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KOBE UNIVERSITY

ROKKO KOBE JAPAN

2002. 24

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Discussion Paper Series

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by

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[Abstract]
This paper aims to find the optimal size of an urban private rail organization according to its supply size, as well as to evaluate cost difference by ownership, "optimal size" being defined as the size which attains minimum average cost. When restructuring an overly large monopolized railway organization into discrete parts, policy makers need to know how big those parts should be. The methodology of this analysis is as follows. First, privately owned rail companies are carefully selected, according to the type of rail service they offer and the technology they use. Explanatory variables which affect the cost of rail service are explored. Second, keeping in mind previous cost studies of the urban passenger rail industry, we estimate both the variable and the total cost function with the translog cost function and compare these results. Third, based on the average cost function, conditions are pinpointed which attain minimum average cost. Finally, based on estimated results, we calculate the size of an urban private rail company and the ownership effects on cost. We conclude that optimal size is about 194 million vehicle-km per year, with a network of 85km length. In terms of total costs, public railways have higher costs than private railways. But there is no cost difference in variable costs.

[Key Words]
Optimal size, Privately owned railways, Translog cost function, Japanese railway companies

[JEL Classification] L3, L9, R4

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* Portions of this research were supported by the Science Research Fund of the Ministry of Education.

1 INTRODUCTION

An important policy issue in the rail industry these days is the privatization of formerly government-owned railway organizations. Publicly owned railways have been widely perceived to be inefficient, and the movement toward privatization has met with little resistance, with citizens seeming to recognize the debilitating lack of competition in the industry and the absence of incentives to improve. However, despite an apparent consensus that privatization should be carried out, to do so is not simple. Hard decisions must be made as to what sorts of private railway companies should be formed from the old ones. How should overly large railway organizations be divided? How big should the resulting organizations be? How should they be managed for maximum efficiency? How can competition be encouraged? These questions faced policy makers responsible for privatizing and dividing the Japan National Railway (JNR) in 1987. In the case of Japan, the huge former national railway was divided into six regional passenger companies. Other countries have chosen different ways of dividing their unwieldy national railways, with British Railways, for example, being divided into 25 franchising regions. What is the correct way to subdivide a national railway? Policy makers facing similar choices in the future would benefit from knowing the optimal size of a railway, and that question is what most concerns us in this paper. Preston (1996) concluded that the railway of optimal size, or the size which results in the lowest operating costs, would have a network of around 4,000km and run 120 million train-km per annum. Preston's pioneering results might prove a benchmark for policy makers, but his research is based on samples only of European railways. A larger sample would help us obtain more definitive results.

First, perhaps we need to show whether the private sector is really more efficient than the public. Different studies give different answers. While some empirical evidence suggests that in the railway industry, the private sector is more efficient than the public (Miyajima and Lee, 1984, and Mizutani, 1994), other research indicates there is little difference between the two sectors (Caves and Christensen, 1980). There is even a study, conducted by the U.S. Accounting Office in 1981, suggesting that in at least one measure the public sector is the more efficient (Tittenbrun, 1995). In sum, regarding the rail industry, three studies show that private is more efficient, two studies show that there is not much difference, and one study shows that public is more efficient than private (Mizutani, 2000). Answering the question of which is more efficient is complicated in the case of the Japanese railway privatization, because the railways resulting from the breakup were not fully privatized at the beginning of the privatization process, and in fact remain only partially privatized to this day. Partial privatization has not been unique to Japan, however, and we may look at the case of the privatization of the German railway (DB) as well, where railway stock is still held by the German government. To our growing list of questions, we need to add the question of how efficiency might differ among partially and fully privatized organizations.

The purpose of this paper is to address some of these questions. The main goal will be to determine the optimal size of a railway operation and to find any cost differences related to ownership. The structure of the paper is as follows after the introduction. In the first section, I give an overview of the private rail industry in Japan, some background to aid in understanding the rail market and the sample selection for the analysis found in the following section. I also explain the mode share of passenger transport and the organization of the rail industry. In the second section, the methodology for the cost models will be explained. After a summary of previous cost studies, the cost models to be used here are presented. In this section, I address both total and variable cost function. Third, I will estimate cost functions. After the assessment of cost functions, I will construct the long-run total cost function from variable cost functions. Fourth, by using these results, I also explain the methods for obtaining minimum average costs and cost differences by ownership. I calculate the optimal organization size for attaining minimum average costs and analyze cost differences by ownership. Finally, I summarize my results in a conclusion.

2 AN OVERVIEW OF THE PRIVATE RAIL INDUSTRY IN JAPAN

2.1 Mode Share of Passenger Transport

Although auto transport has increased dramatically since World War II, rail transport still plays a very large role in transportation in Japan. Especially when compared with the situation in other industrial countries, such as the U.K., Germany, and France, where rail share has declined to just a few percent, rail share accounted for 27.3% of Japanese transportation in 1998. For commuters in large metropolitan areas such as Tokyo and Osaka, rail was the dominant transportation mode. Table 1 shows the trends in passenger transport and its mode share in Japan.

Table 1 Trends in Passenger Transport and Mode Share

Year	Passenger kilometer (million)				Mode Share (%)			
	Rail	Auto	Air	Maritime	Rail	Auto	Air	Maritime
1950	105,468	9,000	-	2,628	90.1	7.7	0.0	2.2
1955	136,112	27,500	225	1,996	82.1	16.6	0.1	1.2
1960	184,340	55,531	737	2,670	75.8	22.8	0.3	1.1
1965	255,484	120,756	2,952	3,402	66.8	31.6	0.8	0.9
1970	288,815	284,229	9,319	4,814	49.2	48.4	1.6	0.8
1975	323,800	360,868	19,148	6,895	45.6	50.8	2.7	1.0
1980	314,542	431,669	29,688	6,132	40.2	55.2	3.8	0.8
1985	330,101	489,260	33,119	5,752	38.5	57.0	3.9	0.7
1990	385,364	853,060	51,623	6,275	29.8	65.7	4.0	0.5
1995	400,084	917,419	65,012	5,527	28.8	66.1	4.7	0.4
1996	402,156	931,721	69,049	5,635	28.6	66.1	4.9	0.4
1997	395,278	944,972	73,243	5,368	27.9	66.6	5.2	0.4
1998	388,917	954,807	75,988	4,620	27.3	67.1	5.3	0.3

(Source): Ministry of Transport (ed.) (1999), p.11

There are several reasons why rail transport is still so important in Japan. The most obvious is that urban areas are so densely populated that rail operators can provide rail service efficiently and rail users can consume services more frequently. Because rail organizations in Japan are expected to be self-supporting through rail fare revenues and independent of government subsidy, this dense urban structure is important to the railways' continued well-being. Second, it could be argued that rail share remains high because private railways have always done their work very well, providing what is popularly regarded as high quality service. In fact, the example of the successful private railway companies was the trigger for the privatization of the Japan National Railway (JNR) in 1987. These companies have not only managed their rail businesses well, but have ensured their survival, indeed their prosperity, by diversifying their businesses--operating feeder bus services, developing real estate such as housing and office complexes along their lines, building department stores at terminals, and opening their own travel agencies (Killeen and Shoji, 1997). These activities have the demonstrable effect of increasing rail ridership and the more abstract one of enhancing and propagating the company name. Despite the success of the private rail industry, however, rail share is still less than that of the auto, which is the dominant transportation mode in Japan as it is in other industrialized countries. Outside the Tokyo and Osaka metropolitan areas, rail companies in Japan struggle to maintain their dwindling share of the transportation market.

2.2 The Organization of the Rail Industry

The rail industry in Japan can be distinguished by the existence of a multitude of rail operators, most of which are privately owned. According to Mizutani (1999a), as of September 1, 1996, there were 188 organizations defined as rail operators. Of these, 160 were heavy and light rail operators, and the others were monorails, automated guideway transit systems, and cable cars.

Table 2 Classification of the Passenger Rail Industry in Japan

Operators	Number of Operators	Legal Classification	Ownership	Service Type	Main Service Areas
Large private	15	Private Corporation	Private	Urban	Large metropolitan areas (e.g. Tokyo, Osaka, etc.)
Medium private	6	Private Corporation	Private	Urban	Large metropolitan areas (e.g. Tokyo, Osaka, etc.)
Small private	67	Private Corporation	Private	Urban	From large to small urban areas
Quasi-private	36	Private Corporation	Private-Public	Urban	From large to small urban areas
JR	6	Special Corporation	Partly public or Public	Inter-city and Urban	6 regions in Japan
Eidan	1	Special Corporation	Public	Urban	Tokyo
Public	13	Public	Public	Urban	Tokyo, Osaka, Nagoya

		Organization			and 6 other large cities
(Note): This table was modified by the author based on the table in Mizutani (1999a, p.265).					

