measures such as abandonments, the fundamental relationship between average costs, density and scale of operations has not been measurably altered." (Barbera et al., 1987). While the findings of the two studies were consistent, their results should be considered preliminary. Most likely, it took some time for the railroads to adjust to the new operational freedoms offered through deregulation.

Work by Berndt et al. (1991) provides the most recent comprehensive analysis of rail productivity. The objective of their work was to "disentangle the effects of deregulation on real costs and productivity from those directly attributable to mergers and acquisitions" (Berndt et al., 1991). Their results suggest that 91 percent of the cost savings since 1980 arose from deregulation. The other 9 percent cost reduction arose from mergers and acquisitions. "Moreover, the cost-reducing effects of mergers are short-lived than are those due to deregulation" (Berndt et al., 1991).

In summary, the previous research provides a strong foundation for rail cost analysis. Our research complements and extends prior work by separating output and size variables into measures of high and low density output that are directly tied to corresponding capital measures (miles of track). Our estimates of productivity and cost savings are assessed on an annual basis since 1978. Further, a measure of the effects of deregulation on productivity is developed and estimated. Finally, this research uses the most complete data (i.e., the most inclusive cross-section) and the most recent data to date (1978-1989).

III. CONCEPTUAL ISSUES

The central objective in this research is to assess empirically the level of productivity in the railroad industry since 1978. This is achieved by considering the direct and indirect effects of regulation (and therefore deregulation) on costs. Each of these effects are drawn empirically from a model of cost minimizing behavior with regulatory constraints in regulated periods.

Let $T(Q,X;\beta,R,t)$ represent the transformation function where: Q is a vector of outputs, X is a vector of inputs, β is a vector of fixed parameters to be estimated, R is a variable indexing the state of regulation, and t represents time. The variable R represents the direct effect of regulation on the technology. Firms are assumed to minimize cost given the transformation function and input prices, w_i. Without considering the indirect effects of regulation (constraints on input prices), the cost minimization problem confronted by firms is

$$\underset{X_i}{MIN}\ C = \sum_i w_i X_i \tag{1}$$
$$\textit{subject to:}\quad T(Q, X; \beta, R, t) = 1$$

Under the appropriate regularity conditions, the solution yields a set of conditional factor demands (X_i^*) and the minimum cost function

$$\begin{aligned} C &= \sum_i w_i X_i^* (Q, w; \beta, R, t) \\ &= C(Q, w; \beta, R, t) \end{aligned} \tag{2}$$

Given the transformation function and its corresponding minimum cost function, Caves, Christensen, and Swanson (1981) define two related measures of productivity. They are "the common rate at which all outputs can grow over time with inputs held fixed [PGY]" and "the common rate at which all inputs can be decreased over time with outputs held fixed [PGX]." These productivity measures, PGY and PGX, are related to the minimum cost function and each other by the following:

$$rPGX = -\frac{\partial \ln C}{\partial t}, \tag{3}$$

$$PGY = -\frac{\partial \ln C / \partial t}{\sum_i (\partial \ln C / \partial \ln Q_i)},\ \textit{and} \tag{4}$$

$$PGY = RTS * PGX \tag{5}$$

where RTS represents returns to scale.

In our particular model, the transformation function and the corresponding productivity measures depend directly on the state of regulation. In terms of the Caves, Christensen, and Swanson model above, a measure of the effects of regulation on the level of productivity can be calculated as the difference between a specific measure evaluated at two different states of regulation. For example, to measure the effects of regulation on an input defined productivity measure (i.e., PGX),

$$PGX^R = \frac{-\partial \ln C(R_1)}{\partial t} - \frac{-\partial \ln C(R_0)}{\partial t} \tag{6}$$

where R_1 and R_0 represent two different regulated states.

We now turn to the indirect effects of regulation. Regulated firms often face constraints on the choices of particular inputs. For example, in the railroad industry restrictions on abandonment act as input choice constraints for miles of road. In the cost minimization framework, these types of restrictions appear as constraints placing minimum values on the choice of an input, i.e., $X \geq X^R$. Therefore, in minimizing costs, the regulated firm might be envisioned as solving the following:

$$\underset{X_i}{MIN}\ C = \sum_i w_i X_i \tag{7}$$
$$\textit{subject to:}\quad T(Q, X; \beta, R, t) = 0 \quad \textit{and} \quad X \geq X^R$$

For notational simplicity, let X be a vector containing the inputs chosen without regulatory restrictions and let K represent the inputs chosen with binding regulatory restrictions. Further, let w and r be the corresponding price vectors. The variables are indexed by an R and P when in a regulated and partially regulated environment, respectively. Under these notational conveniences, the solution in a regulated environment (under appropriate regularity conditions) can be written as

$$\begin{aligned} C^R &= C^R(Q, w, K^R; \beta, R) + \sum_j r_j K_j^R \\ &= \sum_i w_i X_i^R\ (Q, w, K^R; \beta, R) + \sum_j r_j K_j^R \end{aligned} \tag{8}$$

where $X_i^R(\bullet)$ is the conditional input demand equation for input i under a regulated environment. In a partially regulated environment, the inputs in K are not subject to minimum levels. Rather they are chosen freely. Costs are then given by

$$C^P = C^P(Q,w,r;\beta) = \sum_i w_i X_i^P(Q,w,r;\beta) + \sum_j r_j K_j^P(Q,w,r;\beta) \tag{9}$$

The total cost of regulation, given Q, w, r, and the set of regulated constraints, is

$$\begin{aligned} C^R - C^P &= \sum_i w_i X_i^R(Q,w,K^R;\beta,R) + \sum_j r_j K_j^R - \{\sum_i w_i X_j^P(Q,w,r;\beta) + \sum_j r_j K_j^P(Q,w,r;\beta)\} \\ &= \sum_i w_i \{X_i^R(Q,w,K^R;\beta,R) - X_i^P(Q,w,r;\beta)\} + \sum_j r_j \{K_j^R - K_j^P(Q,w,r;\beta)\} \end{aligned} \tag{10}$$

The first bracketed term represents the costs of the indirect distortion in input choices made by the firm from sub-optimally choosing K in a regulated environment (relative to the unregulated technology). The second term represents the direct cost from constraining the firm to use more of an input than they would choose in a regulatory free environment. The magnitude of the cost savings from lifting the restrictions on capital variables depends on the elasticities of substitution among the inputs and the degree that the regulatory constraint is binding. Our empirical focus is on estimating productivity gains since 1978, productivity gains from deregulation, and finally evaluating the degree of distortion caused by regulation as measured by C^R - C^P.

IV. EMPIRICAL MODEL

In this section, our specification of the multiple output translog cost function, the variables of the model, the measures of productivity for regulated and partially deregulated technologies, and the measures of indirect cost savings through deregulation are presented. We then discuss a variety of specification issues raised in the recent literature and our tests of those issues.

A. Specification of the Cost Function

A translog cost function is used to model the technology. From this model, productivity gains and cost savings through time and deregulation can be identified. In a general form together with the dual factor shares, this function is given by:

$$\begin{aligned}\ln C = \alpha_o &+ \sum_i \beta_i \ln q_i + \sum_j \zeta_j \ln w_j + \sum_m \delta_m \ln K_m + \sum_n \eta_n \ln t_n + \sum_p \gamma_p Z_p \\ &+ .5 \sum_{ij} A_{ij} \ln q_i \ln q_j + .5 \sum_{ij} B_{ij} \ln w_i \ln w_j + .5 \sum_{ij} C_{ij} \ln K_i \ln K_j \\ &+ .5 \sum_{ij} D_{ij} \ln t_i \ln t_j + .5 \sum_{ij} E_{ij} Z_i Z_j + \sum_{ij} F_{ij} \ln q_i \ln w_j \\ &+ \sum_{ij} G_{ij} \ln q_i \ln K_j + \sum_{ij} H_{ij} \ln q_i \ln t_j + \sum_{ij} I_{ij} \ln w_i \ln K_j \\ &+ \sum_{ij} J_{ij} \ln w_i \ln t_j + \sum_{ij} K_{ij} \ln K_i \ln t_j + \sum_{ij} L_{ij} (\ln q_i) Z_j \\ &+ \sum_{ij} M_{ij} (\ln w_i) Z_j + \sum_{ij} N_{ij} (\ln K_i) Z_j + \sum_{ij} O_{ij} (\ln t_i) Z_j + \varepsilon\end{aligned} \tag{11}$$

$$\begin{aligned}S_i = \frac{\partial \ln C}{\partial w_i} = \zeta_i &+ .5 \sum_j B_{ij} \ln w_j + \sum_j F_{ij} \ln q_j \\ &+ \sum_j I_{ij} \ln K_j + \sum_j J_{ij} \ln t_j + \sum_j M_{ij} Z_j\end{aligned} \tag{12}$$

where: C is variable costs; q_i = the ith output; w_j = the jth input; K_m = the mth measure of capacity (the fixed factor); t_n = the nth technological variable associated with the ith output; Z_p = time related variables; ε is the disturbance term; and S_j is the dual factor share equation. Associated with this specification are the homogeneity and symmetry restrictions. The homogeneity restrictions are given by

$$\sum_j \zeta_j = 1,\ \sum_j \beta_{ij} = 0\ \forall\ i,\ \sum_j F_{ij} = 0\ \forall\ i,\ \sum_i I_{ij} = 0\ \forall\ j,\ \sum_i J_{ij} = 0\ \forall\ j,\ and \sum_i M_{ij} = 0\ \forall\ j \tag{13}$$

The symmetry conditions are given by

$$A_{ij}=A_{ji},\ B_{ij}=B_{ji},\ C_{ij}=C_{ji},\ D_{ij}=D_{ji},\ E_{ij}=E_{ji},\ F_{ij}=F_{ji},\ G_{ij}=G_{ji},\ H_{ij}=H_{ji},\ I_{ij}=I_{ji},$$
$$J_{ij}=J_{ji},\ L_{ij}=L_{ji},\ M_{ij}=M_{ji}, \text{ and } N_{ij}=N_{ji} \text{ (for all i and j).} \tag{14}$$

Two specifications of the model are estimated. The first specification separates output and size variables into two categories based on traffic density. With similar variables as found in the previous studies, the second specification is a more traditional rail cost model. Thus, it provides a basis of comparison with previous work. Our specifications are summarized in Table 1, while in Table 2 we summarize the specifications used in several previous studies. In the next section, a brief discussion of variables used in estimating our specifications is provided. A significantly more detailed discussion of the variables and their measurement is found in Appendix A.

