Railroad Economies of Scale, Scope, and Density Revisited
Author(s): C. Gregory Bereskin
Source: *Journal of the Transportation Research Forum*, Vol. 48, No. 2 (Summer 2009), pp. 23-38
Published by: Transportation Research Forum
Stable URL: http://www.trforum.org/journal

Railroad Economies of Scale, Scope, and Density Revisited

by C. Gregory Bereskin

The movement of freight on railroads is subject to a number of technological characteristics that make costing of specific traffic a complex process. Among these restrictions are conditions of joint production, economies of scale, scope, and density, and a lack of data on specific expenditures related to individual freight movements.

In this paper, an econometric cost model using publicly available data and methodology is developed for the examination of average and marginal costs in the industry. The model is decomposed into individual elasticity estimates for operating parameters to examine economies of scope. Finally, the size of the firm is varied through multiplying the capital stock measurements and estimating the cost behavior as firm capital stock is varied between one-quarter and two times the level of 2005.

Results indicate that the railroad industry has effectively exhausted the possible economies of scale but can still gain from economies of density and scope. In addition, there appears to be little economic justification for mergers creating transcontinental railroad systems.

INTRODUCTION

Rail freight movements, like most transportation services, are subject to a number of technological characteristics that make costing of specific traffic a complex process. Among these restrictions are conditions of joint production, economies of scale, scope, and density, and a lack of data on specific expenditures related to individual freight movements. As a result, historic rail costing has been divided into two general areas.

The first area is movement costing, which has traditionally involved the use of accounting-based allocative costing models, such as the Uniform Rail Costing System (URCS) originally developed by the Interstate Commerce Commission for use in regulatory hearings and currently in use by the Surface Transportation Board. The URCS relies on simple linear relationships in order to evaluate specific railroad costs. This costing system has not been updated since the 1980s.

The second area of rail cost analysis consists of economic models of railroad activity. In general, these studies have been aimed at characterizing the underlying economic nature of costs with little or no application to the cost of providing a specific service. Most of the research has concentrated on either productivity gains resulting over time or due to mergers, as in the studies of Caves, Christensen and Swanson (1980, 1981a, 1981b, 1981c) and Bereskin (1996), or on the general shape of the cost function and the resulting economies of scale, scope, or density, as in the models of Spady (1979); Spady and Friedlaender (1976); Friedlaender and Spady (1980); Bereskin (1983); Barbara, Grimm, Phillips and Seltzer (1987); and Lee and Baumel (1987). Oum and Waters (1996) discussed the status of transportation cost study advances over the prior two decades and described various refinements in the modeling methodology that has allowed researchers to further test for economies of scale and scope, as well as productivity growth. All of these studies generally agree in their conclusions that the railroad industry has been achieving productivity gains both over time and through mergers, and that rail costs are decidedly non-linear in nature.

The Barbara, Grimm, Phillips and Selzer study (1987) is primarily concerned with directly estimating the cost relation in order to test hypotheses concerning economies of scale and density in the industry, and thus estimates only the cost function. Alternatively, Lee and Baumel (1987) deal with a simultaneous estimation of both the cost and demand functions for rail services for the years

1983 and 1984. In this study, the translog function is used as a Taylor series approximation to an unknown underlying cost function while the demand function, being a derived relationship, is modeled as a Cobb-Douglas structure. Both studies find that economies of density exist, although the estimates obtained by Lee and Baumel (1987) are significantly lower than for Barbara, Grimm, Phillips and Selzer (1987). Additionally, both agree that returns to scale appear to be insignificant. One problem with the analysis is that the proxy variable used for the size of capital stock in each of these studies is miles-of-road, an approximation that may introduce a bias into the results, as miles-of-road fails to address the condition and level of quality of the roadway capital.

More recently, in an effort to determine the effects of density and railroad mergers on costs, Ivaldi and McCullough (2001) have estimated a translog model of short-run railroad costs using different types of car-miles as a measure of traffic. They find three implications for railroads that are of interest here. First, Class I railroads have returns to density. Second, there are significant second order effects among railroad operational outputs. Third, there are vertical cost relationships between freight operations and infrastructure operations. All of these conclusions are consistent with the findings of this paper. Alternatively, in an effort to explain productivity growth in the deregulated industry, Bitzen and Keeler (2003) have applied both miles-of-road and developed price indices for right-of-way capital structure, as well as for equipment capital to explain the effects of capital within railroad costs. They conclude that railroad productivity growth has continued at much the same rate as it grew in the decade immediately following deregulation. A major distinction between this analysis and earlier models is in the use of a vector of intermediate output or operating measures to define the railroads outputs. This compares with the use of either a single output measure or the use of proxy instruments to measure output in earlier studies.

METHODOLOGY

The Cost Function

Duality between the cost and production functions indicates that any well-behaved technology may be described equally well via the use of either function. Following the general methodology of the development of short-run as opposed to long-run cost functions, the costing optimization criteria for the firm in the general case will be defined as:

(1) $C_L(Q,P,T) = \text{Min } (P * X)$ Subject to $F(X;T) = Q$

where $Q = (Q_1,Q_2,. . . ,Q_N)$ is a vector of intermediate measures of output[1] that, when combined, define the characteristics of the final output;[1] $P = (P_1, P_2, . . ., P_M)$ is a vector of factor input prices such that p_j is the price of factor input x_J, included in the vector of input factors X; and T is the vector of technological factors that may vary across railroads and over time. This function must be considered a long-run function, as all inputs are assumed to be variable.

Since firms are generally not operating in the long-run but rather have some (effectively) fixed factors, the emphasis here will be on short-run analysis. It is possible, without loss of generality, to assume that the first factor (x_1) is fixed. The short-run cost function may then be written as:

(2) $C(Q, P^1, x_1; T) = p_1 * x_1 + C (Q , P^1, x_1; T)$

where P^1 is the vector of prices less the fixed factor price. This then leads to a short-run cost function of the form:

(3) $C = C (Q , P^1, x_1; T)$.