Of the 160 heavy and light rail operators, passenger rail services are most numerous, at 144. Freight rail operators accounted for only 16 of the total. In Japan, passenger rail operators are classified in four ways: according to their legal classification, their ownership, their transport type, and their main service areas. First, there are three legal categories: private corporations, public organizations, and special corporations. Private corporations are organizations legally considered to be private companies, whose shares are held by the private sector. It is worth noting that companies whose shares are partly held by the public sector are included in this category. A public organization is a department of the government such as the department of transportation of a local government. A special corporation is defined as an organization which is set up and regulated by special law (Uekusa, 1991). JR and Eidan are considered special corporations. Second, there are three categories of ownership: private, public, and private-public. Most Japanese rail operators are privately owned, with public ownership being limited to only 13 operators. The recently "privatized" JRs are not fully private because most of their shares are still held by the public sector (Mizutani and Nakamura, 1997; Mizutani, 1999b). As for classification according to transportation type, the most common type is the urban railway serving a large metropolitan area. The major 15 private railways, those that have been private since they were established long ago, fall into this group, and contrast with the newly private companies, the JRs, which have both urban and intercity rail services.

Trends in passenger transport according to type of rail organization are summarized in Table 3, which shows that the overall volume of passenger transport on the JRs is greatest, accounting for 62.4% in 1998. However, private railways' share is still significantly high, accounting for 26.7% in 1998. Their good performance might be a result of their entrepreneurial behavior.[1] In contrast to the JRs, which provide both intercity and rail services, large private railways continue to provide highly essential service in large metropolitan areas.

Table 3 Trends in Passenger Transport and Share by Type of Rail Organization

Year	Passenger kilometer (billions)					Share by Organization (%)				
	Large Private	Other Private	JR	Eidan	Public	Large Private	Other Private	JR	Eidan	Public
1965	60.4	7.6	174.0	4.5	8.8	23.6	3.0	68.1	1.8	3.4
1970	75.8	8.4	189.7	8.5	6.1	26.2	2.9	65.7	2.9	2.1
1975	82.6	8.2	215.3	10.5	7.3	25.5	2.5	66.5	3.2	2.3
1980	91.6	8.8	193.1	11.7	9.3	29.1	2.8	61.4	3.7	3.0
1985	97.5	9.3	197.5	14.0	11.8	29.5	2.8	59.8	4.2	3.6
1990	110.5	8.1	235.5	16.0	15.3	28.7	2.1	61.1	4.2	4.0
1991	112.7	8.4	247.0	16.1	15.8	28.2	2.1	61.8	4.0	4.0
1992	112.2	8.6	249.6	16.1	15.9	27.9	2.1	62.0	4.0	4.0
1993	111.8	8.6	250.0	16.1	16.3	27.8	2.1	62.1	4.0	4.0
1994	111.0	8.7	244.4	15.9	16.4	28.0	2.2	61.7	4.0	4.1

1995	109.9	8.7	249.0	15.8	16.7	27.5	2.2	62.2	3.9	4.2
1996	108.7	9.2	251.7	15.9	16.7	27.0	2.3	62.6	4.0	4.2
1997	105.5	9.5	247.7	15.9	16.7	26.7	2.4	62.7	4.0	4.2
1998	103.8	9.4	242.8	16.0	16.9	26.7	2.4	62.4	4.1	4.3

(Note): Monorails, automated guideway transit systems, and cable cars are included in the category of Other Private, but their numbers are small.
(Source): Ministry of Transport (ed.) (1999), p.13

3 Cost Models

3.1 Previous Cost Studies Regarding the Passenger Rail Industry

Over forty studies have been undertaken, with various goals. Published papers include estimations of cost function or overviews of the industry (Borts, 1960; Meyer et. al.,1975; Brown et.al., 1979); a study of cost allocation (Griliches, 1972); examinations of economies of scale and density (Harris, 1977; Keeler, 1974; Braeutigam et al., 1984; Caves et al., 1981a, 1985; Preston and Nash, 1993; Savage, 1997); an examination of economies of scope (Kim, 1987); and a study of capital adjustment (Friedlaender et.al, 1993). In the 1980s and 1990s, there were several studies related to regulation issues: regulation effects (Caves et. al, 1981b; Friedlaender and Spady, 1981; Vellturo et.al, 1992); an estimation of mergers' effect (Levin et.al, 1979; Harris and Winston, 1983; Berndt et.al, 1993). It has also been popular to measure productivity growth (Caves et.al, 1980; Dodgson, 1993; McGeehan, 1993; Loizides and Giahalis, 1995; Hensher et. al, 1995). Some studies concern methodology and model specifications (Hasenkamp, 1976; Braeutigam et.al, 1982; De Borger, 1991, 1992)

Regardless of the purpose of these studies, the functional forms of the cost function used are mostly the log-linear and translog cost functions, the latter being widely used in recent studies. The disadvantage of this function is that, because it includes both first-order and second-order variables, a large number of observations are required before it can be useful for assessing policy change. However, the translog cost function is considered a more flexible and therefore superior functional form because the scale measure varies with output level, the elasticity of substitution is not one, and the function is not homothetic. Therefore, I judge this form to be appropriate for the purpose of my study here, which is the calculation of the optimal size of a railway.

Previous cost studies cover mostly freight railways or both passenger and freight railways, and studies on passenger railways are very limited. Analysis of passenger transport as discrete from freight transport is necessary, as current state railway reforms tend to separate their passenger divisions from their freight operations (e.g. British Railway and JNR). Several researchers have analyzed passenger transport, such as Viton (1980), Marumo (1984), Miyajima and Lee (1984), Mizutani (1994), Nakamura (1994), and Savage (1997). For example, Viton (1980), employing the translog cost function, evaluates economies of network density in North American rail transit systems. More recently, Savage (1997) analyzes scale economies in U.S. urban railways, taking into account service quality variables considered important factors affecting the cost structure of urban transit firms.

There are not many studies about ownership effects or costs of private railways. Marumo's (1984) study is an analysis of urban private railways in Japan. He analyzes the relationship between average cost and several explanatory variables by using log-linear cost models. Miyajima and Lee's (1984) study is an efficiency comparison between the private and public sectors. Although the authors do not construct a cost function, they compare several performance measures, including operating costs, and they conclude that private railways are more efficient than public railways.

More recent cost studies on private railways have been carried out by Filippini and Maggi (1992, 1993), Mizutani (1994), and Nakamura (1994). It is worth noting that observations used by Filippini and Maggi are not for passenger transport only but for both passenger and freight transport. The main focus of Filippini and Maggi's (1992, 1993) study is to evaluate economies of network density, scale and network structure in Swiss railways and the factors' effect on efficiency. What distinguishes their study from other cost studies in the rail industry is that they analyze "privately" owned rail operators. The methodology itself is not different from other studies, but they employ a translog cost model and estimate both total and variable cost functions, and in this way detect the presence of economies of network density and scale. However, the "privately" owned railways in these studies cannot be considered truly private railways, being owned partly by the federal state, the cantons, and the communes. In fact, private shareholders of these companies account for only 1 to 52% of all shareholders. Also questionable is their finding that ownership does not significantly correlate with cost efficiency.

On the other hand, Mizutani (1994) and Nakamura (1994) have studied railways which are clearly privately owned. The main purpose of Mizutani's study is to evaluate the cost difference between privately and publicly owned railways. After estimating the translog and the log-linear cost functions, he evaluates the private-public cost difference while controlling output and network factors, and concludes that public railways have about 10 to 20% higher total costs than private railways. Nakamura's study aims to examine economies of scale and network density. He constructs a translog cost function and concludes that there are both economies of scale and network density. While Mizutani's study has provided empirical evidence that the private sector is more efficient than the public, there remains the problem that the effect due to technological difference in the cost function has not been removed. As for Nakamura's study, there is the worry that results may have been affected by the fact that some private railways receive subsidies, which may affect their behavior.