TABLE 1. Definitions of Variables

Variable	Specification 1	Specification 2
OUTPUT		
q_1	High Density Gross Ton-Miles	Revenue Ton-Miles
q_2	High Density Gross Ton-Miles	Load Factor (RTM/GTM)
INPUT PRICES		
w_1	Labor	Labor
w_2	Equipment	Equipment
w_3	Fuel	Fuel
w_4	Materials & Supplies	Materials & Supplies
SIZE		
K^1	High Density Miles of Track	Miles of Road
K_2	Low Density Miles of Track	Average Running Speed Rate
TECHNOLOGY		
t_1	1 - % Unit Train	1 - % Unit Train
t_2	% Interlined Traffic	% Interlined Traffic
t_3	Length of Haul	Length of Haul
t_4	Time	Time
t_5	Stagger's Dummy	Stagger's Dummy

TABLE 2. Years of Data, Number of Observations, and Variables for Output, Input Prices, Size, and Technology

Item	Study					
	Friedlaender & Spady (1981)	Caves et al. (1985)	Barbera et al. (1987)	Lee and Baumel (1987)	Berndt et al. (1991)	Dooley et al. Specification 1 (1991)
Years of data	1968-70	1951-75	1979-83	1983-84	1974-86	1978-89
Number of Observations	57	820	uncertain	53	229	305
Output	RTM; Passenger Service	RTM; Passenger Miles	RTM	RTM	RTM	RTM; High Density GTM; Low Density GTM
Input Prices	Labor (three types); Fuel & Materials; Equipment	Labor; Fuel; Capital & Materials	Labor; Fuel; Materials & Supplies; Capital	Labor; Fuel	Labor; Fuel; Equipment; Materials & Supplies	Labor; Fuel; Equipment; Materials & Supplies
Size Variables	MR; Way & Structures Capital	MR	MR	MR	MR	MR; High Density MT; Low Density MT
Technology	ALH; Low-density Route-miles; Traffic Mix	ALH; ALT; Firm Effects	Net Freight Tons	ALH; % Unit Train; Load Factor	ALH; % Agricultural; % Coal; Time; Merger	ALH; % Unit Train; % Interlined; Time; Staggers; Firm Effects

NOTE: RTM = revenue ton-miles, GTM = gross ton-miles, MR = miles of road, MT = miles of track, ALH = average length of haul, ALT = average length of trip

B. Definition of Variables

The dependent variable in the regression is the operating cost for each railroad, with two adjustments. First, labor and fringe benefit costs associated with capital investment activities (e.g., track laying) are subtracted from operating costs. Second, following previous work, an opportunity cost for owned rolling stock is added to operating costs. Thus, we estimate a short run variable cost function variable costs and fixed factors as defined below.

All recent rail cost studies have used revenue ton-miles (RTM) as the output measure (Table 2). Friedlaender and Spady (1981) and Caves et al. (1985) also included some measure of passenger service. Passenger service is no longer included as an output variable because Amtrak has hauled virtually all passenger traffic since the early 1970s.

Our measures of output are very different between specifications. The first specification has two outputs, separating output into high and low density traffic on the basis of gross ton miles (GTM) per track mile (Table 1). Data for high density traffic are from lines with more than 5 GTM per track mile, while low density figures come from lines with less than 5 GTM per track mile. The output measure for the second specification is the more traditional RTM.

The use of GTM rather than RTM obviously raises a red flag. GTM has been criticized as a railroad output measure because it includes the weight of locomotives and cars with freight (Harris, 1977). Fully aware of this data problem, the GTM measurement is chosen because it is the only means to observe directly high and low density output and size.

Our size variables are also very different between specifications. In specification 1, the size measures are directly tied to the output measures. Thus, there are high and low density measures of miles of track (MT) that correspond to the high and low density GTM outputs. The traditional measure of size, miles of road (MR), is the size variable in specification 2 (Tables 1 and 2). The measures of high and low density miles of track in the first specification act as proxies for different types of fixed capital. In the second specification, average running speed for high and low density track is added as an index of capital intensity. As such, both models avoid the specification error identified by Lee and Baumel (1987), yet are able to distinguish the effects of different types of capital on costs.[1]

Since the size measures in specification 1 are measured in *miles of track* instead of the traditional miles of road, data problems analogous to output arise. Traditionally, MR is preferred over MT because

> "the institutional problem of excess capacity is related to the rail *route system,* not trackage. The regulatory barriers to abandonment apply to the provision of service to shippers and communities; therefore, it is the cost of this basic indivisibility — the length of road required to connect two points — that we should measure." (Harris, 1977).

The use of MT is not a critical problem in this analysis for two reasons. First, as measured, the data for MT excludes way and yard switching track. Second, when the data are separated into high and low density track, MT may be preferable over MR. MT includes passing tracks, turnouts, crossovers, and secondary main track. MT is preferable over MR because these additional types of track allow a carrier to increase the hauling capacity over a specific high density line.

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[1]Most recent rail cost studies have added some measure of capital cost to operating cost to obtain a total cost. However, as noted by Lee and Baumel (1987), by including both a capital price and firm size, the specification "violates the domain of either a short-run or a long-run cost function. A short-run cost function should not include a capital price variable while a long-run cost function should not include a firm size variable." Friedlaender and Spady (1981) suggest there is an important distinction between way-and-structures capital and trackage. Specifically, "two railroads with an identical number of track-miles may have very different reproduction values, if for example, the condition of their track is different" (Friedlaender and Spady 1981).

We follow many of the previous studies (Table 2) in defining input categories by including prices for labor, fuel, equipment, and materials and supplies.[2] Our specific measurements are discussed in some detail in Appendix A. The price of labor is adjusted, as in prior studies, to be consistent with total operating cost. Maintenance of way labor costs for investment is subtracted and fringe benefits are added to labor cost. The price of fuel is the average fuel price paid by carriers instead of the commonly used fuel index.[3] As such, this measure is much richer because it reflects the purchasing power of larger carriers and those carriers with more fuel-efficient locomotive fleets. The equipment price was calculated from data reported by the carriers in Schedule 415. Thus, our data includes equipment prices for all carriers, regardless of size. Finally, as in all other studies, we use an AAR Index for Materials and Supplies as the price for materials and supplies.

Both specifications also include a vector of three technological variables, a time trend variable, and a regulation dummy variable. The time trend is measured over the twelve year sample as 1978=1, 1979=2, ..., 1989=12. The regulation variable (STAGGERS) is a dummy variable equal to 1 after 1980 and zero otherwise.

The technological variables are average length of haul (ALH), the percent of unit train traffic (UTF), and the percent of interlined traffic (INTRLINE). Average length of haul appears in all of the recent empirical studies.[4] As length of haul get longer, the fixed costs per shipment are spread over more miles and costs are expected to fall. "These

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[2]As is evident in Table 2, there are some discrepancies among studies in the delineation of factors, and what factors are fixed. The studies range from including two variable factors (labor and fuel) in Lee and Baumel (1987) to five variable factors (three types of labor, fuel and materials, and equipment) in Friedlaender and Spady (1981).

[3]Barbera et al. (1987) also calculated an average fuel price from Schedule 750 data.

[4]Average length of haul in Barbera et al. (1987) is the coefficient on net ton-miles.

economies are achieved mainly by spreading origination and termination costs over more output" (Barbera et al., 1987). Between 1978 and 1989, the average length of haul increased from 326 miles to 457 miles.

Other technological variables have differed across studies (Table 2). All have included average length of haul, but differ in the remaining variables. In our analysis, two technological variables are included besides average length of haul. They are percent of unit train traffic and percent of traffic interlined. Both of the variables are thought to reflect the effects of deregulation.

The percent of unit train traffic is a relatively new variable in empirical cost studies. The mean annual percentage of unit train traffic has increased from 6.1 percent in 1978 to 16.8 percent in 1989. The unit train is a "system including efficient, rapid loading and unloading facilities, matched up with trains of cars and locomotives assigned to the service" (Armstrong, 1978). The sources of unit train efficiency include a higher equipment utilization rate (because freight cars are not switched) and the use of specialized equipment. Lee and Baumel (1987) included a unit train factor in their model. Variables in other studies likely pick up some of the effects of unit trains. These include Friedlaender and Spady's (1981) traffic mix and Berndt et al.'s (1991) percent agricultural traffic and percent coal traffic.

Interlined traffic is traffic that is handled by more than one carrier as it moves from origin to destination. Over the period of the sample, the mean annual percent of interlined traffic has fallen from 78.7 percent in 1978 to 61.2 percent in 1989, largely (perhaps) as a result of mergers. As interlined traffic falls, costs also should fall due to the elimination of freight transfer between carriers. Any interchange entails costs for switching and an associated paper trail.

Specification 2 includes two additional technological variables, load factor and average running speed. Load factor is the ratio of revenue ton-miles to gross ton-miles. The same variable was used by Lee and Baumel (1987). As discussed previously, average speed rating for high and low density track is introduced as an index of capital intensity or quality.

A final set of variables are akin to firm effects as developed by Caves et al. (1985) and modified by Berndt et al. (1991). These variables are designed to represent unobserved network effects.[5] By defining new firm specific effects for merged carriers, these variables also can capture the effects of mergers. These effects are discussed in greater detail in Appendix B.

Not all the mergers in our data set parallel those modeled by Berndt et al. (1991). For example, they have the UP-WP-MP merger effective in 1983. However, separate R-1 data were reported for each of these three carriers through 1985. Serious measurement error for the variable INTRLINE do not allow the data to be aggregated when consolidated reports are not filed. Discussions with rail company officials suggest that some mergers are phased in.[6] Thus, in cases of phased mergers where individual reports are reported we retained the individual firm effects dummy variable for each carrier. We also introduced a *merged effect* dummy variable for each firm to capture the effects of mergers that a firm experiences before reports are consolidated. For example, a consolidated R-1 report for the UP-MP-WP was not filed with the ICC until 1986. Thus, we treat these railroads as separate railroads through 1985. However, for each railroad

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[5]However, it is noted that dummy variables may also capture other unobserved effects that vary across firms.

[6]A description of the mergers during the sample period is found in Appendix A.

we introduced a dummy variable taking a value of 1 for 1983, 1984, and 1985 to pick up the effects of partial merger.

C. Measuring Productivity and Cost Savings

As in several studies, including Ying's (1990) recent work in trucking, productivity enters as a time trend. In equation (11) of our specification, let Z_1 represent time and let Z_2 represent deregulation. In its most general form, deregulation can impact productivity through the interaction term with the deregulation dummy variable, Z_{12}, or

$$\frac{\partial \ln C}{\partial Z_1} = \gamma_1 + .5 \sum_j E_{1j} Z_j + \sum_i L_{i1} \ln q_i + \sum_i M_{i1} \ln w_i + \sum_i N_{i1} \ln K_i + \sum_i O_{1j} \ln t_j \tag{15}$$

In applying the measure, the actual rate of technological change can be calculated in three different ways. First, equation (15) is evaluated at the observed sample points. Second, it can be evaluated at mean values of the data through time. Finally, the time alone effects can be calculated, or equation (15) can be evaluated at sample means across observations and through time. However, as in Ying (1990), the arguments of the rate of technological change may also be a function of regulation.[7]

In estimating the cost savings from deregulation, the translog analog to equation (11) is evaluated at regulated and partially regulated states. Costs calculated from the cost function are evaluated at pre- and post-Staggers levels. The cost savings are:

$$\frac{C_F - C_R}{C_R} = exp\,[\gamma_2 + .5\ E_{12} Z_1 + \sum_i L_{i2} \ln q_i + \sum_i M_{i2} \ln w_i + \sum_i N_{i2} \ln K_i + \sum_i O_{i2} \ln t_i] - 1 \tag{16}$$

[7]We were unable to efficiently identify the effects of deregulation on those variables.

where C_R and C_F represent the pre-Staggers and post-Staggers cost function, respectively. The effects of Staggers are calculated at three different reference points: (1) the sample mean for each point in the data, (2) the annual mean values of the righthand side variables, and (3) the overall sample mean of the righthand side-variables.

D. Issues in Estimation

In estimating the translog, issues remain about the possible endogeneity of output and the measurement of variables. In this section, we describe our approach to each of these potential problems.

Under deregulation railroads have some flexibility in establishing rate and output levels. Lee and Baumel (1987), therefore, included a demand function and pricing relation into their econometric model. Berndt et al. (1991) performed a Hausman (1978) test to test for significant bias, finding significant differences between SUR and three stage least squares parameter estimates.[8] Our specification is quite different, and therefore, the Hausman (1978) specification test is performed in recognition of these differences.