For purposes of this analysis, the cost function will be modeled using the translog specification. The translog function is one of a group labeled flexible functional forms, which have been shown to be approximations of unknown underlying functions. As such, the translog has been applied extensively in cost analysis for its desirable characteristics.

Technological Variations in the Model

Technological variation (other than that implied by the structure of the model itself) both over time and across firms is of importance in the development and estimation of the model. It is assumed that these variations may be described as the combination of two terms, one relating to time and a second relating to inter-firm differences. The time-shift factor is assumed to account for technological changes in the production process that are occurring over time and are thus directly reflective of the rate of change in productivity.

The inter-firm variations are accounted for by shift parameters on a firm by firm basis. For notational simplicity, these terms have been included in the technology vector T above and are reflective of the differences in operating philosophy, territory, terrain, local conditions and the mix of traffic. This would cause the commonly defined output variable to be slightly different across firms, rather than being directly reflective of the economies that may occur from the combination of firms. For purposes of simplification, these variations will be assumed Hicks neutral (production is neither labor nor capital augmenting), so that an increase in all input factor prices by the same percent will allow costs also to increase by "x" percent. This allows the cost function to be written:

(4) $C = (Q, P^1, x_1; T) = h(T) * C(Q, P^1, x_1)$

A further assumption is that the time and industry portions of this vector are multiplicative in nature, so that the technology function may be developed as:

(5) $h(T) = e^{time} * h_f(T)$

where the subscript f refers to the individual firm variable.

By substitution of (5) into (4) and taking the natural log of (4), the cost function becomes:

(6) $\ln C = time + \ln h_f(T) + \ln C(Q, P^1, x_1)$

which, in its translog form exclusive of the time and technology shift parameters, may be written as equation (7), where the K values are measures of the firm capital stock (for roadway capital and equipment capital) developed using the analysis of Bereskin (2007) and are assumed to be fixed factors in the short-run.

(7)
$$\ln C = a_{00} + \sum_{i=1}^{N} a_i \ln Q_i + a_{k_1} \ln K_1 + a_{k_2} \ln K_2 + \sum_{j=1}^{M} a_j \ln P_j^1$$
$$+ \sum_{i=1}^{N}\sum_{k=1}^{N} b_{ik} \ln Q_i \ln Q_k + \sum_{i=1}^{N}\sum_{l=1}^{2} b_{ik_l} \ln Q_i \ln K_l$$
$$+ \sum_{j=1}^{M}\sum_{n=1}^{2} b_{jk_n} \ln K_n \ln P_j^1 + \sum_{i=1}^{N}\sum_{j=1}^{M} b_{ij} \ln Q_i \ln P_j^1$$
$$+ \sum_{j=1}^{M}\sum_{l=1}^{M} b_{jm} \ln P_j^1 \ln P_m^1$$

Use of the translog function requires that certain restrictions are met in order to ensure that the cost function is well behaved, as required by economic theory. One implication is that the cost function should be linearly homogeneous. As such, the regression model requires restrictions on the coefficients within the cost equation. These restrictions are:

(8a) $$\sum_{j=1}^{n} a_j = 1$$

and

(8b) $$\sum_{j=1}^{M} b_{jk} = 0 \quad \forall\, k = \mathrm{K_k};\, i = 1,\ldots,N\,;\, j = 1,\ldots,M$$

where the a_j terms correspond to the coefficients on the linear price terms of the translog equation, and the b_{jl} values are the coefficients for the quadratic price variables in the translog specification. Symmetry conditions indicate that $b_{jl} = b_{lj}$.

The variables included in the model are described in Table 1. Four input prices are included: the prices of labor (as measured by wages and supplements), the price of materials and supplies index, and the price of other items indicated by the Association of American Railroads (AAR) index for other expenses. Indexes are used since input prices for specific railroads for 20 years are not available. Output is measured by a combination of intermediate operating measures: gross-ton-miles, car-miles, train-miles, locomotive-horsepower-miles and total-switching-hours. Through the use of five measures of output simultaneously, it is expected that the cost differences due to varying traffic patterns may be sufficiently accounted for.[2]

In much of the transportation literature, plant size is accounted for by the measure of miles-of-road operated. A potential problem exists in the use of miles-of-road as a proxy for capital in that the railroads may invest in the roadway structure, upgrading their potential to haul traffic while abandoning unprofitable or little used lines. Rather than using miles-of-road to measure the size of the railroad for this analysis, two measures of capital stock were adopted: one for roadway capital and one for equipment capital. These were created by applying the models set forth in the research of Bereskin (2007). In this methodology, equations for both degradation and investment in railway capital for roadway and for equipment are estimated and then simulated using the actual operating parameters for the individual railroads. Using a simple difference equation, an estimate for capital stock in each period may be developed from the preceding period's value. Thus, the two capital stock measures include some value related to miles-of-roadway but go far beyond to also include the potential for better quality of existing roadway, as was found by Bereskin (2007), where capital stocks were estimated to be increasing while miles-of-road was seen to be decreasing.

Finally, one additional variable was added, that being the number of shipper-owned cars. As the number of shipper-owned cars increases, there is less need for the railroad firms to invest in their own equipment capital. This variable was also used in the estimation process for capital stock.

DEVELOPMENT OF SPECIFIC COSTS

Average Costs

Development of average costs for the firm is a straight forward process of evaluating total cost based on some specification of railroad operating parameters and dividing by the level of a chosen operating parameter. As applied here, average costs will be denoted in terms of dollars per gross-ton-mile. Other measures, such as car-miles or train-miles, could be applied as easily, but gross-ton-miles (GTMC) appears to be the most appropriate.