3.2 Economic Theory of Rail System

Long-run and Short-run Cost Function

Based on previous studies, I will summarize the basic idea of this study. I will begin by explaining the general microeconomic theory on cost, largely following the theoretical background of five studies: Friedlaender and Spady (1981); Braeutigam, et. al (1984); Caves, et. al (1985); Friedlaender, et. al (1993); and Savage (1996). This study aims to find the optimal size of a railway organization, the size which attains minimum average cost in terms of output and network size.

If a firm minimizes all kinds of input factors under a given output level (Q) and given input factor prices (w), then the long-run total cost function is expressed as follows:

$$C = C(Q, \mathbf{w}), \tag{1}$$

where C: long-run total cost

Q: output

w: vector of input factor prices.

However, if there are certain fixed input factors, the firm cannot minimize total cost by adjusting such fixed input factors in the short-run. In this case, the firm is considered to minimize the variable costs under the condition of having the fixed input factors. In this case, the short-run total cost is expressed as follows:

$$C^S = C^V(Q, \mathbf{w}_v, \mathbf{K}) + \mathbf{w}_f \mathbf{K}, \tag{2}$$

where C^S: short-run total cost

C^V: variable cost

$\mathbf{w}_v$: vector of input factor prices of variable input

$\mathbf{w}_f$: vector of input factor prices of fixed input

K: vector of fixed input.

Long-run total costs are always less than short-run total costs, except at that output level for which the assumed fixed input is appropriate to long-run cost minimization. However, at the long-run equilibrium, short-run marginal costs with respect to output must equal long-run marginal costs ($\partial C^V / \partial Q = \partial C / \partial Q$) (Friedlander and Spady, 1981). Furthermore, at the optimal choice of the fixed input factor, K_i , the following condition must hold:

$$\partial C^S / \partial K_i = \partial C^V(Q, \mathbf{w_v}, \mathbf{K}) / \partial K_i + w_{fi} = 0. \tag{3}$$

To solve the equation (3) for K_i, we can obtain the optimal size of the fixed input factor:

$$K_i^* = K(Q, \mathbf{w_v}, w_{fi}). \tag{4}$$

By substituting equation (4) into equation (2), we can obtain the transformed log-run total cost function:

$$C = C^V(Q, \mathbf{w}_v, \mathbf{K}^*(Q, \mathbf{w_v}, w_{fi})) + \mathbf{w}_f \mathbf{K}^*(Q, \mathbf{w_v}, w_{fi}). \tag{5}$$

An Approach to Constructing Cost Function

The research methodology of previous cost studies on the rail industry could be divided into three groups. One category of methods uses direct estimation of the long-run total cost function (I will call it the "total-cost approach"). Caves et. al use this approach in their 1985 study, which assumes that a firm can quickly adjust fixed input to optimal size. Their approach is aparently correct because the estimation results are very similar to the indirect estimation based on variable cost function. However, in the case where the estimation result of the long-run marginal costs is not the same as for the short-run marginal costs, then this approach is not appropriate.

The second category uses the variable cost function. This approach is assuming that there is disequilibrium with respect to the stock of way and structure and that a variable cost function is more appropriate. This approach is divided into two further categories by a difference in the recognition of network factors. The first approach (the "variable cost approach") considers as fixed input network variables such as route length. This approach adheres more closely to economic theory, and typical studies using this approach are Savage (1996) and Braeutigam, et. al (1984).

On the other hand, there are studies which consider network variables to be different from the fixed input factor (the " variable-cost with network approach"). Studies of this type include Friedlaender and Spady (1981), and Friedlaender, et. al (1993). Friedlaender and Spady (1981) argue that network factors such as route length are different from the fixed input factor because the network variables show a tendency different from the property satisfied by fixed input factor.

Variables Used for Cost Models in the Rail Industry

Using previous cost studies on rail industries, I will obtain the long-run total cost function. I will approach the problem using the three methods outlined above: the total-cost approach, the variable-cost approach, and the variable-cost with network approach. The basic structure of the cost models used here is a function of output measure (Q), vector of input factor prices (**w**), and vector of network factor (**N**)[2]. In this study, I use pooled data so that the technology index variable (T) is included in the cost function. I assume that the technology is identical among rail organizations for a given year but varies from year to year.[3] This cost function is specified as a single output cost function of passenger service, and the components of input factor are of four kinds: labor, energy, material, and capital costs. And as for network variables, three kinds of network variables such as line length, station spacing and number of lines are included.

However, rail service as output could in actuality differ among railway companies because output components might differ. Furthermore, the service output provision of each railway could vary based on demand conditions because the railway companies in this study are all privately owned and they could use output strategically rather than exogenously. In fact, Savage (1997) specifies many kinds of output characteristics variables such as average journey length, peak-base ratio, and load factor. These variables could indeed be important in urban railway cost study estimations. Therefore, in this study, I include the conditions of service output provision as a function of passenger demand, as well as quality of service. The total cost function, variable cost function, and service output provision function are expressed as follows:

$$C = C\,(Q, \mathbf{w}; T, \mathbf{N}) \qquad (6)$$

$$C^V = C^V\,(Q, \mathbf{w}_v, \mathbf{K}; T, \mathbf{N}) \qquad (7)$$

$Q = g(Q_d, \mathbf{Z}),$ (8)

where C: long-run total costs

C^V: short-run variable costs

Q: rail service output measure

Q_d: rail service demand measure

w: vector of input factor price

$\mathbf{w}_v$: vector of input factor prices of variable input

K: vector of fixed input

T: technology

N: vector of network factor

Z: vector of service quality condition.

3.3 Econometric Cost Models

The functional form of the cost function is specified as translog cost model as follows. I specify three kinds of cost functions because I have applied three separate approaches.

The first model is a variable cost model (VC1), which specifies the variable cost function. In this approach, I assume that the network length is the fixed input defined in economic theory. On the other hand, the second model is a variable cost with network model (VC2). In this model, the network variables are different from fixed input as Friedlaender and Spady (1981) argue. Therefore, in this model, the total assets of rail facilities are considered the fixed input. The long-run total cost functions (TC1and TC2) are obtained from these variable cost functions as the transformed total cost function. I will explain the method later. Finally, the last model (TC3) is the long-run total cost model. This model includes the network variables included by Caves et al (1985). The models are as follows:

(VC1 model):
$$\ln C^V = \alpha_0 + \delta_Q \ln Q + \Sigma_i \beta_i \ln w_i + \Sigma_m \gamma_m \ln N_m + 1/2\ \delta_{QQ} (\ln Q)^2 + \Sigma_i \delta_{Qi} (\ln Q)(\ln w_i) + \Sigma_m \delta_{Qm} (\ln Q)(\ln N_m) + 1/2\ \Sigma_j \Sigma_i \beta_{ij} (\ln w_i)(\ln w_j) + \Sigma_m \Sigma_i \beta_{im} (\ln w_i)(\ln N_m) + 1/2\ \Sigma_n \Sigma_m \gamma_{mn} (\ln N_m)(\ln N_n) + \gamma_U \ln N_U + \tau \ln T, \quad (9)$$

(VC2 model):
$$\ln C^V = \alpha_0 + \delta_Q \ln Q + \Sigma_i \beta_i \ln w_i + \gamma_K \ln K + \Sigma_m \gamma_m \ln N_m + 1/2\ \delta_{QQ} (\ln Q)^2 + \Sigma_i \delta_{Qi} (\ln Q)(\ln w_i) + \delta_{QK} (\ln Q)(\ln K) + \Sigma_m \delta_{Qm} (\ln Q)(\ln N_m) + 1/2\ \Sigma_j \Sigma_i \beta_{ij} (\ln w_i)(\ln w_j) + \Sigma_i \beta_{iK} (\ln w_i)(\ln K) + \Sigma_m \Sigma_i \beta_{im} (\ln w_i)(\ln N_m) + 1/2\ \gamma_{KK} (\ln K)^2 + \Sigma_m \gamma_{Km} (\ln K)(\ln N_m) + 1/2\ \Sigma_n \Sigma_m \gamma_{mn} (\ln N_m)(\ln N_n) + \gamma_U \ln N_U + \tau \ln T, \quad (10)$$

(TC3 model):
$$\ln C = \alpha_0 + \delta_Q \ln Q + \Sigma_i \beta_i \ln w_i + \Sigma_m \gamma_m \ln N_m + 1/2\ \delta_{QQ} (\ln Q)^2 + \Sigma_i \delta_{Qi} (\ln Q)(\ln w_i) + \Sigma_m \delta_{Qm} (\ln Q)(\ln N_m) + 1/2\ \Sigma_j \Sigma_i \beta_{ij} (\ln w_i)(\ln w_j) + \Sigma_m \Sigma_i \beta_{im} (\ln w_i)(\ln N_m) + 1/2\ \Sigma_n \Sigma_m \gamma_{mn} (\ln N_m)(\ln N_n) +$$

$\gamma_U \ln N_U + \tau \ln T,$ (11)

where C: total costs

C^V : variable costs

Q: rail service output measure (vehicle-km)

w_i: input factor price (i (or j) = L (labor), E (energy), M (material and repair) for variable costs) (i (or j)= L (labor), E (energy), M (material and repair), F (capital) for total costs)

K: fixed input

N_m: network factor (m (or n) = N (line length), S (station spacing), R (number of lines)).