The second issue corresponds to the measurement of variables. In 1983, the official accounting method changes from betterment to depreciation based accounting methods. Various approaches have been followed in using data through time. Lee and Baumel (1987) did not use data before 1983, terming the data as not comparable. Berndt et al. (1991) "adjusted" the data and used the result. *A priori*, it is uncertain which method is appropriate or whether any *errors in variables* remain after adjustments are made.

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[8]They treated revenue ton-miles, average length of haul, the percentage of agricultural and coal traffic and the corresponding transformations as endogenous.

As discussed in the data appendix, we followed much of the previous literature in adjusting the accounts in the raw data to reflect economic rather than accounting measurements. In terms of the adequacy of these adjustments, a Hausman (1978) specification test is performed for errors in variables. Specifically, for the subset of the sample from 1983 to 1987, the ICC maintained two sets of records based on betterment and depreciation accounting. Based on these data, depreciation accounting based data are treated as the appropriate data. Those data are used as instruments for the potential of poorly measured betterment accounting data. The result allows a Hausman (1978) test to determine whether the use of adjusted betterment data introduces bias into the specification.[9]

V. DATA

The principal data were taken from the annual R-1 reports that Class I carriers file with the ICC. The data were obtained from the ICC Trans.xx files for the years 1978 through 1989. Beginning in 1978, the R-1 data are more detailed, thereby allowing richer specifications than previously. Over the range of the data (1978-1989), the number of Class I railroads fell from 35 in 1978 to 15 in 1989.[10] Other data for fuel usage and prices and track characteristics, not included in the Trans.xx files, were also obtained from the ICC.

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[9]We note that out initial specifications suggested that the differences between betterment and depreciation based accounting data did not vary much through time, but did vary substantially across firms. Thus, the use of firm specific dummy variables to represent firm specific network effects is highly questionable.

[10]Observations for the Elgin, Joliet, and Eastern were excluded because it is a switching carrier. Observations for the Long Island were excluded because it is a commuter rail line.

Three major differences distinguish this data from that used in the railroad studies discussed in the literature review. First, the analyses by Barbera et al. (1987) and Lee and Baumel (1987) were necessarily limited by a lack of observations. Barbera et al. had data from 1979 to 1983, while Lee and Baumel had data for 1983 and 1984. As Lee and Baumel noted, "additional data will provide the degrees of freedom needed to experiment with models to deal with what Caves, Christensen, Tretheway and Windle refer to as unobserved network effects." Thus, the additional years of observations allow for the estimation of a more complete specification.

Second, several attributes of the data allow a much richer specification than previously allowed; indeed a specification that more closely approximates many of the policy issues raised in the last twenty years. Specifically, these data allow separate measures of high and low density traffic movements that are directly tied to high and low density size measures (i.e., miles of track). Much of the debate over the indirect effects of deregulation (i.e., those passing through the arguments of the cost function) bear directly on this type of disaggregation.

Finally, some of the earlier studies eliminated many observations from their data sets.[11] Using data from 20 of 44 railroads, Friedlaender and Spady (1985) only used 57 of approximately 130 possible observations. Observations for six coal carriers were eliminated because they were consistent outliers. In addition, observations for 18 Class I carriers were deleted because they found "the *Carload Waybill Statistics* were clearly inadequate" (Friedlaender and Spady, 1981). Similarly, Berndt et al. (1991) excluded firms that lost Class I status, bankrupt carriers with data that were judged to be

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[11]See Appendix A, Table A-2 for an identification of which railroads (by year) were included in the data sets for Caves et al. (1985), Lee and Baumel (1987), Berndt et al. (1991), and this study.

unreliable, and carriers with incomplete bond histories. The latter were excluded because it was impossible to generate correct capital equipment costs. It also appears that Caves et al. excluded some observations from their data set. We note that the observations eliminated in the earlier studies are almost exclusively those for smaller Class I carriers.

While we also experienced frustrations with some data validity, every effort was made to preserve a complete data set. To that end, several discussions were held with ICC and Association of American Railroads rail costing officials about data measurement. The result of those discussions is a data set containing the most complete cross-section and the most recent time frame. Despite these efforts, 19 observations were excluded because of suspect values in either track characteristics data (Schedule 720) or fuel data (Schedule 750). Thus, the final data set consists of 305 observations over 12 years.

VI. EMPIRICAL RESULTS

A. Estimation Results and Regularity Conditions

In Appendix B, a description is provided of our statistical tests of specification issues and model selection criteria. In addition, Appendix B also includes all coefficients of the final models estimated and summary statistics for each model.[12] The results are comparable in direction of effects with previous studies and with *a priori* expectations. Where comparable variables are used, the results also are generally consistent with previous studies in magnitudes.

The models fit the data extremely well, and the regularity conditions are generally satisfied. Concavity restrictions were calculated and satisfied at every point in the data,

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[12]An attempt was made to identify a set of restrictions on second order terms to reduce the number of parameters. In all tests performed, the F-statistic did not allow the null hypothesis to be accepted at the 10 percent level.

i.e., the bordered Hessian matrix of C(•) is negative semi-definite for all observations. Marginal costs are positive for 300 of the 305 (98 percent) of the observations in specification 1 (high and low density output measures). They are positive for 295 or the 305 (97 percent) in specification 2 (for the revenue ton-mile output measure).

B. Summary of Effects

The linear terms of the estimation are reported in Table 3. All coefficients are of the expected sign and are consistent across comparable dimensions of the two specifications. The output terms and the size terms are not directly comparable between the two specifications. Factor price effects are nearly identical in magnitude between the specifications. The common technological variables, (the unit train factor, the degree of interlined traffic, and average length of haul) yield similar qualitative, but slightly different quantitative effects.

The unit train factor (1- percent unit train) has a positive and significant influence on costs. Thus, when the proportion of unit train traffic increases, our measure, the unit train factor falls, and costs fall. The elasticity measure averages .326 and .433 for specifications 1 and 2, respectively (Table 3). As the level of unit train traffic has almost tripled since 1978, (increasing from an average of 6 to 17 percent) these results suggest dramatic reductions in cost.

The level of interlined traffic (the linear term) is not a significant variable in either specification. While the amount of interlined traffic has fallen dramatically since deregulation, it does not seem to have a direct influence on cost (i.e., through the linear term). However, some of the interaction terms are quite significant.

Average length of haul, as in previous studies, has a negative influence on costs. The elasticity of cost with respect to average length of haul averages about -.460 and -.554

TABLE 3. Parameter Estimates on Linear Terms

Parameter	Estimate	Standard Error	T-Ratio
SPECIFICATION 1			
INTERCEPT	0.264448	0.04349	6.08
Q1 (High Density GTM)	0.765329	0.07629	10.03
Q2 (Low Density GTM)	0.122094	0.03815	3.20
K1 (High Density MT)	0.146405	0.09135	1.60
K2 (Low Density MT)	0.017348	0.06022	0.29
W1 (Price Labor)	0.430248	0.00651	66.05
W2 (Price Equipment)	0.183142	0.00653	28.01
W3 (Price Fuel)	0.090512	0.00246	36.66
W4 (Price Materials)	0.296097	0.00676	43.78
T1 (% Unit Train)	0.325625	0.14194	2.29
T2 (% Interline)	0.005841	0.11072	0.05
T3 (Length of Haul)	-0.460385	0.06969	-6.61
T4 (Time)	-0.022385	0.01828	-1.22
T5 (Staggers)	0.170760	0.09194	1.86
SPECIFICATION 2			
INTERCEPT	0.255807	0.04489	5.70
Q1 (RTM)	0.897111	0.05764	15.57
Q2 (RTM/GTM)	-1.007475	0.22823	-4.41
K1 (MR)	0.237516	0.05764	4.12
K2 (SPEED)	0.222044	0.17432	1.27
W1 (Price Labor)	0.419884	0.00669	62.69
W2 (Price Equipment)	0.187222	0.00595	31.45
W3 (Price Fuel)	0.091991	0.00251	36.55
W4 (Price Materials)	0.300903	0.00667	45.10
T1 (% Unit Train)	0.432590	0.16289	2.66
T2 (% Interline)	0.089161	0.13138	0.68
T3 (Length of Haul)	-0.554196	0.07869	-7.04
T4 (Time)	-0.036865	0.01929	-1.91
T5 (Staggers)	0.268910	0.09298	2.89

in specifications 1 and 2, respectively (Table 3). Since passage of Staggers, the remaining Class I carriers have longer average lengths of haul. In 1978, the average length of haul was 331 miles. This figure has grown to about 457 miles in 1989, thereby lowering costs.

In general, the technological variables described above have had expected *a priori* effects on costs. Further, since deregulation, or perhaps because of deregulation, each of these variables has moved in the direction of reducing costs. As a result, these changes reflect major cost savings.

C. Density and Scale Elasticities

Measures of density and scale elasticities[13] were calculated through time (Table 4). These measures are evaluated at overall sample means.[14] Returns to scale in the industry are slightly decreasing over time. However, these decreasing returns appear to dissipate with time. As the effects of the variables enter non-linearly, we also evaluated scale elasticities at every point in the sample. The average scale economy, for firms observed in the data, is about 1.04 and 1.01 in specifications 1 and 2, respectively. These results are quite comparable with the results of previous studies (see Barbera et. al., 1987). Further, they do not appear to vary much by regulatory status, with values of 1.03 and .99 for periods before Staggers and 1.03 and 1.02 for periods after Staggers in specifications 1 and 2, respectively. This finding is also consistent with the limited previous research on the effects of deregulation.

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[13]For density economies, we use $1/(\Sigma\, \partial \ln C/\Sigma\, \partial \ln Q_i)$ and for scale economies we use $1/(\Sigma\, \partial \ln C/(\Sigma\, \partial \ln Q_i + \Sigma\, \partial \ln K_i))$ where Q_i denotes outputs and K_i denotes the miles of road or miles of track size measures.

[14]Similar patterns emerge that are roughly comparable in magnitude when calculated at annual averages.

TABLE 4. Estimates of Returns to Density and Scale from Specification 1 and 2

	Evaluated at the Annual Mean		Evaluated at the Overall Mean	
YEAR	DENSITY	SCALE	DENSITY	SCALE
SPECIFICATION 1				
1978	1.19302	0.94775	1.11085	0.95454
1979	1.16302	0.96137	1.09530	0.95778
1980	1.12490	0.96779	1.08017	0.96104
1981	1.28388	0.97519	1.25798	0.96191
1982	1.30740	0.98425	1.23807	0.96521
1983	1.21332	0.98108	1.21877	0.96852
1984	1.17312	0.97751	1.20007	0.97186
1985	1.12354	0.98284	1.18194	0.97522
1986	1.08179	0.96788	1.16434	0.97861
1987	1.05060	0.98138	1.14727	0.98202
1988	1.05406	0.97467	1.13068	0.98545
1989	1.01988	0.97290	1.11457	0.98891
SPECIFICATION 2				
1978	1.15307	0.91347	1.14571	0.89238
1979	1.17830	0.92504	1.17851	0.90370
1980	1.18962	0.94262	1.21324	0.91530
1981	1.20368	0.95361	1.25958	0.92469
1982	1.32499	0.96424	1.29934	0.93684
1983	1.35929	0.96031	1.34169	0.94932
1984	1.42910	0.95285	1.38688	0.96213
1985	1.43657	0.95993	1.43524	0.97530
1986	1.46339	0.96579	1.48708	0.98883
1987	1.56523	0.96462	1.54281	1.00274
1988	1.70178	0.96027	1.60288	1.01705
1989	1.72312	0.971421	.66781	1.03177

In evaluating density, we observe some differences across specifications and through time. In specification 1, density economies increase through about 1982, then fall reaching near unity in 1989 (Table 4). In contrast, in specification 2, the density economies measure increases throughout the period of analysis, indicating very significant economies of density in latter periods. Evaluated at every point in the sample, yields an average value of 1.34 and 1.52 in specifications 1 and 2, respectively. Measured before and after deregulation, results in values of 1.22 before Staggers and 1.39 after Staggers in specification 1, and 1.29 before Staggers and 1.64 after Staggers in specification 2.