Table 1: Definition of Variables

C = TOT_EXP	Total railroad operating expenses
GTMC	Gross-ton-miles of cars contents and cabooses for firm f at time t (in millions)
CM:	Car-miles for firm f at time t
TM:	Train-miles for firm f at time t
THP	Thousands-of-horsepower-miles (locomotive unit miles x average horsepower)
THS	Total-switching-hours (road switching + yard switching)
K_RD	Estimated value of Road Capital*
K_EQ	Estimated value of Equipment Capital*
PF:	Price index for fuel (applicable only to the transportation sector)
PWS:	Price index for wages and supplements
PMS:	Price index for materials and supplies
PO:	Price index for other operating expenses
D_rr_#	Separate dummy variables representing firms. Where mergers have occurred, each firm is indicated by a pre-merger number and a post merger number. Mergers are assumed to have occurred when the reporting entities are changed.
D_rr_sc#	Dummy variable to account for special charges to expenses as taken by a specific railroad in a specific year. Some railroads have booked more than one special charge.
Time	Time variable for underlying productivity trend experienced over the whole data period
Scar	Number of shipper owned cars

* Developed in Bereskin (2007)

** The natural log of any of the specific mnemonics above is indicated by prefixing with the letter L. For example: LMOW = log (MOW). This convention will be followed throughout the paper. Squared terms are indicated by a 2 at the name end, while cross terms are indicated by a combination of the two names with the second 'L' deleted. For example, LGTMC * LCM = LGTMCM and LCM * LCM = LCM2.

*** The Illinois Central railroad has been deleted from the sample for the year 1997, a year in which the railroad reported zero switching hours. Conrail, Norfolk Southern, and CSX have been deleted from estimation for 1999 due to their merger activity.

Marginal Costs

Because of the joint production nature of railroad operations, the estimation of marginal costs is somewhat more complex than the process of averaging the total cost estimate. This is especially true when the cost model simultaneously uses multiple measures of activity to describe the complex nature of railroad activity. Bereskin (2001) has applied the use of partial elasticity estimates computed from the translog cost function to evaluate costs for various train types. The partial elasticity estimates were multiplied by the percentage changes in operating parameter levels, due to the marginal operation of hypothetical trains to develop marginal costs. Average costs were then estimated by assuming that, for averaging, all parameters were changed by the same percentage, allowing for summing of the elasticity values and dividing the marginal cost estimate by this value. For this study, this method will be used in reverse.

From the translog total cost function, the total differential may be developed as

$$(9)\quad d\ln C = \sum_{i=1}^{n}\left(\frac{\partial \ln C}{\partial \ln q_i} * d\ln q_i\right) + \sum_{k=1}^{2}\left(\frac{\partial \ln C}{\partial \ln K_k} * d\ln K_k\right) + \sum_{j=1}^{m}\left(\frac{\partial \ln C}{\partial \ln p_j^1} * d\ln p_j^1\right)$$

where technology for a given firm during a given period of time is fixed. As the analysis is initially concerned with the short-run, it is also appropriate to assume that the capital stock measures (K_k) and input prices are fixed as well, so that:

(10) $$d \ln C = \sum_{i=1}^{n} \left(\frac{\partial \ln C}{\partial \ln q_i} * d \ln q_i \right)$$

Given small changes in output or cost, it follows that

(11) $$d \ln C = \frac{dC}{C} \quad ; \quad d \ln Q = \frac{dQ}{Q}$$

Substituting (11) into (9) and solving for dC yields:

(12) $$dC = C \left(\sum_{i=1}^{n} \left(\frac{\partial \ln C}{\partial \ln q_i} * d \ln q_i \right) \right)$$

where dC is the incremental (marginal) cost of rail traffic when the actual movement of the traffic is characterized by the incremental intermediate operating measures $dq_1, \ldots, dq_n$. If these are assumed to increase by equal percentages so that:

(13) $$d \ln Q = d \ln q_1 = d \ln q_2 = \ldots = d \ln q_n$$

the logarithmic cost function may now be restated as:

(14) $$d \ln C = \left(\sum_{i=1}^{n} \frac{\partial \ln C}{\partial \ln q_i} \right) * d \ln Q$$

Substituting for the logarithmic cost and quantity terms (14) yields:

(15) $$\frac{dC}{C} = \left(\sum_{i=1}^{n} \frac{\partial \ln C}{\partial \ln q_i} \right) * \frac{dQ}{Q}$$

or otherwise:

(16) $$\frac{dC}{C} * \frac{Q}{dQ} = \left(\sum_{i=1}^{n} \frac{\partial \ln C}{\partial \ln q_i} \right)$$

This may be restated in terms of marginal cost dC/dQ or of average costs C/Q:

(17a) $$\frac{dC}{dQ} = \frac{C}{Q} * \left(\sum_{i=1}^{n} \frac{\partial \ln C}{\partial \ln q_i} \right)$$

and

$$(17b) \quad \frac{C}{Q} = \frac{\frac{dC}{dQ}}{\left(\sum_{i=1}^{n} \frac{\partial \ln C}{\partial \ln q_i}\right)}$$

where C/Q is the estimated average variable cost, and dC/dQ is the estimated incremental cost of the rail movement. Thus, incremental costs are developed as an inflation (by a cost elasticity) of the average costs, with the inverse being applied to obtain marginal costs if the average cost is known.

DATA AND ESTIMATION

During the long period of railroad regulation, the Interstate Commerce Commission (ICC) required the railroads to supply information on their costs and expenditures. Following deregulation, the Association of American Railroads (AAR) has continued to provide a public source of data on railroad operations. The data, as collected by the AAR, is available through their two publications, "Analysis of Class I Railroads" and the "Railroad Cost Recovery Indexes," which supplies indices of input prices. Using these two sources, a fairly complete picture of rail operations may be developed.