N_U: underground length

T: technology index (which varies by year only).

In this model, we also impose the restriction on input factor prices such that $\Sigma_i \beta_i = 1$, $\Sigma_i \delta_{Qi} = 0$, $\Sigma_i \beta_{ij} = 0$, $\Sigma_i \beta_{im} = 0$, $\beta_{ij} = \beta_{ji}$, $\gamma_{mn} = \gamma_{nm}$. Furthermore, we apply Shepherd's Lemma from equation- (9) to (11) and obtain the input share equations:

$S_i = \beta_i + \Sigma_j \beta_{ij} \ln w_j + \delta_{Qi} \ln Q + \Sigma_m \beta_{im} \ln N_m$ for VC1, (12)

$S_i = \beta_i + \Sigma_j \beta_{ij} \ln w_j + \delta_{Qi} \ln Q + \beta_{iK} \ln K + \Sigma_m \beta_{im} \ln N_m$ for VC2, (13)

$S_i = \beta_i + \Sigma_j \beta_{ij} \ln w_j + \delta_{Qi} \ln Q + \Sigma_m \beta_{im} \ln N_m,$ for TC3, (14)

where S_i : input i's share of total costs.

The service output provision function is specified as the log-linear function as follows:

$\ln Q = \delta_0 + \delta_{Qd} \ln Q_D + \Sigma_i \zeta_i \ln Z_i,$ (15)

where Q_D : rail service consumption (passenger-km)

Z_i: quality of service conditions (i = T (trip length), P (peak ratio), L (average load factor)).

As for the estimation method, I apply the FIML (Full Information Maximum Likelihood) for the total cost function, three input share equations and the output provision equation, which I estimate simultaneously. For the estimation, I will divide all observations of each variable by the sample mean.

4 Estimation of Cost Function of Privately Owned Railways

4.1 Sample Selection and Definition of Variables

The observations used here, from which I estimate total cost function, are from a pooled data set of 59 privately owned railway companies for six time periods, the fiscal years 1970, 75, 80, 85, 90 and 95, a total of 354 observations. A privately owned railway company is defined as a rail company in which privately owned stock shareholders account for more than fifty percent of all shareholders, and the main data source is each year's Annual Rail Statistics (Tetsudo Tokei Nenpo), edited by the Ministry of Transport.

The variables used here are defined as follows and shown in Table 4. First, total costs (TC) are the sum of labor, energy, material (including repair) and capital costs. And variable costs (VC) are sum of costs except capital costs. Among these costs, energy costs consist of electricity and light oil expenditures, with depreciation expenditures being considered capital costs because these are mainly consumed for rail facilities and rolling stock.

Service output (Q) is measured as annual vehicle kilometer. According to Small (1992), there are two kinds of output measures: final outputs (or demand-oriented measures) and intermediate outputs (or technical output measures). Examples of the former are passenger trips, passenger-miles, or revenue passengers, while examples of the latter are vehicle-miles, vehicle-hours, or seat-miles. The main purpose of this study is related to the purely technical efficiency issue of a company's production, making it appropriate to choose intermediate outputs. Although seat-kilometer is desirable as an output measure, unavailability of data compels me to use the measure of vehicle kilometer instead. However, in this study, in order to control differences in demand conditions, I also use four kinds of variables: passenger kilometer (Q_D), trip length (Z_T), peak ratio (Z_P), and load factor (Z_L). Trip length is measured as average travel length per passenger. Peak ratio is measured as the ratio of rail pass users to total passengers, assuming that rail pass users are commuters. The load factor is calculated as the percentage of number of passengers to designated capacity of a train vehicle.

As for input factor prices, labor price (w_L) is defined as the annual average salary per person, as reported in the Annual Rail Statistics. While it would seem that in a competitive market, wage levels should not be different, in this sample selection, larger private railways have higher wages. I cannot find a concrete theoretical justification for this difference, but it may result somehow from a difference in the level of skill required of workers at larger railways. These firms pay higher wages and have more generous fringe benefits perhaps because they require various kinds of skills and fast, intelligent reaction to unexpected accidents. For example, in a larger system, operators have to operate many kinds of trains such as super express, express, semi-express, and regular trains, and are sometimes required to operate on rail tracks outside their own network. Furthermore, engineers of train schedules must accommodate many different kinds of trains in their diagram. Thus, larger systems require more complicated skills than smaller systems, perhaps accounting for the higher wage level. Energy price (w_E) is obtained by dividing electricity expenditures by electricity consumption. However, some rail operators owning diesel vehicles use oils, so that I translate oil consumption into the equivalent electricity consumption [4]. Material price (w_M) is obtained by dividing material and repair expenditures by the aggregate material index[5]. Aggregate material index is defined as weighted average of route-km and amount of rolling stock because main material expenditures are considered as expenses related to both tracks and rolling stock. Capital price (w_F) is defined as the price index of capital times the sum of the depreciation rate and the interest rate of short-term government bonds.[6] The depreciation rate is obtained by dividing depreciation expenditures by fixed assets of rail division. As for network factors, three kinds of network characteristic variables are defined. First, the average line length (N_N) is used, which is measured by route kilometer per line. Second, it is also important to include station spacing (N_S) in order to distinguish characteristics of each urban railway system. Station spacing is defined as the average route kilometer between stations. Third, number of lines (N_R) is used for network characteristics. Furthermore, underground length (N_U) is also used to control the technological difference. Finally, fixed (capital) input (K) for VC is defined as fixed capital related to rail facilities.

Table 4 The Definition of and Statistics on Used Variables

variable		definition	mean	standard deviation	minimum	maximum
TC	total cost	sum of labor, energy, material and repair, and depreciation costs (thousand yen)	13,985,300	25,871,700	19,579	167,991,000
VC	variable cost	sum of labor, energy, and material and repair costs (thousand yen)	11,163,300	20,479,400	14,863	135,253,000
Q	service output	annual vehicle kilometer (thousand)	28,285	54,187	13	347,517
w_L	labor price	average annual salary per person (yen/person)	5,580,690	1,715,746	1,503,960	17,155,500
w_E	energy price	electricity expenditure per kwh (yen/kwh)	12.926	6.664	0.837	44.716
w_M	material price	material and repair expenditure per aggregate input index (yen/input index)	12,791	11,647	561	72,591
w_F	capital price	sum of the depreciation rate and the interest rate of government's short-term bonds (%)	15.371	5.116	6.400	51.194
N_N	average route length	route kilometer per line (km)	18.767	12.359	4.200	78.500
N_S	station spacing	average kilometers between stations (km)	1.421	0.573	0.465	3.580
N_R	number of lines	total number of lines which a railway company operates	3.853	4.947	1.000	27.000
N_U	underground length	underground kilometer (km)	2.959	6.280	0.000	39.037

K	fixed input	fixed capital related to rail facilities (million yen)	209,959	433,767	101	3,307,068
Q_D	demand of rail service	annual passenger kilometer (thousand)	1,710,820	3,267,431	112	15,136,400
Z_T	trip length	average trip length per passenger (km)	9.200	4.206	2.815	27.570
Z_P	peak ratio	ratio of rail pass users to total passengers	0.584	0.117	0.192	0.781
Z_L	load factor	percentage of number of passengers to designated capacity of a vehicle (%)	36.558	16.070	5.122	153.518
		[continued]				
T	technology	technology index measured by accident rate	96.002	5.913	83.212	100.000
		For total cost function				
S_L	labor share	ratio of labor costs to total costs	0.6105	0.1151	0.3394	0.8421
S_E	energy share	ratio of energy costs to total costs	0.0655	0.0252	0.0077	0.1424
S_M	material share	ratio of material costs to total costs	0.1912	0.0650	0.0735	0.3774
S_F	capital share	ratio of capital costs to total costs	0.1328	0.0740	0.0075	0.3720
		For variable cost function				
S_L	labor share	ratio of labor costs to total costs	0.6999	0.0928	0.4678	0.8905
S_E	energy share	ratio of energy costs to total costs	0.0768	0.0317	0.0102	0.1828
S_M	material share	ratio of material costs to total costs	0.2234	0.0803	0.0773	0.4739