D. Structure of Costs and Regulatory Status

Another description of the behavior of costs over time is given by plotting the average variable cost functions. In Figure 1, the average variable cost per high density gross ton-mile is plotted against high density gross ton-miles. In Figure 2, average variable cost per revenue ton-mile is plotted against revenue ton-mile for various years and regulatory status. Two average cost functions are presented for each case. In panel (a) of each figure is the 1978-pre-Stagger's average cost function and the 1989-Staggers average cost function (i.e., evaluated at 1978 and 1989 average values, respectively). In panel (b) of each figure, is the 1989-regulated and the 1989-Staggers average cost functions.

The implication in each case is clear. Deregulation has resulted a downward shift in the average variable cost function. Firms of all sizes are much more cost efficient than under a regulatory regime. Further, whether in terms of direct (panel b) or indirect effects (panel a), costs savings are dramatic.

The distribution of firms across the perspective output definitions are also presented in Figures 1 and 2. Regardless the definition of output, there has been a

FIGURE 1. Average Cost per High Density Gross Ton Miles and Number of Firms

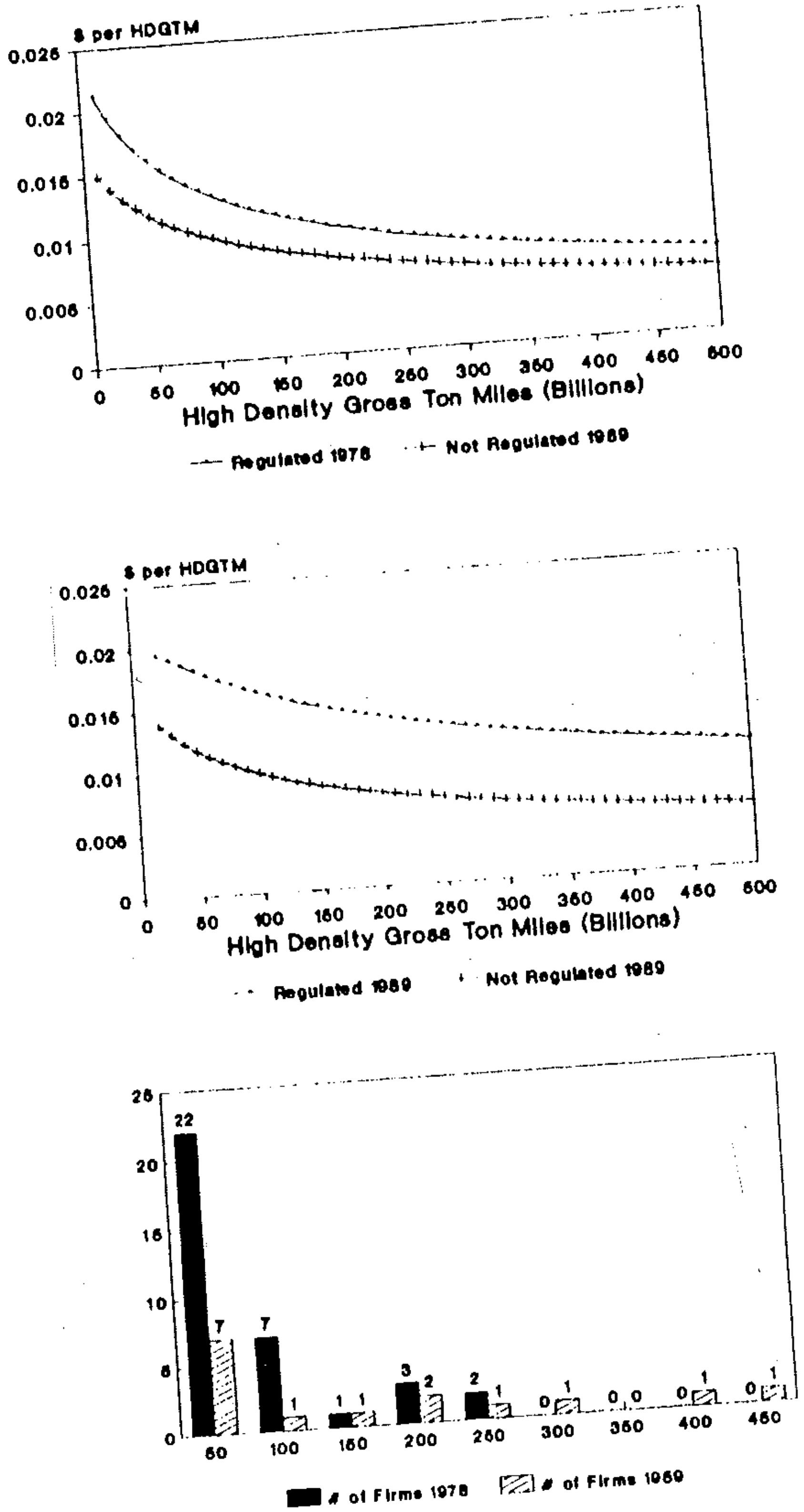
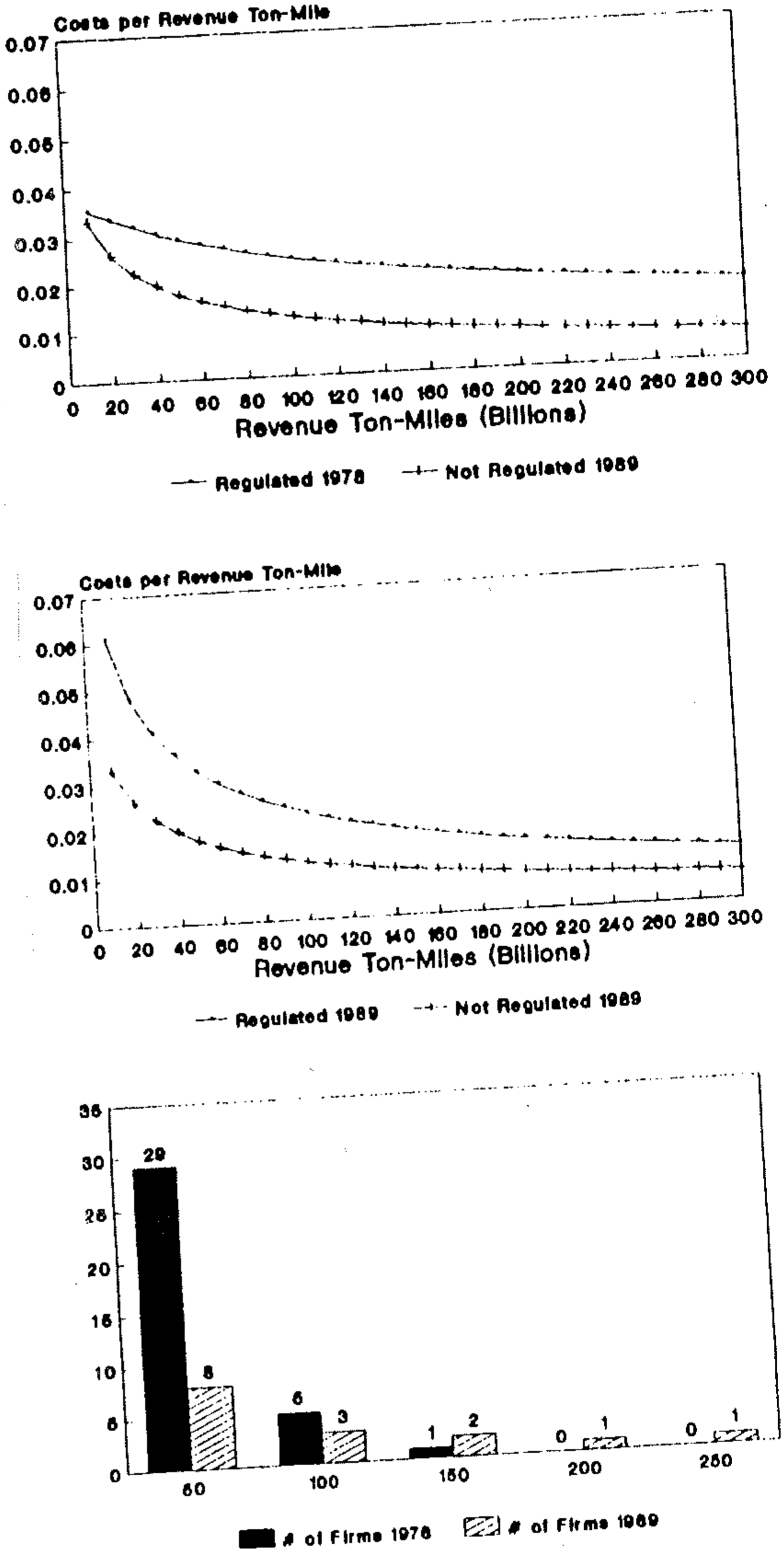


FIGURE 2. Average Cost per Revenue Ton Miles and Number of Firms



remarkable change in the composition of firms. In each output definition, the number of firms has declined from 35 in 1978 to 15 in 1989. Further, almost all the change is represented by the decline in the number of smaller output firms. Thus, the distribution of firms is now much more heavily weighted by the lower cost large firms.

E. Cost Saving and Productivity Enhancement

Summary measures of cost saving and productivity enhancement as a result of the Staggers Rail Act were also calculated (Table 5). These effects are calculated as the percentage change in variable costs under a regulated and a partially deregulated environment $\{(C^R-C^P)/C^P*100\}$. They are evaluated at three different reference points, the overall sample averages, the annual sample averages, and the average effect experienced by each point in the data.

TABLE 5. The Average Effect of Deregulation on Costs, by Specification, by Year

	Specification 1			Specification 2		
YEAR	DEREG[1]	DEREGX[2]	DEREGM[3]	DEREG[1]	DEREGX[2]	DEREGM[3]
1981	-3.4948	-4.3239	-2.9596	-2.4061	-2.4098	-1.6625
1982	-6.5624	-7.5928	-7.7108	-10.3981	-9.9671	-8.4407
1983	-11.0426	-11.3190	-12.2295	-15.7735	-14.9732	-14.7517
1984	-14.9913	-15.4727	-16.5268	-20.0923	-19.8239	-20.6277
1985	-19.0893	-19.2519	-20.6138	-25.0989	-24.7856	-26.0986
1986	-22.2708	-22.6392	-24.5007	-30.2921	-30.2229	-31.1925
1987	-25.9119	-26.7077	-28.1972	-33.2551	-33.5514	-35.9353
1988	-28.8233	-29.3484	-31.7128	-36.9097	-37.1628	-40.3511
1989	-31.6052	-32.5836	-35.0563	-40.7781	-41.0262	-44.4626

[1]DEREG is the average effect of deregulation calculated at each point in the sample.
[2]DEREGX is the average effect of deregulation calculated at annual averages in the data.
[3]DEREGM is the average effect of deregulation calculated at the overall mean values.

While the figures differ slightly in magnitude, there is no ambiguity in direction of effects. Deregulation has reduced costs. The effects in 1981 were modest ranging from -1.6 to -4.3 percent depending on the reference point and the specification (Table 5). However, by 1989, the effects of deregulation are quite dramatic, ranging from -31 to -45 percent.