Due to an accounting change, the data used here are limited to the period 1984 through 2005. In 1983, the industry changed to depreciation accounting from RRB (Retirement, Replacement, Betterment) accounting, leading to an inconsistency with data from earlier periods. A second problem involves the shrinking number of railroads, as mergers or bankruptcies occurred and as some firms were dropped due to insufficient revenues to remain classified as Class I. Where mergers have occurred, dummy variables for the firms prior to and following the merger were included in the model to act as proxies for changing railroad structure. As each merger was concluded, a new dummy variable was created using the railroad name and a higher number. For example, when the Union Pacific added the Missouri Pacific and Western Pacific, the variable D_UP_1 took on the value 0 and the value of D_UP_2 became 1. Likewise, a number of special accounting charges were taken over the 22-year period. In each year where a firm took a special charge against expenses, this was modeled with a 0,1 dummy variable. The rationale for modeling the charges this way was to allow the remaining variables to operate more freely within the model, as well as to explain costs rather than modifying the data set to reflect charges that may not be directly related to the level of the firm's operations in any given year.

The data set as constituted consisted of 22 years of observations with 28 firms before consolidation. After consolidation and removal of several firms from the list of Class I railroads due to reduction in comparative revenues, the final year (2005) consisted of data for only seven firms. Constructing the data in this manner gave 266 observations for a varying number of firms for the 22 years, a large enough sample to provide sufficient degrees of freedom for most estimation techniques associated with pooled data.

The model was estimated for the translog functional form (equation 7) of the cost model. In addition to the cost function, factor share equations were developed for fuel, labor (wages and supplements) and other operating expenses.[3] Estimation was performed using the full-information-maximum-likelihood algorithm in the Soritec econometric software package. The causal variables consisted of the parameters for gross-ton-miles, car-miles, train-miles, thousands-of-horsepower-miles, total-switching-hours, roadway capital, equipment capital, input price indices for fuel, wages and supplements, materials and supplies and other expenses, and the dummy variables representing individual firms, mergers and special charges. The firm dummies and special charge dummies were not included as quadratic terms in the translog functional relationship, but appear as 0,1 shift parameters. The restrictions on the regression were required in order to ensure linear homogeneity of the input prices within the cost function. Results of the regression of the 161 variables translog function using 266 observations have not been included here due to space limitations, but may be obtained from the author. The regression results are reasonable for a translog specification. There may be a concern over the number of variables whose t-statistics do not indicate a strong level of significance. This is not an uncommon situation when a complete translog function is estimated, due to the large number of factors included in the functional form and the general close relationship of the variables, which is expected to cause some degree of multicollinearity. As long as each individual variable (gross-ton-miles, train-miles, car-miles, etc.) is important and included, the choices for getting desirable t-statistics are limited. One possibility is to individually parse the regression terms until only statistically significant terms remain. This method may cause the translog to lose its validity as an approximation to an unknown underlying function. Since all of the variables are believed to be important cost related elements in the movement of trains and the factors as a group were significant to the regression, each of the variables was left in the estimated equation.

A further consideration in the evaluation of the regression involved the values and signs of the partial elasticity estimates that resulted from the regression equation. As expected, the absolute values of the partial elasticities were generally between zero and one. Some of the partial elasticities are negative, indicating that an increase in this operating parameter, all others held constant, will decrease costs. Of course, it must be noted that none of the variables will work completely independently of the others. For example, an increase in gross-ton-miles will normally be accompanied by increased car-miles, train-miles, locomotive-horsepower-miles and potentially switching-hours. In reality, all of the factors work together and given that the partial elasticities are the derivative of the translog function, each will depend on all of the other variable factors and will change with each independent change in other factors.

RAILROAD COSTS

The Average Railroads

Since the partial elasticities of costs are dependent on the level of service already being provided, it is appropriate to look at the levels of costs for a specific or average railroad. Two types of average railroads were developed by averaging the operating parameters, capital stocks, prices and mileages of the actual railroads in the sample for the year 2005. One was created by a simple arithmetic average of all of the factors and will be denoted as the "Arithmetic Average Railroad." A second, the "Geometric Average Railroad," was created by using a weighted average of the parameters with gross-ton-miles as the weighting factor. Characteristics of the average firms operating parameters are indicated in Table 2.

Economies of Scope

Economies of scope result from the use of the same factors of production to produce a number of different outputs. For example, in the railroad industry this is shown by the ability of the railroads to use the same track structure or locomotives to move both heavy coal trains and lighter, higher speed intermodal freight. The combination of differing partial elasticities and the use of the same factors of production to produce different outputs at different cost levels indicates that economies of scope are present.

For the hypothetical (arithmetic and geometric) average railroads described in Table 2, it is possible to develop partial elasticity estimates relating changes in parameter values to changes in total rail cost. The estimates are given in tabular form in Table 3 for each of the last four years (2002-2005) and, for comparison, for a railroad averaged over these four years. Only the partial elasticity estimates for GTMC, CM, TM, THP and THS are applied in estimating marginal and average costs, as the capital stock levels and input prices are assumed fixed in any given year. For years prior to 2005, the capital stock levels for 2005 were used rather than capital stock estimates for each of the

Table 2: Characteristics of the Arithmetic and Geometric Average Railroads

		Arithmetic Average Railroad	Geometric Average Railroad	CSX Transport	Norfolk Southern	CNGT	Soo	Kansas City Southern	BNSF Railway	Union Pacific
Gross-Ton-Miles (x1,000,000)	GTMC	449093	823351	459396	382892	102748	44498	49081	1061110	1043920
Car-Miles (x1000)	CM	538740	9760300	5680620	4789900	1338070	569786	557698	10736400	14039900
Train-Miles (x1000)	TM	78224	137460	96542	81150	16480	8457	840	168802	167737
Locomotive-Horsepower-Miles (x1,000,000)	LRM	720327	1350710	748454	600959	91155	55066	74118	1844910	1627630
Thousands of Switching Hours	THS	2316000	3492430	3268440	3175550	1147370	465695	437833	2643010	5074090
Miles of Road	MR	17223.6	27642.1	21357	21184	6736	3511	3197	32154	32426
Miles of Track	TR	28377.7	44866.1	37670	38041	11267	4962	4472	49565	52667
Roadway Capital Stock Estimate	K_RD	9513060	15385400	13726000	11894000	3259870	1632400	853480	16530900	18694700
Equipment Capital Stock Estimate	K_EQ	3639900	5655720	5896860	5576280	868393	576534	386503	5361850	6812880

previous years. Because of the specification of the partial elasticities as partial derivatives of the cost function, it is expected that the elasticity measures will vary with any change in one or more of the individual parameters. As traffic makeup changes, the partial elasticities will also change, indicating differential costs for differential train types. For example, higher speed trains will have greater numbers of horsepower-miles relative to the gross-ton-miles. Likewise, a unit coal train will have greater gross-ton-miles relative to other measures and therefore a differing cost level. Thus, as the parameters of the movement are changing, the cost levels for each of the trains are changing. Where economies of scope exist, and many different train types and specifications can be described, the partial elasticities demonstrate that the cost levels will change with the train specification.