4.2 Estimation Results of Cost Function

The estimation method is the FIML (Full Information Maximum Likelihood) method for the total cost function with input share equations and the output provision function, which are shown in equation (3) to equation (5). A summary of estimation results is shown in Tables 5 and 6. The goodness-of-fit in the regression of these variable and total cost functions is acceptably high and the first-order coefficients in these functions seem to show a reasonable sign. The estimated result meets almost all of the required properties. First, as for the symmetry and homogeneity conditions, because I impose restrictions on the cost model, symmetry and homogeneity in input factor prices are satisfied. Second, the monotonicity conditions are met in output and input factor prices. Finally, the concavity condition in input factor prices was also satisfied at around the sample mean because the Hessian matrix holds at negative semidefinite. Strictly speaking, the concavity condition does not satisfy globally, but I conclude that this function is acceptable because it satisfies in 80.8% of observations for VC1, 81.4% for VC2 and 86.4% for TC3. In sum, the estimation results seem reasonable enough to justify the following policy analysis. However, there are some differences in the results between the variable cost and the total cost function. Especially, the coefficient of the first-order output measure (δ_Q) in the total cost function is significantly larger than that of variable cost functions. The different results might account for rail organizations failing to choose the optimal size of capital in the short-run. Therefore, based on a comparison of the coefficients of output measures and other statistics, in the next section we will evaluate which results are reasonable.

Table 5 Estimation Results of the Translog Cost Function: Coefficients and Standard Error

Model	VC1	VC2	TC3	Model	VC1	VC2	TC3
	VC function and K=network length	VC function and K=fixed capital	Direct estimation of TC		VC function and K=network length	VC function and K=fixed capital	Direct estimation of TC
α_0	16.1587 *** (0.0299)	16.1468 *** (0.0311)	16.4150 *** (0.0328)	β_{MM}	0.1212 *** (0.0056)	0.1193 *** (0.0057)	0.1089 *** (0.0049)
δ_Q	0.7307 *** (0.0203)	0.7561 *** (0.0479)	0.8161 *** (0.0223)	β_{MF}	-	-	- 0.0067 (0.0046)
β_L	0.6794 *** (0.0066)	0.6775 *** (0.0071)	0.5625 *** (0.0080)	β_{FF}	-	-	- 0.0318 *** (0.0107)
β_E	0.1010 *** (0.0017)	0.1012 *** (0.0018)	0.0827 *** (0.0014)	β_{LK}	-	- 0.0093 (0.0060)	-
β_M	0.2196 *** (0.0059)	0.2213 *** (0.0062)	0.1737 *** (0.0057)	β_{LN}	- 0.0035 (0.0090)	- 0.0059 (0.0096)	0.0266 ** (0.0109)
β_F	-	-	0.1811 *** (0.0050)	β_{LS}	- 0.0426 *** (0.0102)	- 0.0398 *** (0.0104)	- 0.0654 *** (0.0132)
γ_K	-	- 0.0166 (0.0361)	-	β_{LR}	- 0.0245 *** (0.0070)	- 0.0257 *** (0.0075)	0.0083 (0.0094)
γ_N	0.2733 *** (0.0519)	0.2614 *** (0.0538)	0.1685 *** (0.0571)	β_{EK}	-	0.0012 (0.0027)	-
γ_S	- 0.2743 *** (0.0590)	- 0.2710 *** (0.0608)	- 0.1786 *** (0.0633)	β_{EN}	- 0.0096 *** (0.0030)	- 0.0092 *** (0.0032)	- 0.0028 (0.0025)
γ_R	0.2670 *** (0.0356)	0.2562 *** (0.0386)	0.1708 *** (0.0348)	β_{ES}	0.0105 *** (0.0036)	0.0102 *** (0.0037)	0.0051 * (0.0031)
γ_U	0.0015 (0.0014)	0.0011 (0.0015)	0.0029 ** (0.0013)	β_{ER}	- 0.0105 *** (0.0024)	- 0.0102 *** (0.0026)	- 0.0045 ** (0.0020)
τ	- 1.4991 *** (0.1617)	-1.5372 *** (0.1662)	- 1.2151 *** (0.1534)	β_{MK}	-	0.0081 (0.0054)	-
δ_{QQ}	0.1120 ***	0.1366 ***	0.1182 ***	β_{MN}	0.0131 *	0.0151 *	0.0278 ***

	(0.0111)	(0.0388)	(0.0132)		(0.0076)	(0.0081)	(0.0065)
δ_{QL}	0.0195 *** (0.0040)	0.0298 *** (0.0084)	- 0.0079 (0.0051)	β_{MS}	0.0321 *** (0.0090)	0.0296 *** (0.0091)	0.0148 * (0.0077)
δ_{QE}	0.0146 *** (0.0015)	0.0132 *** (0.0034)	0.0088 *** (0.0012)	β_{MR}	0.0350 *** (0.0062)	0.0359 *** (0.0064)	0.0434 *** (0.0052)
δ_{QM}	- 0.0341 *** (0.0035)	- 0.0430 *** (0.0073)	- 0.0423 *** (0.0031)	β_{FN}	-	-	- 0.0517 *** (0.0075)
δ_{QF}	-	-	0.0415 *** (0.0037)	β_{FS}	-	-	0.0455 *** (0.0092)
δ_{QK}	-	- 0.0299 (0.0307)	-	β_{FR}	-	-	- 0.0472 *** (0.0069)
δ_{QN}	- 0.0921 *** (0.0180)	- 0.0616 (0.0438)	- 0.0955 *** (0.0194)	γ_{KK}	-	0.0352 (0.0275)	-
		(cont.)					
δ_{QS}	- 0.1062 *** (0.0226)	- 0.0669 (0.0508)	- 0.0739 *** (0.0240)	γ_{KN}	-	- 0.0255 (0.0303)	-
δ_{QR}	- 0.0846 *** (0.0201)	- 0.0588 (0.0364)	- 0.0938 *** (0.0224)	γ_{KS}	-	- 0.0348 (0.0377)	-
β_{LL}	0.1402 *** (0.0073)	0.1389 *** (0.0077)	0.0901 *** (0.0161)	γ_{KR}	-	- 0.0235 (0.0284)	-
β_{LE}	- 0.0249 *** (0.0033)	- 0.0253 *** (0.0033)	- 0.0273 *** (0.0036)	γ_{NN}	0.1826 *** (0.0560)	0.1765 *** (0.0598)	0.1607 *** (0.0564)
β_{LM}	- 0.1153 *** (0.0059)	- 0.1136 *** (0.0061)	- 0.0983 *** (0.0068)	γ_{NS}	0.0913 * (0.0536)	0.0924 (0.0575)	0.0439 (0.0549)
β_{LF}	-	-	0.0355 *** (0.0119)	γ_{NR}	0.0976 ** (0.0454)	0.0826 * (0.0466)	0.1026 * (0.0528)
β_{EE}	- 0.0308 *** (0.0023)	- 0.0310 *** (0.0024)	0.0282 *** (0.0020)	γ_{SS}	0.1247 (0.1530)	0.1292 (0.1533)	0.1336 (0.1489)
β_{EM}	- 0.0059 *** (0.0022)	- 0.0057 ** (0.0024)	- 0.0038 ** (0.0018)	γ_{SR}	0.1423 ** (0.0562)	0.1399 ** (0.0582)	0.1107 * (0.0616)
β_{EF}	-	-	0.0029 (0.0029)	γ_{RR}	0.0010 (0.0521)	- 0.0030 (0.0547)	0.0017 (0.0539)

(Note)
(1) Log of likelihood: 34.173 for VC1, 34.805 for VC2, 58.393 for TC3.
(2) Pseudo R^2: 0.9861 for VC1, 0.9861 for VC2, 0.9885 for TC1.
(3) Number of observations: 354 for VC1, VC2 and TC3.
(4) Significant at 1 percent (***), 5 percent (**) and 10 percent (*).