A similar procedure is followed in presenting our productivity figures. Our productivity measure ($\partial \ln C/\partial t$) is interpreted as the percentage change in costs per year (Table 6). The measure is evaluated at the same three reference points as above, the overall sample mean, the annual sample means, and the average value of all data points. Again the specifications yield qualitatively similar, but numerically different results. Productivity levels were very low before deregulation (usually less than 2 percent reduction in costs per year).[15] Productivity increased dramatically with deregulation, to values ranging from about a 5 to 7 percent reduction in costs per year (Table 6). However, since 1987 these values have fallen and are currently about the same levels as in 1978.

VII. SUMMARY AND CONCLUSIONS

After years of strict regulation, the class I carriers were partially deregulated with a series of acts, culminating with the Staggers Rail Act of 1980. Since 1980, the class I rail industry has been restructured as the carriers adapted and changed in response to new regulatory freedoms. Ultimately, these changes are reflected in the cost structure and in productivity gains. Thus, our goal has been to assess empirically the annual level

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[15]Actually, the linear term in specification 1 is not statistically significant, although it is comparable in magnitude to the same term in specification 2 which is statistically signification at the 10 percent level.

TABLE 6. Average Productivity Effect on Costs, by Specification, by Year

	Specification 1			Specification 2		
YEAR	PROD[1]	PRODX[2]	PRODM[3]	PROD[1]	PRODX[2]	PRODM[3]
1978	-0.0122	-0.0146	-0.0175	-0.0110	-0.0220	-0.0278
1979	-0.0065	-0.0089	-0.0126	-0.0037	-0.0145	-0.0188
1980	-0.0022	-0.0045	-0.0076	0.0054	-0.0069	-0.0098
1981	-0.0502	-0.0517	-0.0529	-0.0592	-0.0709	-0.0722
1982	-0.0441	-0.0466	-0.0480	-0.0411	-0.0554	-0.0631
1983	-0.0405	-0.0427	-0.0431	-0.0357	-0.0490	-0.0541
1984	-0.0376	-0.0391	-0.0382	-0.0330	-0.0440	-0.0451
1985	-0.0335	-0.0358	-0.0332	-0.0259	-0.0366	-0.0360
1986	-0.0310	-0.0330	-0.0283	-0.0147	-0.0298	-0.0270
1987	-0.0270	-0.0283	-0.0234	-0.0119	-0.0252	-0.0180
1988	-0.0229	-0.0244	-0.0185	-0.0076	-0.0190	-0.0089
1989	-0.0188	-0.0203	-0.0136	-0.0006	-0.0119	0.0001

[1]PROD is the average productivity effect calculated at each point in the sample.

[2]PRODX is the average producitivty effect calculated at annual averages in the data.

[3]PRODM is the average productivity effect calculated at the overall mean values.

of productivity and cost savings since 1978. In addition, we extend the prior work by separating output and size variables into measures of high and low density output and miles of track. Finally, this work uses a more complete and more up-to-date data set. Three conclusions can be drawn.

First, deregulation has resulted in a dramatic downward shift in the average variable cost function. The average effect of deregulation on costs began slowly, but has steadily increased over time. In 1981, costs were lower by -1.6 to -4.3 percent as a result of deregulation. By 1989, however, the effects of deregulation had risen from -31.6 to

-44.5 percent. The annual cost savings for specification 2 were more than 20 percent larger in 1989 than those for specification 1. Specification 2 was the model comparable to previous studies, while specification 1 was the model with high and low density output and size measures.

Second, annual productivity levels were very low before deregulation, somewhere around a 1 percent reduction in costs per year. Productivity increased dramatically with deregulation, to annual cost reductions ranging from about 5 to 7 percent. However, since 1987 these values have fallen and are currently about the same levels as in 1978. The results are consistent for both specifications. Further, our results are consistent with those of Tretheway and Waters (1991) who used a different approach on data running through 1987.

Third, the findings for economies of size for the class I carriers varies by specification. For specification 2, the findings for economies of density and scale are consistent for the latter years of the data set. However, they were generally lower for the earlier years in the sample. One possible explanation is the early years of our sample included many more small class I carriers than found in other studies. Their presence may have lowered economies of density because many of these small class I carriers had very high traffic densities. In the latter years, the findings are more consistent because most of the small class I carriers had either been merged into larger systems or declassified as class I carriers. Thus, our sample for the latter years is comparable to that of the other studies.

In specification 1, density economies increase through 1982, before falling and reaching near unity in 1989. Discussions with operations personnel from some class I carriers suggests that congestion is an emerging problem on some high density corridors. Taken together, the results of specifications 1 and 2 suggest that while economies of density continue to be an important source of future cost savings, class I carriers may have already realized these savings to a large extent on some high density corridors.

In conclusion, deregulation has and continues to be a crucial source of cost savings. Deregulation has allowed class I carriers to position themselves as low-cost providers of transportation. Without the significant cost savings attributable to deregulation, one questions whether the class I carriers could compete for traffic with other modes. While productivity rose dramatically in the first five or six years after 1980, those gains have since slowed to historical levels. Finally, the results of the two cost specifications are not entirely consistent. The level of cost savings from deregulation is more than 20 percent higher for the traditional rail cost model. Further, the multiple output cost model suggests that economies of density have largely been realized. This suggests that additional work needs to be done to reconcile and understand these differences.

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APPENDIX A

DESCRIPTION OF DATA SOURCES, VARIABLES, AND MERGERS

A.1 Data Sources

A list of the railroads included in the data set, an abbreviation of the name, and the years that the carrier were Class I carriers is provided in Table A-1. In addition, a brief evolutionary description of each railroad is also included in Table A-1. For example, BN1 was formed in 1980 as a combination of the old SLSF and BN. Two Class I carriers are excluded from Table A-1. The EJE was eliminated because it is a switching carrier. Observations for the Long Island were eliminated because it is a commuter rail line.

Nineteen observations were excluded from the final data set (Table A-2). Twelve observations were deleted because of suspect values in either track characteristics data (Schedule 720) or fuel data (Schedule 750). Data were excluded for the ROCK for 1978, the WM for 1982, the BM for 1985 and 1987, the BLE for 1984, and all seven years that the PLE was a Class I carrier. Seven observations of low density output were zero and thus deleted; five for the CLN and two for the DMIR. Thus, the final data set includes 305 of 324 possible observations.

For comparison purposes, we summarize observations from our sample (Dooley et al.) and those from previous studies in Table A-2. Berndt et al. (1991) excluded railroads from their data set for three reasons. First, railroads that lost Class I status between 1974 and 1986 were excluded. This includes the BLE, DMIR, EJE, and PLE, as well as six carriers[1] that lost Class I carrier status before 1978 (Table A-2). Second, two bankrupt carriers, MILW and Penn Central, were excluded because their data were felt to be unreliable. Finally, carriers with incomplete bond histories were also excluded. Bond prices were used to generate capital equipment costs. This group of carriers included the BO, BM, CO, DH, FEC, SSW, SCL, and perhaps the DTI, LN, WM, and CCO.

[1]Ann Arbor, Central of New Jersey, Detroit & Toledo Shore Line, Erie Lackawanna, Lehigh Valley, and Reading Railway.

TABLE A-1. U.S. Class 1 Railroads and Abbreviations, 1978-89

Railroad	Abbreviation	Years Observed in Data Set	Comment
Atchison, Topeka, & Sante Fe	ATSF	1978-89	
Chicago & Northwestern	CNW	1978-89	
Consolidated Rail Corp.	CR	1978-89	
Denver, Rio Grande & Western	DRGW	1978-89	
Florida East Coast	FEC	1978-89	
Illinois Central Gulf	ICG	1978-89	
Kansas City Southern	KCS	1978-89	
St. Louis, Southwestern	SSW	1978-89	
Southern Pacific	SP	1978-89	
Burlington Northern	BN	1978-79	
St. Louis, San Francisco	SLSF	1978-79	merged into BN
Colorado Southern	CS	1978-81	merged into BN
Forth Worth, Denver	FWD	1978-81	merged into BN
Burlington Northern I	BN1	1980-81	BN + SLSF
Burlington Northern II	BN2	1982-89	BN1 + CS + FWD
Chesapeake & Ohio	CO	1978-85	merged into CSX
Baltimore & Ohio	BO	1978-85	merged into CSX
Seaboard Coast Line	SCL	1978-85	merged into CSX
Clinchfield & Ohio	CLN	1978-82	reported with SCL
Louisville & Nashville	LN	1978-82	reported with SCL
Western Maryland	WM	1978-82	reported with BO
CSX	CSX	1986-89	CO + BO + SCL
Grand Trunk & Western	GTW	1978-83	
Detroit, Toledo & Ironton	DTI	1978-83	merged into GTW
Grand Trunk & Western I	GTW1	1984-89	GTW + DTI
Soo Line	SOO	1978-84	
Chicago, Milwaukee, & St. Paul	MILW	1978-84	acquired by Soo Line
Soo Line I	SOO1	1985-89	SOO + MILW
Norfolk & Western	NW	1978-84	merged into NS
Southern Railway	SOU	1978-82	consolidated into Southern Ry System

TABLE A-1. U.S. Class 1 Railroads and Abbreviations (continued)

Railroad	Abbreviation	Years Observed in Data Set	Comment
Alabama & Great Southern	AGS	1978-82	consolidated into Southern Ry System
Central Georgia	CGA	1978-82	consolidated into Southern Ry System
Cincinnati & Texas Pacific	CNTP	1978-82	consolidated into Southern Ry System
Southern Railway System	SRS	1983-84	SOU + AGS + CGA + CNTP
Norfolk Southern	NS	1985-89	SRS + NW
Union Pacific Railway	UP	1978-85	
Missouri Pacific	MP	1978-85	merged into UP
Western Pacific	WP	1978-85	merged into UP
Missouri-Kansas-Texas	MKT	1978-87	merged into UP
Union Pacific I	UP1	1986-87	UP + WP + MP
Union Pacific II	UP2	1988-89	UP1 + MKT
Bessemer & Lake Erie	BLE	1978-84	Declassified as Class I
Boston & Maine	BM	1978-87	Declassified as Class I
Chicago, Rock Island & Pacific	ROCK	1978	Bankrupt
Delaware & Hudson	DH	1978-87	Declassified as Class I
Duluth, Missabe & Iron Range	DMIR	1978-84	Declassified as Class I
Pittsburgh, Lake Erie	PLE	1978-84	Declassified as Class I

Caves et al. (1985) used data from 1951-1975. In terms of our data, Caves et al. (1985) excluded at least 17 railroads that operated after 1978 from their data set (Table A-2). No reasons were given for the deletion. Among the railroads deleted are 5 of the surviving 15 Class I carriers in 1991 - the CNW, GTW, ICG, KCS, and SSW. Their data set also included 22 carriers that have since been merged or gone out of business.