Economies of Density

Economies of density, the cost efficiencies that result when the existing capital stock is used to transport more traffic, may be estimated for both of the arithmetic and geometric average railroads by holding capital stock and prices constant and allowing the operating parameters to vary. In this study, economies of density are measured by changing all of the intermediate outputs by an equal percentage. That is, total traffic increases with the same makeup of train types. From equation 17b, we can see that average cost is equal to marginal cost divided by the sum of the partial elasticities. If the sum of the partial elasticities of the output variables is less than one, average cost will exceed marginal cost and density economies should exist. If the sum of these partial elasticities is greater than unity, marginal costs will exceed average costs.

Estimates of the returns to density (output) are obtained for the average railroads operating at year 2005 levels by increasing (decreasing) the original levels of all of the intermediate operating parameters (GTMC, CM, TM, THP and THS, for which the average levels were given in Table 2) by

Table 3a: Partial Elasticity Estimates (Operating Parameters)

Year	GTMC	CM	TM	THP	THS
2002	-0.2272	0.5973	0.1312	0.0623	0.0832
2003	-0.1720	0.5490	0.1161	0.0807	0.0818
2004	-0.1428	0.5026	0.1791	0.0814	0.0784
2005	-0.1343	0.5527	0.1865	0.0736	0.0755
2002-2005	-0.1691	0.5504	0.1552	0.0745	0.0797

Table 3b: Partial Elasticity Estimates (Capital and Price Indices)

Year	K_RD	K_EQ	P_F	P_WS	P_O	P_MS
2002	0.3381	0.1057	0.0820	0.3771	0.4868	0.0541
2003	0.3363	0.1060	0.0935	0.3838	0.4682	0.0545
2004	0.3292	0.0776	0.1114	0.3990	0.4324	0.0572
2005	0.3027	0.0525	0.1355	0.3990	0.4084	0.0572
2002-2005	0.3266	0.0855	0.1056	0.3897	0.4490	0.0557

multiples ranging from 0.8 to 1.6. For each of these levels, the partial elasticity values will vary, allowing marginal costs to be proxied from the estimates of average cost. Average costs are indicated relative to gross-ton-miles and shown in Tables 4a and 4b. The results are also demonstrated in Figures 1a and 1b.

Of particular interest relative to the examination of economies of density is an examination of the relationship of average to marginal cost as it varies around actual current activity levels. If marginal cost is seen to be less than average cost, economies of density (output) exist. However, if marginal cost exceeds average cost, then there are diseconomies to density. Here, Tables 4a and 4b and Figures 1a and 1b indicate that for the current railroads economies of density may be increasing significantly on a system-wide basis, as marginal cost is less than average cost up to at least 1.1 times the average 2005 traffic level, as measured by the five activity measures. It must be noted, however, that this finding is for an industry average railroad, and the situation may vary for individual firms, with some firms being more efficient than the average while others are operating at a higher cost level or are closer to the minimum point of their short-run average costs.

Economies of Scale

Economies (and diseconomies) of scale may be demonstrated by the shape of the long-run average cost function. Since the long-run function is not directly observable, in order to examine long-run behavior it is necessary to evaluate the cost function on a "what if" simulation basis. This has been done using the methodology described above. The short-run cost function has been adjusted by multiplying the capital stock values sequentially by 0.25, 0.50, 0.75, 1.00, 1.50 and 2.00 and increasing the level of operations by additional multiples from 0.8 to 1.6, so as to examine the short-run cost function at each of the hypothetical levels of capital stock. Results of this simulation process are shown graphically in Figures 2a and 2b for the arithmetic and geometric average railroads, both using the year 2005 base levels. Examination of the graph and the data used to generate them indicate that the industry has evolved to a point of virtually exhausting the available economies of scale. The data also shows that should individual firms increase in size, they may soon experience significant diseconomies.

Figure 1a: Average and Marginal Cost Estimates — Arithmetic Average Railroad 2005 Multiplied from 0.8 to 1.6