Table 6 Estimation Results of the Output Provision: Coefficients and Standard Error

Model	VC1	VC2	TC3
	VC function and K=network length	VC function and K=fixed capital	Direct estimation of TC
δ_0	0.2598 *** (0.0245)	0.2598 *** (0.0250)	0.2580 *** (0.0251)
δ_{Qd}	0.9270 *** (0.0072)	0.9271 *** (0.0075)	0.9257 *** (0.0076)
ζ_T	- 0.0406 (0.0318)	- 0.0420 (0.0329)	- 0.0367 (0.0310)
ζ_P	- 0.1996 *** (0.0450)	- 0.1994 *** (0.0450)	- 0.2054 *** (0.0455)

ζ_L	- 0.6150 *** (0.0320)	- 0.6151 *** (0.0333)	- 0.6055 *** (0.0329)
R^2	0.9924	0.9924	0.9923
Significant at 1 percent (***), 5 percent (**) and 10 percent (*).			

4.3 Transformation of Variable Cost Function to Long-run Total Cost Function

In this section, I will explain the method of construction of the long-run cost function from the short-run variable cost function. The main framework used here is based on a study by Braeutigam, Daughety and Turnquist (1984).

As explained in section 3.2, according to microeconomic theory, at the optimal choice of the fixed input equation- (3) must hold. By solving equation- (3) for fixed input, we can obtain the optimal amount of fixed input from equation- (4). However, because in this equation there are other variables such as output and input factor prices, we cannot decide upon only one value of fixed input. Braeutigam et al. (1984) find the optimal size of fixed input by holding other variables except for fixed input at sample mean points. To simplify, I assume that the fixed input is one, which is the total fixed capital of rail facilities. Following their method, we can get the following equation from the specific translog cost function for the VC2 model:

$$C^S = \exp[\alpha_0 + \gamma_K \ln K + (1/2)\gamma_{KK} (\ln K)^2] + w_f K. \quad (16)$$

From the condition shown in equation - (16), we can get the following result:

$$[(\gamma_K + \gamma_{KK} \ln K)/K] \exp [\alpha_0 + \gamma_K \ln K + (1/2)\gamma_{KK}(\ln K)^2] + w_f = 0 \quad (17)$$

From equation- (17), we can find the optimal size of capital input, K^*. According to my calculation, the optimal size is $K^* = 1.6024 \underline{K}$, when the capital at the sample mean is $\underline{K}$. In the VC1 model, a variable of total fixed capital of rail facilities is included. But in this case, I choose line length as a proxy measure of fixed input. Therefore, I calculate the same way by assuming that line length (N_N) is capital input (K)

Next, we will obtain the transformed long-run total cost function based on the optimal size of capital input, K^*. The transformation method is such that the parameters of variables which have a cross-term with capital input are recalculated by substituting the optimal size of capital input. The results of the transformed total cost function are summarized in Table 7. If we compare the transformed total cost function with the directly estimated total cost function, the overall results seem to be similar but strictly speaking, the first-order coefficients of output measure could be different. When I apply the t-test for the difference in the coefficients of output measure (δ_Q), I get a result showing a difference. Furthermore, from the results of the variable cost function, we get a result showing that rail organizations did not choose the optimal size of railway facilities. Therefore, I conclude that the transformed total cost function should be used. Between the transformed total cost functions, there is not much difference. However, the log of likelihood in the variable cost function suggests that VC2 is slightly better than VC1. Therefore, I decided to use the TC2 function for policy evaluation.

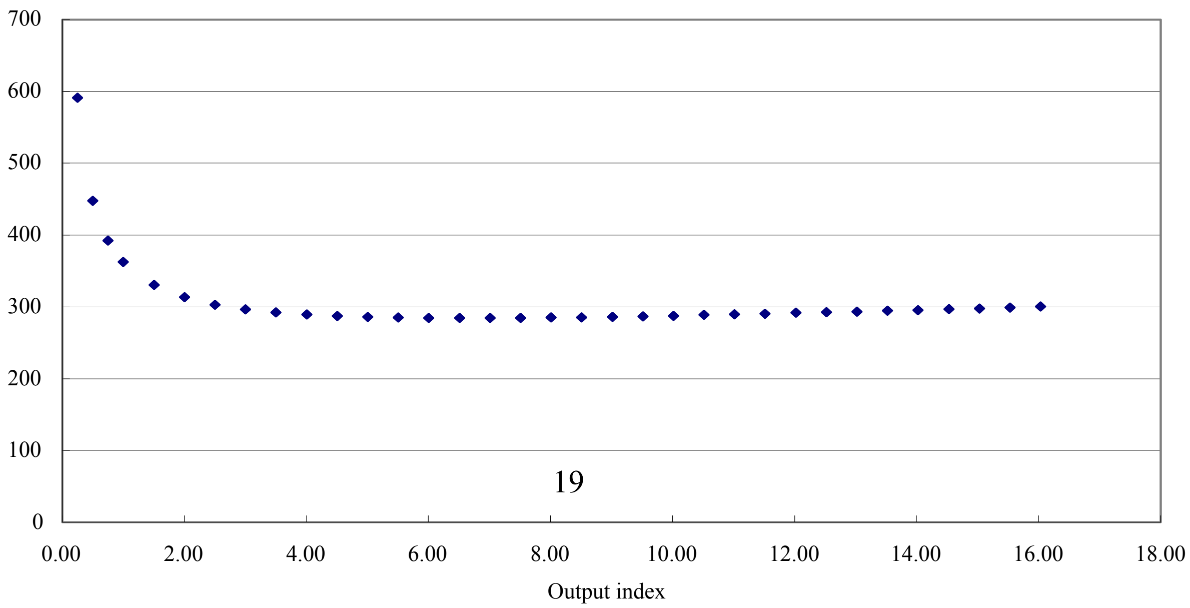
Table 7 Comparison of Long-run Total Cost Function: Coefficients and Standard Error							
Model	TC1	TC2	TC3	Model	TC1	TC2	TC3
	Transformed TC function used by VC1	Transformed TC function used by VC2	Direct estimation of TC		Transformed TC function used by VC1	Transformed TC function used by VC2	Direct estimation of TC
α_0	15.9542 *** (0.1136)	16.1429 *** (0.0352)	16.4150 *** (0.0328)	β_{MM}	0.1212 *** (0.0056)	0.1193 *** (0.0057)	0.1089 *** (0.0049)
δ_Q	0.8705 *** (0.0394)	0.7420 *** (0.0505)	0.8161 *** (0.0223)	β_{MF}	-	-	- 0.0067 (0.0046)
β_L	0.6847 *** (0.0162)	0.6731 *** (0.0080)	0.5625 *** (0.0080)	β_{FF}	-	-	- 0.0318 *** (0.0107)
	(cont.)						
β_E	0.1156 *** (0.0050)	0.1017 *** (0.0024)	0.0827 *** (0.0014)	β_{LK}	-	-	-
β_M	0.1997 *** (0.0137)	0.2251 *** (0.0071)	0.1737 *** (0.0057)	β_{LN}	-	- 0.0059 (0.0096)	0.0266 ** (0.0109)
β_F	-	-	0.1811 *** (0.0050)	β_{LS}	- 0.0426 *** (0.0102)	- 0.0398 *** (0.0104)	- 0.0654 *** (0.0132)
γ_K	-	-	-	β_{LR}	- 0.0245 *** (0.0070)	- 0.0257 *** (0.0075)	0.0083 (0.0094)
γ_N	-	0.2494 *** (0.0546)	0.1685 *** (0.0571)	β_{EK}	-	-	-
γ_S	- 0.4129 *** (0.1000)	- 0.2874 *** (0.0632)	- 0.1786 *** (0.0633)	β_{EN}	-	- 0.0092 *** (0.0032)	- 0.0028 (0.0025)
γ_R	0.1187 *** (0.0830)	0.2451 *** (0.0439)	0.1708 *** (0.0348)	β_{ES}	0.0105 *** (0.0036)	0.0102 *** (0.0037)	0.0051 * (0.0031)
γ_U	0.0015 (0.0014)	0.0011 (0.0015)	0.0029 ** (0.0013)	β_{ER}	- 0.0105 *** (0.0024)	- 0.0102 *** (0.0026)	- 0.0045 ** (0.0020)
τ	- 1.4991 *** (0.1617)	-1.5372 *** (0.1662)	- 1.2151 *** (0.1534)	β_{MK}	-	-	-
δ_{QQ}	0.1120 *** (0.0111)	0.1366 *** (0.0388)	0.1182 *** (0.0132)	β_{MN}	-	0.0151 * (0.0081)	0.0278 *** (0.0065)
δ_{QL}	0.0195 *** (0.0040)	0.0298 *** (0.0084)	- 0.0079 (0.0051)	β_{MS}	0.0321 *** (0.0090)	0.0296 *** (0.0091)	0.0148 * (0.0077)
δ_{QE}	0.0146 *** (0.0015)	0.0132 *** (0.0034)	0.0088 *** (0.0012)	β_{MR}	0.0350 *** (0.0062)	0.0359 *** (0.0064)	0.0434 *** (0.0052)
δ_{QM}	- 0.0341 *** (0.0035)	- 0.0430 *** (0.0073)	- 0.0423 *** (0.0031)	β_{FN}	-	-	- 0.0517 *** (0.0075)
δ_{QF}	-	-	0.0415 *** (0.0037)	β_{FS}	-	-	0.0455 *** (0.0092)
δ_{QK}	-	-	-	β_{FR}	-	-	- 0.0472 *** (0.0069)
δ_{QN}	-	- 0.0616 (0.0438)	- 0.0955 *** (0.0194)	γ_{KK}	-	-	-
δ_{QS}	- 0.1062 *** (0.0226)	- 0.0669 (0.0508)	- 0.0739 *** (0.0240)	γ_{KN}	-	-	-
δ_{QR}	- 0.0846 *** (0.0201)	- 0.0588 (0.0364)	- 0.0938 *** (0.0224)	γ_{KS}	-	-	-
β_{LL}	0.1402 *** (0.0073)	0.1389 *** (0.0077)	0.0901 *** (0.0161)	γ_{KR}	-	-	-
β_{LE}	- 0.0249 ***	- 0.0253 ***	- 0.0273 ***	γ_{NN}	-	0.1765 ***	0.1607 ***