TABLE A-2. Years of Observations in Data Sets for Various Rail Costing Studies

Railroad	UGPTI	Berndt et al.	Lee and Baumel	Caves et al.
ATSF	1978-89	1974-86	1983-84	1951-75
CNW	1978-89	1974-86	1983-84	Missing data
CR	1978-89	1977-86	1983-84	Not applicable
DRGW	1978-89	1974-85	1983-84	1951-75
FEC	1978-89	Missing data	1983-84	1951-75
ICG	1978-89	1974-86	1983-84	Missing data
KCS	1978-89	1974-86	1983-84	Missing data
SSW	1978-89	Missing data	1983-84	Missing data
SP	1978-89	1974-86	1983-84	1951-75
BN	1978-79	1974-79	Not applicable	1970-75
SLSF	1978-79	1974-79	Not applicable	Missing data
CS	1978-81	1974-81	Not applicable	Missing data
FWD	1978-81	1974-81	Not applicable	Missing data
BN1	1980-81	1980-81	Not applicable	Not applicable
BN2	1982-89	1982-86	1983-84	Not applicable
CO	1978-85	1974-80	1983-84	1951-75
BO	1978-82	Missing data	1983-84	1951-75
SCL	1978-82	1974-80	Not applicable	1951-75
CLN	Excluded (zero values)	Missing data	Not applicable	1951-75
LN	1978-82	Missing data	Not applicable	1951-75
WM	1978-81	Missing data	Not applicable	Missing data
SCL1	1983-85	Missing data	1983-84	Not applicable
BO1	1983-85	Missing data	Not applicable	Not applicable
CSX	1986-89	1981-86	Not applicable	Not applicable
GTW	1978-83	1975-86	1983-84	Missing data
DTI	1978-83	Missing data	1983	Missing data
GTW1	1984-89	Not applicable	Not applicable	Not applicable
NW	1978-84	1974-81	1983-84	1951-75
SOU	1978-82	1974-81	Not applicable	1951-73
AGS	1978-82	Missing data	Not applicable	Missing data

TABLE A-2. Years of Observations in Data Sets (continued)

Railroad	UGPTI	Berndt et al.	Lee and Baumel	Caves et al.
CGA	1978-82	Missing data	Not applicable	Missing data
CNTP	1978-82	Missing data	Not applicable	Missing data
SRS	1983-84	Missing data	1983-84	Not applicable
NS	1985-89	1982-86	Not applicable	1951-73
SOO	1978-84	1974-86	1983-84	1961-75
MILW	1978-84	Missing data	1983-84	1951-75
SOO1	1985-89	Not applicable	Not applicable	Not applicable
UP	1978-85	1974-82	1983-84	1951-75
MP	1978-85	1974-82	1983-84	1951-75
WP	1978-85	1974-82	1983-84	1951-75
MKT	1978-87	1974-86	1983-84	Missing data
UP1	1986-87	1983-86	Not applicable	Not applicable
UP2	1988-89	Not applicable	Not applicable	Not applicable
BLE	1978-83 (excluded 1984 for data validity)	Missing data	1983-84	Missing data
BM	1978-84, 86 (exclu ded 1985, 1987 for data validity)	Missing data	1983-84	1951-75
ROCK	Excluded for data validity	Missing data	Not applicable	1951-75
DH	1978-87	Missing data	1983-84	1951-75
DMIR	1978-82 (excluded 1983-84 for zero values)	Missing data	1983-84	Missing data
PLE	Excluded for data validity	Missing data	1983-84	Missing data

Lee and Baumel (1987) used all 55 observations available to them. Barbera et al. (1987) did not discuss the composition of their data set. Finally, Friedlaender and Spady (1981) used 57 of 130 observations from 20 of 44 Class I railroads. Six coal carriers (BO, CO, DRGW, LN, NW, and Reading Railway) were eliminated because they violated regularity conditions. The other omitted 18 carriers were not identified.

A.2 Definition of Variables

Before 1978, Class I railroads reported data under a different system of accounts. The old uniform system of accounts was generally less specific than the current system. There were fewer account definitions, resulting in more aggregated data. Before 1978, a single expense total was tabulated for a given account. Thus, accounts had to be separated between freight and passenger expenses before analysis could be performed. Under the current system, separate accounts are captured in natural expense accounts: salaries and wages, fuel, materials and supplies, etc. These natural expense accounts conform more closely to major factor inputs and obviate the need for artificial separation of expenses into labor, fuel, and materials.

The new system of accounts also contains improved operating or output reporting procedures. Railroad output measures, such as gross ton-miles and car-miles, are separated among unit train, through train, and way train. This separation allows direct incorporation of unit train production technology into rail cost models.

A.2.1 Total Variable Cost

Data from the annual R-1 Report, Schedule 410 provided the starting point for calculating total variable cost (TVC) (Table A-3). Operating cost (OPERCOST) is the sum of four principal cost categories - maintenance-of-way and structures (MWS), maintenance of equipment, transportation expense, and traffic and general expense. OPERCOST also can be subdivided into salaries and wages, materials and other costs, purchased services, and general expenses. Two major adjustments were made to OPERCOST.

TABLE A-3. Data Description and Sources

Variable	Description	Source
	OPERATING COSTS	
OPERCOST	Total operating cost	Sch 410, Line 620F
MOWLABOR	Maintenance of way (MWS) labor costs in Sch 410 for capitalized activities	Sch 410, Lines 6, 8-30, 101-6, 109, 111, Col B
MOWFRING	Associated MWS fringe benefits	Sch 410, Lines 112-114, Col E
ROICARS	ROI on owned cars	= NETOCARS*COSTKEQP (see equipment cost below)
ROILOCO	ROI on owned locomotives	= NETOLOCO*COSTKEQP (see equipment cost below)
TVC	Total freight cost adjusted for capitalized MWS labor/fringes and equipment opportunity cost	= OPERCOST - MOWLABOR - MOWFRING + ROILOCO + ROICARS
	FACTOR SHARES	
LABOR	Total cost of salary and wages	Sch 410, Line 620B
FRINGE	Fringe benefits, (excluding fringe benefits for MWS)	Sch 410, Lines 205, 224, 309, 414, 430, 505, 512, 522, 611, Col E
LABORADJ	Total labor cost less MWS labor plus fringe benefits	= LABOR - MOWLABOR + FRINGE
FUEL	Subtract the labor cost from fuel	(Sch 410, Line 409, Col F - Col B) + (Sch 410, Line 425, Col F - Col B)
EQUIP	total equipment cost	= CSTOLOCO + CSTLLOCO + CSTOCARS + CSTLCARS, see equipment cost below
MATSUP	material/supplies cost	= TVC - LABORADJ - FUEL - EQUIP
FSLABOR	Factor share for labor	= LABORAJD/TVC
FSFUEL	Factor share for fuel	= FUEL/TVC
FSEQUIP	Factor share for equipment	= EQUIP/TVC
FSMATSUP	Factor share for materials	= MATSUP/TVC
	EQUIPMENT COSTS	
COSTKEQP	URCS cost of capital for equipment	
IBOLOCO	Investment base in owned locomotives	Sch 415, Line 5, Col G
ACDOLOCO	Total accumulated depreciation in owned locomotives	Sch 415, Line 5, Col I

TABLE A-3. Data Description and Sources (continued)

Variable	Description	Source
NETOLOCO	Net investment base in owned locomotives	= IBOLOCO - ACDOLOCO
ANDOLOCO	Annual depreciation for owned locomotives	Sch 415, Line 5, Col C
CSTOLOCO	Equipment cost for owned locomotives	= ROILOCO + ANDOLOCO
IBOCARS	Investment base in owned cars	Sch 415, Line 24, Col G
ACDOCARS	Total accumulated depreciation in owned cars	Sch 415, Line 24, Col I
NETOCARS	Net investment base in owned cars	= IBOCARS - ACDOCARS
ANDOCARS	Annual depreciation for owned cars	Sch 415, Line 24, Col C
CSTOCARS	Equipment cost for owned cars	= ROICARS + ANDOCARS
RENTLOCO	Lease/rental payments for locomotives	Sch 415, Line 5, Col F
ANDLLOCO	Annual depreciation for leased locomotives	Sch 415, Line 5, Col D
CSTLCARS	Equipment cost for leased cars	RENTCARS + ANDLCARS
RENTCARS	Lease/rental payments for cars	Sch 415, Line 24, Col F
CSTLLOCO	Equipment cost for leased locomotives	RENTLOCO + ANDLLOCO
ANDLCARS	Annual depreciation for leased cars	Sch 415, Line 24, Col D
	FACTOR PRICES	
FUELGAL	Fuel gallons	Sch 750, Line 1, Col B
FUELPRCE	Price of fuel	FUEL/FUELGAL
LABRHRSC	Labor hours ala Caves	Wage Form A, Line 700, Col 4 + 6
PLADJC	Adjusted price of labor, Caves	LABORADJ/LABRHRSC
PEQUIP	a weighted equipment price	= POLOCO*(CSTOLOCO/EQUIP) + PLLOCO*(CSTLLOCO/EQUIP) + POCARS*(CSTOCARS/EQUIP) + PLCARS*(CSTLCARS/EQUIP)
PLLOCO	per unit price for leased locos	= CSTLLOCO/LEASLOCO
PLCARS	per unit price for leased cars	= CSTLCARS/LEASCARS
POLOCO	per unit price for owned locomotives,	= CSTOLOCO/OWNLOCO
POCARS	per unit price for owned cars	= CSTOCARS/OWNCARS
LEASLOCO	Number of locomotives leased	Sch 710, Line 10, Col I
LEASCARS	Number of cars leased	Sch 710, Line 53, Col J

TABLE A-3. Data Description and Sources (continued)

Variable	Description	Source
OWNCARS	Number of cars owned	Sch 710, Line 53 Col J
OWNLOCO	Number of locomotives owned	Sch 710, Line 10, Col H
PMATSUP or AARINDEX	Price of other materials/supplies	AAR - Railroad Materials and Supplies Index, indexed for eastern and western roads
	SIZE, OUTPUT, NETWORK VARIABLES	
MT_i	Miles of Track by Density Level	Sch 720 Lines 1-4, Col B
$DENSITY_i$	Millions of GTM per track mile	Sch 720 Lines 1-4, Col C
ALHG	Average length of haul that is consistent with Grimm, Lee, and Caves	= RTM/RTONS
RTM	Revenue ton-miles (use to calc ALHG)	Sch 755 Line 110, Col B
RTONS	Revenue tons (use to calc ALHG)	Sch 755 Line 105, Col B
UTF	Unit train factor (% unit train carmiles)	= UNITCM/CM
UNITCM or UTCM	Unit train carmiles (use to calc unit train factor)	Sch 755, Line 85, Col B
CM	Total carmiles (should be same as CARMILES)	Sch 755, Line 88, Col B
INTERLINE	Percent of traffic interlined	= 1 - CLOT/CLOR
CLOR	Carloads handled	QCS data
CLOT	Carloads originated/terminated	QCS data
MR	Miles of road	Sch 700, Line 57, Col C
GTM	Gross ton miles	Sch 755, Line 104, Col B

First, certain MWS expenses (MOWLABOR) include labor costs for investment activities, such as laying track, that should be capitalized. Thus, MOWLABOR and the associated fringe benefits (MOWFRING) are subtracted from OPERCOST. Second, opportunity costs for owned rolling stock (ROICARS and ROILOCO) was added to

OPERCOST. The costs were calculated as the product of the net investment base in owned cars and locomotives and the cost of capital for equipment (COSTKEQP). The COSTKEQP was obtained from the Uniform Rail Costing System (URCS).[2] The investment base in owned equipment is discussed in greater detail in a following paragraph.

A.2.2 Output and Size Measures

As discussed, the data employed in this analysis separate output into high and low density traffic and miles of track. Data are reported for miles of track (MT) and average annual traffic density in five classes.[3] The criterion for classification is annual freight density. Lines hauling more than 20 million gross ton-miles (GTM) per track mile are classified as class A lines. Classes B, C, D are defined as hauling 5-20, 1-5, and less than 1 GTM per track mile, respectively. Class E, way and yard switching track, is excluded from the analysis. Data for high density traffic and size are from classes A and B, while low density figures come from classes C and D.

A.2.3 Factor Shares

To obtain factor shares, TVC is subdivided into four general cost categories - LABOR, FUEL, EQUIP, and MATSUP. Some minor adjustments are made to the four cost categories. To be consistent with adjustments to TVC, LABOR is adjusted (LABORADJ) by subtracting MOWLABOR and adding fringe benefits (FRINGE).[4] For

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[2]Costs of capital for equipment for the early years in the sample were obtained through a conversation with the developer of the cost of capital for equipment at the ICC.