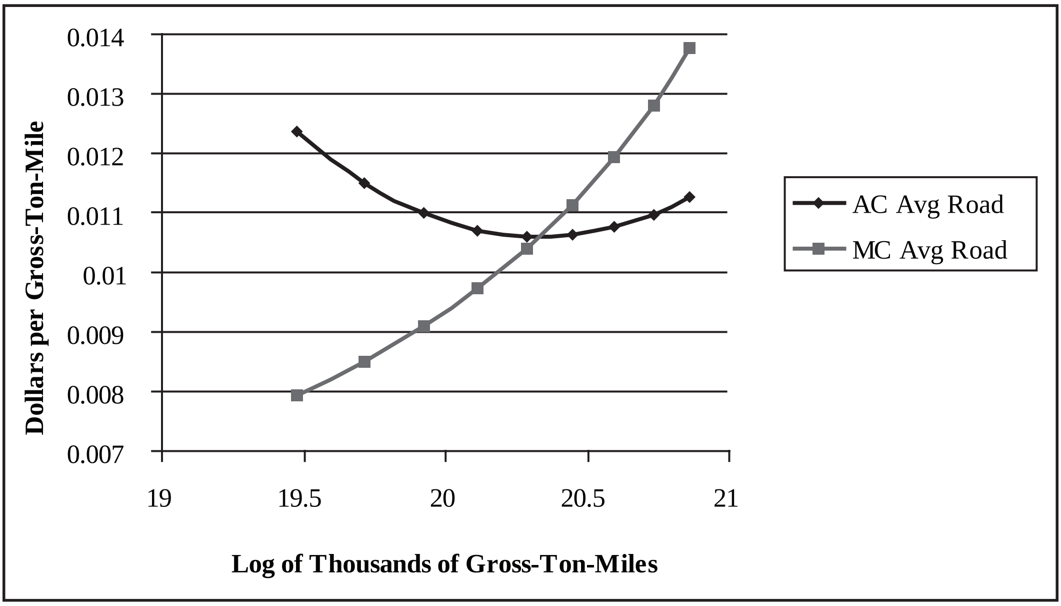


Figure 1b: Average and Marginal Cost Estimates — Geometric Average Railroad 2005 Multiplied from 0.8 to 1.6

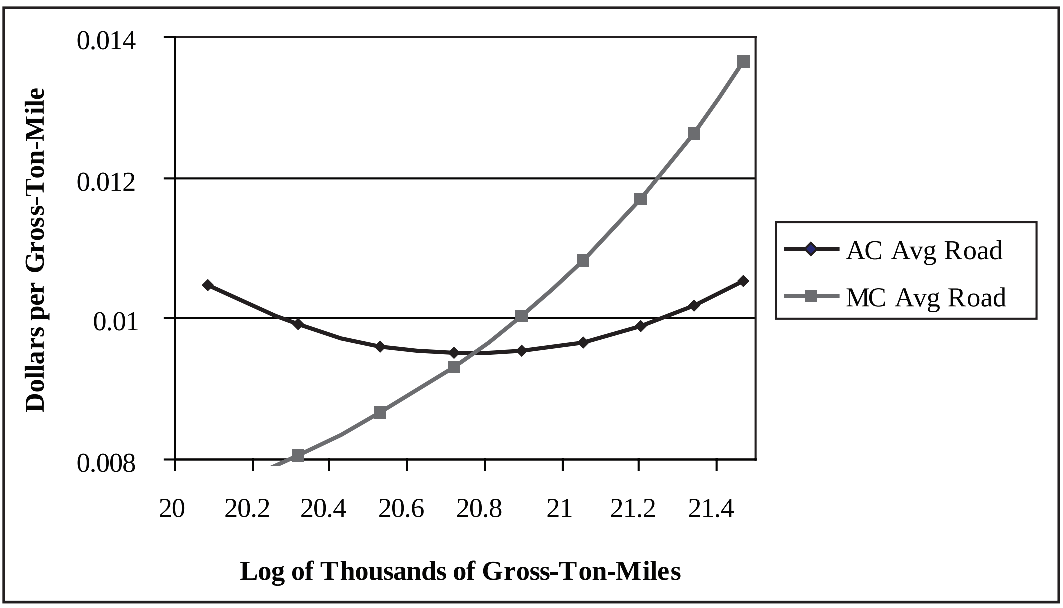


Table 4a: Average and Marginal Cost Estimates – Arithmetic Average Railroad, 2005

Multiplier	Log of GTMC	Average Cost	Marginal Cost
0.80	19.4765	0.0124	0.0079
0.90	19.7120	0.0115	0.0085
1.00	19.9227	0.0110	0.0091
1.10	20.1134	0.0107	0.0097
1.20	20.2874	0.0106	0.0104
1.30	20.4475	0.0106	0.0111
1.40	20.5957	0.0108	0.0119
1.50	20.7337	0.0110	0.0128
1.60	20.8627	0.0113	0.0138

Table 4b: Average and Marginal Cost Estimates – Geometric Average Railroad, 2005

Multiplier	Log of GTMC	Average Cost	Marginal Cost
0.80	20.0826	0.0105	0.0075
0.90	20.3182	0.0099	0.0080
1.00	20.5289	0.0096	0.0087
1.10	20.7195	0.0095	0.0093
1.20	20.8935	0.0095	0.0100
1.30	21.0536	0.0097	0.0108
1.40	21.2018	0.0099	0.0117
1.50	21.3398	0.0102	0.0126
1.60	21.4689	0.0105	0.0136

CONCLUSIONS AND POLICY IMPLICATIONS

The research presented here has several important implications in terms of costing of railroad traffic. First, the model demonstrates that, with only minor simplifying assumptions, a general model of total railroad costs may be used to obtain consistent estimates of costs for railroads in general. These estimates may be obtained for an actual railroad or for theoretical railroads, as are examined here and that closely follow the expectations from economic theory.

Second, the partial elasticity estimates that lead to the varied cost estimates indicate that there are economies of scope in the railroad industry, as multiple outputs (trains) are being produced over the same system networks.

Third, there appears to be a slight range where the industry may be able to gain economies of density from carrying more traffic on the given network. The model indicates that these gains may be limited, as substantial increases in traffic level at current capital stock levels are expected to push marginal costs above average costs, at which diseconomies begin.