	(0.0033)	(0.0033)	(0.0036)			(0.0598)	(0.0564)
β_{LM}	- 0.1153 *** (0.0059)	- 0.1136 *** (0.0061)	- 0.0983 *** (0.0068)	γ_{NS}	-	0.0924 (0.0575)	0.0439 (0.0549)
β_{LF}	-	-	0.0355 *** (0.0119)	γ_{NR}	-	0.0826 * (0.0466)	0.1026 * (0.0528)
β_{EE}	- 0.0308 *** (0.0023)	- 0.0310 *** (0.0024)	0.0282 *** (0.0020)	γ_{SS}	0.1247 (0.1530)	0.1292 (0.1533)	0.1336 (0.1489)
β_{EM}	- 0.0059 *** (0.0022)	- 0.0057 ** (0.0024)	- 0.0038 ** (0.0018)	γ_{SR}	0.1423 ** (0.0562)	0.1399 ** (0.0582)	0.1107 * (0.0616)
β_{EF}	-	-	0.0029 (0.0029)	γ_{RR}	0.0010 (0.0521)	- 0.0030 (0.0547)	0.0017 (0.0539)

(Note)
(1) Significant at 1 percent (***), 5 percent (**) and 10 percent (*).

4.4 Economies of Scale

We can discern several important implications relevant to policy, for example the existence of economies of scale, an issue which has been explored in many previous studies. A method for the calculation of scale economies can be found in Jara-Diaz and Cortes (1996), who present a theoretical background of the measures of scale economies, including the attributes of outputs. I follow the analytical method of Jara-Diaz and Cortes in this study, whereby there are five variables related to the calculation of the measure of scale economies: output measure, average trip length, peak ratio, load factor, average route length, station spacing and number of lines. I define the return to density (RTD) and the return to scale (RTS) as follows. RTD is measured by the inverse of the coefficient of output measure and attributes, and RTS is defined as the inverse of the sum of the coefficients of variables used in RTD and the three network variables of line length, station spacing, and number of lines. Next, according to their method, I assign the value of one as the weight of output measure and network variables, and the weight of average trip length should be zero. I assume that load factor and peak ratio are the same and 0.1851 from the relationship between passenger-km and vehicle-km.[7] Finally, passenger-km as output measure and attributes are modified by the coefficient of vehicle-km.[8] Using this procedure, I obtain the results that RTD at the sample mean is 1.736 and RTS is 1.277.[9] Following the method of Jara-Diaz and Cortes, I obtain the result that there exist both economies of scale and network density at the sample mean, which suggests that the size attaining the minimum average cost



could be larger than the sample mean in this analysis. Finally, when I draw the average cost curve based on the results of cost function (TC2), the shape is certainly U-shaped and the size is larger than the sample mean, as Figure 1 shows.

Figure 1 The Shape of Average Cost Function

(Note) Output Index is calculated by dividing numbers of output by sample mean.

5 Estimation of Minimum Average Cost and Ownership Difference

5.1 Minimum Average Cost

In this section, I will estimate the optimal size of a private rail company based on the transformed total cost functions. Optimal size used here denotes an organization size with the lowest average total cost. From previously expressed equations, I define the average cost function as follows. In this case, as I will use the transformed total cost function from the variable cost function, I will attach an asterisk to the coefficients in order to distinguish the coefficients of the directly estimated total cost function.

$$
\begin{aligned}
AC &= TC / Q \\
&= (1 / Q)\ \mathrm{EXP}[\alpha_0^* + \delta_Q^* \ln Q + \Sigma_i \beta_i^* \ln w_i + \Sigma_m \gamma_m^* \ln N_m + 1/2\ \delta_{QQ} (\ln Q)^2 + \\
&\quad \Sigma_i \delta_{Qi} (\ln Q)(\ln w_i) + \Sigma_m \delta_{Qm} (\ln Q)(\ln N_m) + 1/2\ \Sigma_j \Sigma_i \beta_{ij} (\ln w_i)(\ln w_j) + \\
&\quad \Sigma_m \Sigma_i \beta_{im} (\ln w_i)(\ln N_m) + 1/2\ \Sigma_n \Sigma_m \gamma_{mn} (\ln N_m)(\ln N_n) + \gamma_U \ln N_U + \tau \ln T]. \qquad (18)
\end{aligned}
$$

From the average cost function, I will find the point with the minimum average cost. The main focus of this analysis is to find the minimum average variable cost in terms of output measure (Q) and network factors (N_m), which are related to policy issues. Because the organization size is concerned with network length, here I take two network factors: average line length (N_N) and number of lines (N_R). Differentiating the average cost function by these three measures--service output (Q), average line length (N_N), and number of lines (N_R)-- the following result can be obtained from the first order condition for the minimum average cost:

$$
\begin{aligned}
\partial(AC)/\partial Q &= \partial(TC/Q)/\partial Q \\
&= (1/Q^2)\ [\mathrm{EXP}\ (G)][1 - (\delta_Q^* + \delta_{QQ} \ln Q + \Sigma_i \delta_{Qi} \ln w_i + \Sigma_m \delta_{Qm} \ln N_m)] = 0 \qquad (19) \\
\partial(AC)/\partial N_N &= \partial(TC/Q)/\partial N_N \\
&= (1/QN_N)\ [\mathrm{EXP}\ (G)][\ \gamma_N^* + \delta_{QN} \ln Q + \Sigma_i \beta_{iN} \ln w_i + \Sigma_m \gamma_{Nm} \ln N_m] = 0 \qquad (20) \\
\partial(AC)/\partial N_R &= \partial(TC/Q)/\partial N_R \\
&= (1/QN_R)\ [\mathrm{EXP}\ (G)][\gamma_R^* + \delta_{QR} \ln Q + \Sigma_i \beta_{iR} \ln w_i + \Sigma_m \gamma_{Rm} \ln N_m] = 0, \qquad (21)
\end{aligned}
$$

where $G = [\alpha_0^* + \delta_Q^* \ln Q + \Sigma_i \beta_i^* \ln w_i + \Sigma_m \gamma_m^* \ln N_m + 1/2\ \delta_{QQ} (\ln Q)^2 +$

$\Sigma_i \delta_{Qi} (\ln Q)(\ln w_i) + \Sigma_m \delta_{Qm} (\ln Q)(\ln N_m) + 1/2\, \Sigma_j \Sigma_i \beta_{ij} (\ln w_i) (\ln w_j) +$