[3]These data are reported in Schedule 720, Track and Traffic Conditions. The data also include average running speed limit and track miles under slow orders.

[4]MOWFRING and FRINGE are mutually exclusive and collectively exhaustive. Thus, it was not necessary to subtract MOWFRING from LABOR.

FUEL, labor costs are subtracted from the Schedule 410 reported values for fuel expense. EQUIP is the sum of four classes of equipment cost - owned and leased locomotives, and owned and leased freight cars. Finally, MATSUP is calculated by subtracting LABORADJ, FUEL, and EQUIP from TVC.

The data to derive equipment cost is obtained from Schedule 415, Supporting Schedule for Equipment. A four step process was used to calculate the cost for owned rolling stock. First, the net investment base is obtained as the difference between investment base and total accumulated depreciation. For example, for railroad owned locomotives, NETOLOCO equals IBOLOCO less ACDOLOCO. Second, an opportunity cost (e.g., ROILOCO) is obtained as the product of the net investment base and the URCS cost of capital for equipment. Third, an annual depreciation cost (e.g., ANDOLOCO) for the type of equipment is obtained from Schedule 415. Finally, owned equipment cost is the sum of the opportunity cost and the depreciation cost, (i.e., CSTOLOCO equals ROILOCO plus ANDOLOCO). There is one difference when calculating ownership costs for leased equipment. Annual lease payments are used instead of calculating an opportunity cost.

A.2.4 Factor Prices

Different measures have been used to calculate the price of labor (PLABOR). LABORADJ is the value used for the cost of labor. Hours are reported for Total Hours Worked and for Total Hours Paid For. Total Hours Worked are the hours for straight time and overtime. This measure was used by Friedlaender and Spady (1981) and Caves et al. (1985). To this value, Total Hours Paid For adds the time for vacations and other allowances, such as arbitraries. This measure was used by Barbera et al. (1987). The value for Total Hours Paid For is analogous to LABORADJ because it measures the time chargeable to operating expenses. Thus, our measure of PLABOR uses Total Hours Worked as the denominator, or the same measure as Friedlaender and Spady (1981) and Caves et al. (1985).

Fuel price (PFUEL) is the quotient of FUEL and gallons of diesel (FUELGAL). It is virtually the same variable as that used by Barbera et al. (1987). As the actual average fuel price paid by carriers, PFUEL reflects the purchasing power of larger carriers and those carriers with more fuel-efficient locomotive fleets. This measure is much richer than that used by Friedlaender and Spady (1981), Lee and Baumel (1987), and Berndt et al. (1991), which all used a regional fuel price index. The complex measure of BTUs as developed by Caves et al. (1985) is not necessary in this study because diesel fuel is predominant. Their study captured the change from steam to diesel power.

A weighted equipment price (PEQUIP) was calculated for the four types of rolling stock. An individual price was calculated for each type of equipment as the quotient of the equipment cost by class and the number of units. For example, the price of owned locomotives (POLOCO) = CSTOLOCO/OWNLOCO, where CSTOLOCO is the annual equipment cost for owned locomotives and OWNLOCO is the number of owned locomotives. The four classes of equipment prices are then weighted by the proportion of the classes' equipment cost of total equipment cost.

Friedlaender and Spady (1981) and Berndt et al. (1991) are the only other studies that included an equipment price. Friedlaender and Spady (1981) calculated a rental price of equipment as:

$$w_e = (r + d)p_k$$

"where r is an interest rate, d a depreciation rate of 5 percent, and p_k the GNP deflator for price of rail equipment. Interest rates for each railroad were calculated from *Moody's Transportation Annual* by using the appropriate index of yields for each road's lowest- (i.e., worst-) rated equipment trust certificate."

However, if the carrier did not report a bond price, the observation was deleted from the data set. As previously discussed, this selection process led to a systematic exclusion of smaller Class I carriers. Berndt et al. (1991) "constructed a rental price for equipment, allowing both for equipment depreciation and the cost of floating equipment trusts, the most common form of rolling stock financing." However, they also deleted observations that did not have equipment trust bond prices.

The price for materials and supplies (PMATSUP) is the AAR Railroad Materials and Supplies Index. This value is indexed for eastern and western railroads. Similar indices have been used in all the rail costing studies.

A.2.5 Mergers

There are six remaining Class I carriers that have emerged from one or more mergers since 1978.[5] It is difficult to judge the effective date of a merger through *Moodys* or a review of R-1 data. Thus, we spoke with an official from each of the surviving carriers and asked them to identify when the carriers involved in mergers were effectively merged from an operational perspective. As a result, the dates of our mergers are not entirely consistent with those of Berndt et al. (1991). However, the identification of "effective" merger dates is absolutely critical to recognize correctly either firm effects or merger effects.[6]

The Burlington Northern has acquired three other carriers since 1978 (Table A-2). In 1979, the BN merged with the SLSF. In 1981, the BN acquired the CS and the FWD. Our definition of the BN mergers is consistent with Berndt et al.'s (1991).

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[5] The term merger is defined broadly to include all types of acquisitions, mergers, etc.

[6] In estimating a model with firm effects, a new firm is usually defined after the a major merger and the "old" firms are typically replaced, empirically, with the new firm.

We are not sure how Berndt et al. (1991) developed the mergers for the CSX. They report separate data for the Chessie and Seaboard Systems from 1974 to 1980. They then report two separate CSX systems, the first for 1981 to 1982 and the second from 1983 to 1984. According to CSX officials, this merger did not occur from an operational perspective until 1985. The BO and CO have operated as the Chessie since the mid-1970s. While separate R-1 reports have been filed for the CLN, LN, and WM, they have been operationally integrated throughout the sample. Thus, our data only has one merger, that between the Chessie (CO and BO) and the SCL, beginning in 1986.

The Norfolk Southern has a similar background. The small Class I carriers affiliated with the Southern - CGA, AGS, and CNTP - have long been considered operationally integrated as part of the Southern. Thus, our data include separate firm effects and a company effect for these carriers. Berndt et al. (1991) correctly find that the Norfolk Southern merger was effective in 1982. However, separate R-1 reports were filed through 1985. From an operations perspective, the NS was gradually integrated. Thus, our data has separate company variables for Norfolk and Southern for 1983 and 1984. We also introduce merger dummy variables for these years to capture the effects of the partial mergers.

The Union Pacific provides another example of a phased merger. Separate R-1 data were reported for the UP, MP, and WP through 1985. However, those three carriers merged on paper in 1982. The data reflects the separate firm data through 1985, with merger dummy variables for 1984 and 1985. The UP was involved in a second merger, with the MKT, in 1988.

Finally, our data includes two mergers that Berndt et al. (1991) chose not to include in their data. They most likely excluded the Soo's acquisition of the Milwaukee

Road because of the latter's bankruptcy. Similarly, they probably excluded the GTW merger with DTI because no bond prices are available for the DTI.

APPENDIX B

SUMMARY OF TESTS, SPECIFICATION ISSUES, AND FIT

The cost variable and all righthand side variables except time and the deregulation dummy were normalized around the overall sample means. All estimation was carried out using iterated seemingly unrelated regressions or three stage least squares. Inspection of the residuals did not suggest the presence of either serial correlation or heteroskedasticity. Few authors find the presence of serial correlation using annual railroad data, and our attempts at identifying any serial correlation are consistent with the previous research. With respect to heteroskedasticity, we followed others by weighting the system by various size variables (e.g., Miles of Road, Miles of Track, etc). These results are nearly identical to the results reported for the unweighted system.

Before presenting the empirical results, we first identify our specification tests. First, we tested whether using betterment data (measured with error) results in significant bias. Second, a test was performed to determine whether treating output variables as exogenous results in significant bias. Finally, a set of tests were designed to yield the final model(s) reported.

First, the Wald tests of errors in variables[1] yielded Chi-square statistics that did not suggest that the use of betterment data, with the adjustments discussed in Appendix A, introduce significant bias. In performing this test, we employed a Hausman specification test where variables measured using depreciation based accounting data were used as instruments for variables measured using betterment accounting data. We then estimated the cost model and factor shares using iterated seemingly unrelated regression and then estimated the system using iterated three stage least squares.[2] The

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[1] In performing this test we are limited to only 1983 to 1987 data. The deregulation dummy variable was therefore restricted to zero in performing the test.

[2] As instruments we used a regional dummy variable, gross national product, truck fuel prices, truck equipment prices, and truck wages.

Chi-square test statistic was 1.215 and 1.272 in specifications 1 and 2, respectively. These statistics are considerably lower than the corresponding critical value with 90 degrees of freedom. Therefore, the null hypothesis that no bias is introduced by treating using betterment accounting data cannot be rejected.

We also introduced intercept dummy variables into the models reported later using all the data. These dummy variables are designed to capture any systematic differences in measurement of the cost variable. The dummy variables took a value of 0 before the change from betterment to depreciation based accounting (1983) and a value of 1 after the change in accounting base. In neither case did we find that the t-statistic on the dummy variable was statistically different from zero.

Second, several tests were performed evaluating the possible bias introduced by treating output and certain characteristics as endogenous were performed. The test statistics again were based on a Wald-statistic and followed Hausman (1978). We estimated the system using iterated seemingly unrelated regressions under the presumption that no bias is introduced by treating some variables (see below) as exogenous. The same system was then estimated under the alternative hypothesis, that significant bias is introduced, using iterated three stage least squares. In specification 1, we first treated high and low density gross ton-miles and the unit train factor as endogenous. The Chi-square statistic for this test was 10.3. We then treated high and low density gross ton-miles and average length of haul as endogenous. The Chi-square statistic for this test was 26.8. In specification 2, treating revenue ton-miles, the load factor (RTM/GTM), and ALH as endogenous yielded a Chi-square statistic of 15.23, while treating RTM, RTM/GTM, and the unit train factor as endogenous resulted in a Chi-square statistic of 12.37. In tests performed, the Chi-square statistic was distinctly lower than the critical value for 90 degrees of freedom.

Given the number of parameters in the system, we attempted to place greater structure on the system by constraining non-price and non-time and non-regulatory status interaction terms to zero. In no case did the corresponding F-statistics suggest that these constraints could be placed on the data. All hypotheses could not be accepted at the 10 percent level.

As a last specification issue, we introduced firm specific dummy variable in the models. Following the pioneering research of Caves et al. (1985), these dummy variables may pick up the effects of unobserved network characteristics. Following their research, a dummy variable is introduced into the cost specification for each firm in the sample. If a major merger occurred, the firms comprising the merger are redefined as a single new firm for the period *in which the firms first report consolidated R-1 reports.* Specifically, when a new firm is defined is difficult to assess. Many alternatives are clear. These include when the merger was announced, when operations are consolidated, or when the data for the combined system are reported.

We choose a combination of the latter two definitions. Specifically, we retained the old firms identities until the data reported are consolidated. However, we introduce merger dummy variables for each firm from the time the operations are consolidated to capture any transitory efficiencies that are gained. The result is the addition of 35 more dummy variables into the specification resulting in 125 parameters to estimate.

We do not report these results. In our specifications, we have several network variables. When we perform the estimation with firm variables, the t-statistics on our network variables and our time and deregulating variables become extremely small, while the remaining coefficients remain about the same levels. A possible explanation is that these "network" dummy variables are extremely collinear with the observed network variables. There are not enough time series observations to identify efficiently the effects of these variables.

TABLE B-1. Coefficient Estimates for all Parameters for Specification 1.