Finally, the result obtained from the model demonstrates the lack of scale economies, and that diseconomies may in fact be expected to accrue to significantly larger railroads. Under each of the differing firm size scenarios that were examined through simulation of the cost model, it was demonstrated that while the long-run cost function follows the shape expected from economic theory, with portions of both economies and diseconomies of scale, the point where the railroads are currently operating is very close to, or past the minimum point of the long-run cost function. Thus, merger activity on the part of the industry is not expected to yield any gains from firm size and, to

Figure 2a: Average and Marginal Cost — Arithmetic Average Railroad 2005

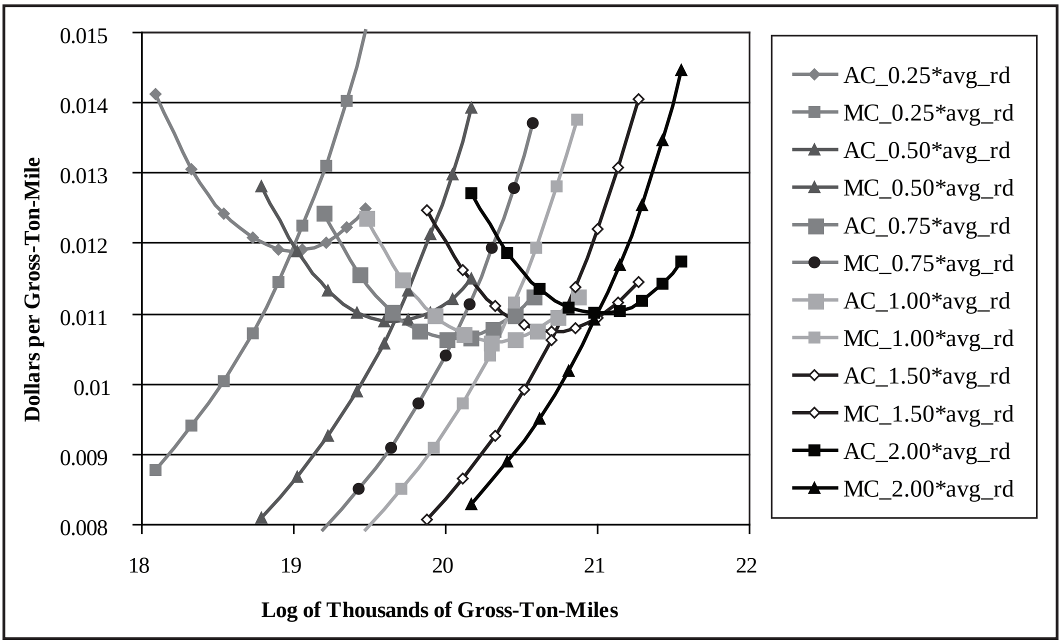
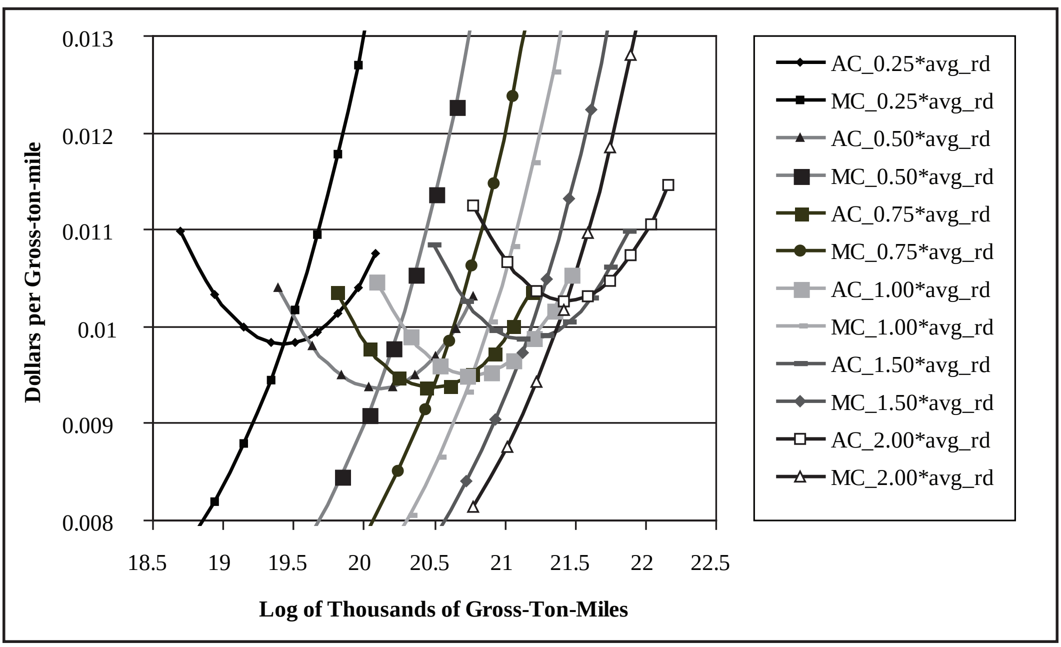


Figure 2b: Average and Marginal Cost — Geometric Average Railroad 2005



the contrary, is expected to lead to increased costs. Gains in reducing costs would have to come from changing technology and productivity aimed at increasing density in the short-run and total factor productivity in the long-run.

The current model is not designed to be the final word on rail costing. Several modifications toward a multi-level model, as suggested by Bereskin (1983, 1996), may in fact be appropriate in order to give even more flexibility to rail costing. A bi-level model along these lines would allow for further examination of where productivity is gained and could yield suggestions as to how the industry might become more efficient.

APPENDIX A

RRID	Railroad Name
01	Atchison Topeka and Santa Fe
02	Baltimore and Ohio
03	Bessemer and Lake Erie
04	Boston and Maine
05	Burlington Northern
06	Chesapeake and Ohio
07	Chicago and Northwestern
08	Chicago, Milwaukee, St Paul, and Pacific
09	Chicago, Rock Island, and Pacific
10	Clinchfield
11	Colorado and Southern
12	Conrail
13	Delaware and Hudson
14	Denver Rio Grande and Western
15	Detroit, Toledo, and Ironton
16	Duluth, Massabi, and Iron Range
17	Elgin, Joliet, and Eastern
18	Florida East Coast
19	Fort Worth and Denver
20	Grand Trunk Western
21	Illinois Central Gulf
22	Kansas City Southern
24	Louisville and Nashville
25	Missouri Kansas Texas
26	Missouri Pacific
27	Norfolk and Western
28	Pittsburgh and Lake Erie
29	St. Louis and San Francisco
30	St. Louis Southwestern
31	Seaboard Coast Line
32	Soo Line
33	Southern Pacific
34	Southern Railway System
35	Union Pacific
36	Western Maryland
37	Western Pacific
42	CSX Corporation
43	Norfolk Southern
44	CNGT

Endnotes

1. Where joint production occurs such as in the railroad industry, it is often impossible to get a single measure of output. Frequently, gross-ton-miles or car-miles are used as proxies. Even when these proxy variables are used, it is appropriate to adjust their values for the variations in traffic level, such as was done by McCullough (1993). As used here, the individual intermediate output measures will be applied directly so that specific final outputs can be described by their characteristics. One potential problem is that the measures may actually reflect different operating characteristics for different traffic (a thousand car-miles may consist of one car moving a thousand miles or a thousand cars moving one mile). Unfortunately, given the current state of railroad statistics, there is no realistic way around this problem, which occurs in virtually every rail cost model.