Variable	Parameter	Estimate	Std Error	t-Value
Constant	INTERCEPT	0.264448	0.04349	6.08
High Density GTM	Q1	0.765329	0.07629	10.03
Low Density GTM	Q2	0.122094	0.03815	3.20
High Density MT	K1	0.146405	0.09135	1.60
Low Density MT	K2	0.017348	0.06022	0.29
Labor Price	W1	0.430248	0.00651	66.05
Equipment Price	W2	0.183142	0.00653	28.01
Fuel Price	W3	0.090512	0.00246	36.66
Matls. & Supplies	W4	0.296097	0.00676	43.78
1-% Unit Train	T1	0.325625	0.14194	2.29
% Interline	T2	0.005841	0.11072	0.05
ALH	T3	-0.460385	0.06969	-6.61
Time	T4	-0.022385	0.01828	-1.22
Deregulation	T5	0.170760	0.09194	1.86
	Q1Q1	-0.109336	0.13569	-0.81
	Q1Q2	0.029697	0.05083	0.58
	Q2Q2	0.007430	0.02180	0.34
	K1K1	0.264601	0.21362	1.24
	K1K2	-0.153804	0.09695	-1.59
	K2K2	0.025945	0.06625	0.39
	W1W1	0.102422	0.01253	8.18
	W1W2	0.003960	0.00478	0.83
	W1W3	-0.029914	0.00396	-7.55
	W1W4	-0.076468	0.01334	-5.73
	W2W2	0.009452	0.00566	1.67
	W2W3	-0.008497	0.00154	-5.50
	W2W4	-0.004915	0.00586	-0.88
	W3W3	0.074187	0.00534	13.88
	W3W4	-0.035775	0.00770	-4.66
	W4W4	0.117159	0.01853	6.34
	T1T1	0.124670	0.28935	0.43
	T1T2	1.735355	0.48309	3.59
	T1T3	0.615938	0.31953	1.93
	T1T4	0.065500	0.02086	3.14
	T1T5	-0.138896	0.09975	-1.39
	T2T2	-0.125762	0.17076	-0.74
	T2T3	-0.237048	0.11643	-2.04
	T2T4	0.001608	0.01546	0.10
	T2T5	-0.096567	0.06692	-1.44

TABLE B-1 (continued)

Parameter	Estimate	Std Error	t-Value
T3T3	-0.012044	0.13710	-0.09
T3T4	0.001870	0.01166	0.16
T3T5	0.048249	0.06311	0.76
T4T4	0.004917	0.00302	1.63
T4T5	-0.050201	0.02439	-2.06
Q1K1	0.038538	0.16647	0.23
Q1K2	0.043360	0.08350	0.52
Q2K1	0.006975	0.05996	0.12
Q2K2	-0.009812	0.03802	-0.26
Q1W1	0.000914	0.01114	0.08
Q1W2	0.012420	0.01150	1.08
Q1W3	0.009736	0.00372	2.61
Q1W4	-0.023071	0.01151	-1.98
Q2W1	-0.001284	0.00524	-0.24
Q2W2	-0.001435	0.00538	-0.27
Q2W3	-0.006748	0.00175	-3.85
Q2W4	0.009467	0.00537	1.73
Q1T1	-1.133040	0.19378	-5.85
Q1T2	0.348544	0.16009	2.18
Q1T3	0.282903	0.08971	3.15
Q1T4	0.012462	0.01525	0.82
Q1T5	-0.111777	0.07919	-1.41
Q2T1	-0.101307	0.10875	-0.93
Q2T2	-0.020187	0.04463	-0.45
Q2T3	-0.041307	0.05492	-0.75
Q2T4	0.000323	0.00678	0.05
Q2T5	-0.031861	0.04639	-0.69
K1W1	-0.021574	0.01314	-1.64
K1W2	0.021952	0.01346	1.63
K1W3	-0.007176	0.00438	-1.64
K1W4	0.006798	0.01349	0.47
K2W1	0.034118	0.00844	4.04
K2W2	-0.018880	0.00861	-2.19
K2W3	-0.000346	0.00282	-0.12
K2W4	-0.014891	0.00863	-1.71
K1T1	1.322906	0.29372	4.50
K1T2	-0.011933	0.17592	-0.07
K1T3	-0.416275	0.11303	-3.68
K1T4	-0.011390	0.01831	-0.62
K1T5	0.099025	0.09516	1.04
K2T1	0.140699	0.17779	0.79
K2T2	-0.182668	0.06177	-2.96
K2T3	0.131724	0.08149	1.62
K2T4	-0.004942	0.01075	-0.46
K2T5	0.047221	0.06993	0.68

TABLE B-1 (continued)

Parameter	Estimate	Std Error	t-Value
W1T1	0.062177	0.01479	4.20
W1T2	0.006286	0.00957	0.66
W1T3	-0.061672	0.00927	-6.65
W1T4	-0.001710	0.00151	-1.13
W1T5	-0.000405	0.00970	-0.04
W2T1	0.062381	0.01533	4.07
W2T2	0.028887	0.00978	2.95
W2T3	-0.021285	0.00952	-2.24
W2T4	-0.009701	0.00145	-6.65
W2T5	0.051269	0.00956	5.36
W3T1	-0.043649	0.00494	-8.84
W3T2	-0.003491	0.00321	-1.09
W3T3	0.034118	0.00311	10.94
W3T4	0.000640	0.00068	0.94
W3T5	0.000434	0.00366	0.12
W4T1	-0.080908	0.01517	-5.08
W4T2	-0.031681	0.00986	-3.37
W4T3	0.048838	0.00961	5.18
W4T4	0.010770	0.00161	6.66
W4T5	-0.051298	0.01007	-5.09

Fit-R-Square:

COST	97.58
S1-Labor	38.37
S2-Equipment	27.35
S3-Fuel	72.31
S4-Matl. & Supplies	40.47

TABLE B-2. Coefficient Estimates for all Parameters for Specification 2.

Variable	Parameter	Estimate	Std Error	t-Ratio
Constant	INTERCEPT	0.255807	0.04489	5.70
RTM	Q1	0.897111	0.05764	15.57
RTM/GTM	Q2	-1.007475	0.22823	-4.41
Miles of Road	K1	0.237516	0.05764	4.12
Speed Rating	K2	0.222044	0.17432	1.27
Labor	W1	0.419884	0.00669	62.69
Equipment	W2	0.187222	0.00595	31.45
Fuel	W3	0.091991	0.00251	36.55
Mtl. & Supplies	W4	0.300903	0.00667	45.10
1-% Unit Train	T1	0.432590	0.16289	2.66
% Interline	T2	0.089161	0.13138	0.68
ALH	T3	-0.554196	0.07869	-7.04
Time	T4	-0.036865	0.01929	-1.91
Deregulation	T5	0.268910	0.09298	2.89
	Q1Q1	-0.108994	0.07974	-1.37
	Q1Q2	0.224958	0.16842	1.34
	Q2Q2	2.123792	1.14994	1.85
	K1K1	-0.275385	0.06743	-4.08
	K1K2	0.027671	0.12226	0.23
	K2K2	-0.921146	0.49940	-1.84
	W1W1	0.106590	0.01294	8.23
	W1W2	0.001462	0.00490	0.30
	W1W3	-0.032064	0.00380	-8.42
	W1W4	-0.075989	0.01353	-5.62
	W2W2	0.013415	0.00515	2.60
	W2W3	-0.007819	0.00141	-5.52
	W2W4	-0.007058	0.00559	-1.32
	W3W3	0.075910	0.00518	14.64
	W3W4	-0.036026	0.00735	-4.93
	W4W4	0.119073	0.01832	6.53
	T1T1	-0.388901	0.50796	-0.77
	T1T2	1.193248	0.56133	2.13
	T1T3	1.273100	0.33322	3.82
	T1T4	0.051051	0.02864	1.78
	T1T5	-0.230775	0.10747	-2.15
	T2T2	-0.053092	0.23302	-0.23
	T2T3	-0.187453	0.13955	-1.34
	T2T4	-0.025550	0.01598	-1.60
	T2T5	-0.122770	0.07596	-1.62
	T3T3	-0.112236	0.16854	-0.67
	T3T4	0.009694	0.01198	0.81
	T3T5	0.032314	0.07211	0.45
	T4T4	0.009032	0.00303	2.98
	T4T5	-0.071419	0.02442	-2.93
	Q1K1	0.217920	0.06427	3.39

TABLE B-2 (continued)

Parameter	Estimate	Std Error	t-Ratio
Q1K2	0.089530	0.13403	0.67
Q2K1	-0.470354	0.15423	-3.05
Q2K2	1.195836	0.56478	2.12
Q1W1	-0.030546	0.00743	-4.11
Q1W2	0.043315	0.00672	6.44
Q1W3	0.012552	0.00249	5.04
Q1W4	-0.025320	0.00741	-3.38
Q2W1	-0.054382	0.02837	-1.92
Q2W2	0.107137	0.02554	4.19
Q2W3	-0.046677	0.00950	-4.91
Q2W4	-0.006078	0.02786	-0.13
Q1T1	-0.979524	0.17941	-5.46
Q1T2	0.659920	0.14511	4.55
Q1T3	0.044560	0.08363	0.53
Q1T4	-0.024291	0.01070	-2.27
Q1T5	-0.006035	0.04824	-0.13
Q2T1	-0.187632	0.83118	-0.23
Q2T2	-1.483015	0.28462	-5.21
Q2T3	-0.066162	0.30378	-0.22
Q2T4	-0.047328	0.04154	-1.14
Q2T5	0.321168	0.19859	1.62
K1W1	0.056219	0.00745	7.54
K1W2	-0.044264	0.00675	-6.55
K1W3	-0.019607	0.00249	-7.85
K1W4	0.007652	0.00748	0.95
K2W1	0.012409	0.02036	0.61
K2W2	0.094605	0.01845	5.13
K2W3	-0.022288	0.00680	-3.27
K2W4	-0.084725	0.01994	-4.27
K1T1	0.997291	0.24841	4.01
K1T2	-0.603689	0.12954	-4.66
K1T3	0.007543	0.08840	0.09
K1T4	0.010261	0.01090	0.94
K1T5	0.008977	0.04843	0.19
K2T1	-1.501781	0.62830	-2.39
K2T2	-0.356235	0.27660	-1.29
K2T3	-0.218585	0.18440	-1.19
K2T4	0.001866	0.03131	0.06
K2T5	0.052993	0.14885	0.36
W1T1	0.046147	0.01588	2.91
W1T2	-0.003527	0.00963	-0.37
W1T3	-0.077261	0.01045	-7.39
W1T4	-0.001440	0.00155	-0.93
W1T5	-0.001607	0.00981	-0.16
W2T1	0.088622	0.01445	6.13

TABLE B-2 (continued)

Parameter	Estimate	Std Error	t-Ratio
W2T2	0.038895	0.00871	4.46
W2T3	-0.016866	0.00953	-1.77
W2T4	-0.009791	0.00132	-7.40
W2T5	0.055691	0.00854	6.51
W3T1	-0.053679	0.00532	-10.09
W3T2	-0.001144	0.00322	-0.35
W3T3	0.036180	0.00348	10.37
W3T4	0.000836	0.00068	1.23
W3T5	-0.001155	0.00366	-0.32
W4T1	-0.081090	0.01558	-4.93
W4T2	-0.034223	0.00945	-3.77
W4T3	0.057946	0.01044	5.69
W4T4	0.010394	0.00158	6.52
W4T5	-0.052928	0.00974	-5.41

Fit-R-Square:

Cost	98.70
S1-Labor	38.15
S2-Equipment	43.52
S3-Fuel	72.07
S4-Matl. & Supplies	42.13