2. There is always some concern over specification bias when estimating any cost function. Through use of these five measures, it is expected that the variability in output has been sufficiently explained, especially when compared to models that use single measures of output like gross-ton-miles alone. On the other side, there must be some concern about multicollinearity in these five measures. The primary problem with multicollinear independent variables is that the standard errors of the estimated coefficients balloon and t-statistics all shrink so that it becomes impossible to statistically imply that coefficients are not equal to zero. While many of the coefficients have small t-values, a sufficient number for each of the variables are sufficiently large to indicate that the variables should be included. The tradeoff here is to not under-specify and cause specification bias versus over-specify and have multicollinearity.

3. A fourth factor share equation for materials and supplies was implicitly used. However, inclusion of all four factor share equations in a simultaneous equation model would result in exact multicollinearity of the model. Additionally, the regression coefficients for those terms relating to the price variable (P_MS) for materials and supplies are not directly included in the regression results, as these were all defined relative to the other price measures in order to enforce the linear homogeneity conditions as specified by equation 8.

References

Association of American Railroads. *AAR Railroad Cost Recovery Indexes*, Years 1983-2006.

Association of American Railroads. *Analysis of Class I Railroads*, Years 1983-2005.

Barbara, Anthony, C.M. Grimm, K.A. Phillips, and L.J. Selzer. "Railroad Cost Structure – Revisited." *Journal of the Transportation Research Forum* 27 (1), (1987): 237-244.

Bereskin, C. Gregory. *A Bi-level Model of United States Railroad Costs.* Dissertation (Ph.D.) University of Missouri-Columbia (1983).

Bereskin, C. Gregory. "Econometric Estimation of Post-Deregulation Railway Productivity Growth." *Transportation Journal* 35 (4), (1996): 34-43.

Bereskin, C. Gregory. "Railroad Capital Stock Changes in the Post-Deregulation Period." *Journal of the Transportation Research Forum* 46 (1), (2007): 95-110.

Bereskin, C. Gregory. "Sequential Estimation of Railroad Costs for Specific Traffic." *Transportation Journal* 40 (3), (2001): 33-45.

Bitzen, J. D. and T. E. Keeler. “Productivity Growth and Some of Its Determinants in Deregulated U.S. Railroad Industry.” *Southern Economic Journal* 70 (2), (2003): 232-253.

Caves, Douglas W., Laurites R. Christensen, and Joseph A. Swanson. “Economic Performance in Regulated and Unregulated Environments: A Comparison of U.S. and Canadian Railroads.” *Quarterly Journal of Economics* (46), (1981b): 559-581.

Caves, Douglas W., L.R. Christensen, and J.A. Swanson. “Productivity Growth, Scale Economies and Capacity Utilization in U.S. Railroads, 1955-1974.” *American Economic Review* (71), (1981c): 994-1002.

Caves, Douglas W., L.R. Christensen, and J.A. Swanson. “Productivity in U.S. Railroads, 1951-1974.” *Bell Journal of Economics* Spring, (1980): 166-181.

Caves, Douglas W., L.R. Christensen, and J.A. Swanson. “The High Cost of Regulating U.S. Railroads.” *Regulation* January/February, (1981a): 41-46.

Friedlaender, Ann F. and R.H. Spady. “Economic Costs and the Uniform Railroad Costing System.” Conference on Railroad Costing Procedures: Interstate Commerce Commission, June, 1980.

Ivaldi, M. and G. J. McCullough. “Density and Integration Effects on Class I U.S. Freight Railroads.” *Journal of Regulatory Economics* 19 (2), (2001):161-182.

Lee, Tenpao and C. P. Baumel. “The Cost Structure of the U.S. Railroad Industry Under Deregulation.” *Journal of the Transportation Research Forum* 27 (1), (1987): 245-253.

McCullough, Gerald M. *“Essays on the Economic Performance of U.S. Freight Railroads Under Deregulation.”* Dissertation (Ph.D.), Massachusetts Institute of Technology, 1993.

Oum, Tae Hoon and W.G. Waters II. “A Survey of Recent Developments in Transportation Cost Function Research.” *The Logistics and Transportation Review* 32 (4), (1996): 423-463.

Spady, Richard H. and A.F. Friedlaender. *Economic Estimation of Cost Functions in the Transportation Industries.* Cambridge: MIT Center for Transportation Studies Report Number 76-13, September, 1976.

Spady, Richard H. *Econometric Estimation of Cost Functions for the Regulated Transportation Industries*. Garland Publishing Inc., New York, 1979.

***C. Gregory Bereskin** has been involved with economic costing models of railroad traffic for over 25 years. He is currently employed as professor of economics and finance in the graduate programs at St. Ambrose University in Davenport, Iowa. Prior to his current position, he was manager of economic and financial analysis at the Atchison Topeka and Santa Fe Railway, where he worked on costing, regulatory, and financial problems. He received his Ph.D. in economics from the University of Missouri-Columbia (writing on railroad costs) and his M.A. and B.A. degrees in economics from the University of Cincinnati. He is currently working in two primary areas, developing models that apply econometric methodology to costing of railroad traffic and studying the relationship of transportation services to real estate prices.*