$\Sigma_m \Sigma_i \beta_{im} (\ln w_i)(\ln N_m) + 1/2\, \Sigma_n \Sigma_m \gamma_{mn} (\ln N_m)(\ln N_n) + \gamma_U \ln N_U + \tau \ln T.$

Because EXP(G) ≠ 0, Q ≠ 0, $N_N \neq 0$, and $N_R \neq 0$, the following results are obtained from equations (19) to (21).

$$\delta_Q^* + \delta_{QQ} \ln Q + \Sigma_i \delta_{Qi} \ln w_i + \Sigma_m \delta_{Qm} \ln N_m = 1 \quad (22)$$

$$\gamma_N^* + \delta_{QN} \ln Q + \Sigma_i \beta_{iN} \ln w_i + \Sigma_m \gamma_{Nm} \ln N_m = 0 \quad (23)$$

$$\gamma_R^* + \delta_{QR} \ln Q + \Sigma_i \beta_{iR} \ln w_i + \Sigma_m \gamma_{Rm} \ln N_m = 0. \quad (24)$$

By solving the three equations from (22) to (24) for Q, N_N, and N_R , we can obtain the optimal level of output (Q^*), line length (N_N^*) and number of lines (N_R^*), which attain the minimum average costs. However, it is worth noting that we cannot decide the unique values of these three variables from these general equations because other variables such as input factor prices are not fixed. However, if we take some fixed numbers for other variables, we can obtain unique numbers for output, line length, and number of lines.

5.2 Cost Difference by Ownership

The estimated result of the total cost function of privately owned railways will be used for the estimation of cost differences by ownership. I will consider two kinds of organizations: privately owned railways and publicly owned railways. The profile of the typical rail company of these kinds of organizations is expressed as the combination of actual total cost (TC), output measure (Q), input factor price vector (**w**), and network characteristics vector (**N**) for a given technology level (or year) (T). It is natural to compare these variables, as we estimated the total cost function using them. I will express the combination as (TC^i; Q^i, $\mathbf{w}^i$, $\mathbf{N}^i$) for ownership type i. For example, a private and a public railway's characteristics are expressed as (TC^{pr}; Q^{pr}, $\mathbf{w}^{pr}$, $\mathbf{N}^{pr}$) and (TC^{pu}; Q^{pu}, $\mathbf{w}^{pu}$, $\mathbf{N}^{pu}$) individually.

The simplest method of estimating cost difference by ownership would be to compare the actual total cost of a typical rail company in these three categories, that is to compare $TC^{pr}$and TC^{pu}. However, this method is not appropriate because other conditions such as the size of output, input factor price level, and network characteristics are not the same (Mizutani, 1994). Therefore, I will use the transformed total cost function in order to control the other conditions. For example, when we substitute the combination of explanatory variables (Q^i, $\mathbf{w}^i$, $\mathbf{N}^i$) for each type of organization in given year (T) into the equation, we can obtain the predicted total cost of the privately owned railway. The important point is that the predicted total cost of the private railway is obtained by holding the same conditions in output level, input factor prices, and network characteristics as for railways of different ownership.

$$TC_h^{pr} = f(Q, \mathbf{w}, T, \mathbf{N}) \quad (25)$$

Where TC_h^{pr} : predicted (or hypothetical) total cost by substituting (Q, **w**, **N**) into the transformed total cost function (TC2)).

Therefore, by substituting Q, **w**, and **N** of a typical rail company of each ownership in given year (T), we can obtain the hypothetical private railway's total cost. For example, the hypothetical private railway's total cost with the same conditions as a public railway and a partially private railway is obtained by substituting (Q^{pu}, $\mathbf{w}^{pu}$, $\mathbf{N}^{pu}$) into the equation – (25). Therefore, we can compare the hypothetical private railway's cost, TC_h^{pr}, with the actual public railway's cost, TC^{pu}. I will define the index (R) for the cost comparison by ownership as follows:

$$R_{TC} = TC^{pu} / TC_h^{pr} \quad (26)$$

Where R_{TC}: index for total cost comparison by ownership

TC^{pu} : actual total cost of a public railway company

TC_h^{pr} : total cost of a hypothetical private rail company

(a hypothetical private is divided into three levels: more efficient, average, less efficient).

From this index, we can estimate how much more productive efficiency the private ownership has, compared with other types of ownership. In this case I also compare the variable cost between the two sectors by a similar method:

$$R_{VC} = VC^{pu} / VC_h^{pr} \quad (27)$$

Where R_{VC}: index for variable cost comparison by ownership

VC^{pu} : actual variable cost of a public railway company

VC_h^{pr} : variable cost of a hypothetical private rail company

(a hypothetical private is divided into three levels: more efficient, average, less efficient).

5.3 Estimation Results

Minimum Average Cost

In this section, I will calculate the optimal size of a private rail company in terms of service output, line length and number of lines. In order to obtain optimal size, we can employ the previous equations from (22) to (24), which are the first order conditions for the minimum average cost. In this analysis, I assume that other variables, such as input factor prices except for service output, line length and number of lines, are fixed at the level of sample mean. As a result, because these explanatory variables in total cost function are standardized by dividing by the sample mean, terms which include other variables except for output, line length, and number of lines disappear.

When these three equations are solved based on TC2, the optimal levels for output (Q^*) and the total line length are individually 194,253 thousands vehicle-km and 85.1 km. Compared with the case of the directly estimated total cost function (TC3), the output level and the network length are larger (output: 124,818; total line length: 66.6, based on the TC3 model). Based on my calculations, the optimal network has an average line length (N_N^*) of 4km and number of lines (N_R^*) of 21. In this case, the average costs are 287 yen per vehicle-km. The network size is quite similar to large Japanese private railway companies, which are considered efficient.

Are these numbers reasonable? Preston (1996) reports that the optimal railway size for minimizing operating costs might have a network of around 4,000 km and run 120 million train-km per annum, based on calculations obtained from European state railways. The studies deal with different types of railways: my study is based on privately owned urban railways, while Preston's results come from state railways in Europe. Preston shows that the optimal size in terms of train-km is 120 million train-km, and my results, when translated into the same output measure (i.e. train-km), show optimal size to be about half that, at 65 million train-km (= 194 million vehicle-km / 3 cars per train). However, in terms of network size, I show an optimal total length of about 85 km, a result much smaller than Preston's. Presumably, the difference reflects the fact that my study focuses on urban railways, and that these urban railways are much more densely operated in Japan than in other countries. My result suggests that large private railways in Japan are the right size, which may partially explain their success.

If I evaluate the size of the newly privatized JRs according to my results, I find that JR Shikoku is clearly smaller than the optimally sized railway, while JR East and JR West are too big. Other JR companies such as JR Hokkaido and JR Kyushu seem to have too large a network relative to their output size.

Cost Differences by Ownership

In this section, I will estimate cost differences by ownership. According to the methodology explained in the previous section, I will evaluate cost differences between the two kinds of rail organizations: private and public. A public railway is a railway organization which has from its beginning been owned only by the public sector. For the purpose of this study, a public railway is the sample average of ten public subway systems. Because these public railways are subway systems, in order to avoid bias by technological difference, I included the effect of underground in the cost function. Therefore, in this analysis, the technological difference is subtracted. The cost difference is summarized in Table 7.

Estimated cost difference by ownership is as follows. First, the ratio in variable cost is 0.852, compared with average private. However, compared with more efficient private, the ratio becomes 1.222. According to these results, there is not much difference between private and public rail operators in terms of variable costs. However, the total costs of public railways are certainly higher than those of private railways because the ratio is almost one even if the public is compared with less efficient private. On average, the public ownership still costs 39% more than private ownership in terms of total costs.

These results are slightly different from those found in other studies (e.g. Miyajima and Lee, 1984; Mizutani, 1994; Mizutani, 1999a). While, most previous studies show that in both variable and total costs, private railways are more efficient than public, this study shows no difference or a slight advantage in variable costs for public railways. There are three main reasons. First, smaller private railways are not efficient because they are regional monopolies and fare regulation protects their business. Second, public railways are relatively new so that their new technology saves on operating cost. Third, the privatization of JNR and recent governmental budget constraints have decreased wasteful operating expenditures. However, as total costs of public railways are still higher than private, it may be that publicly owned organizations are overcapitalizing.

Table 7 Ownership Difference between Private and Public operators

Type of private	Variable Cost (R_{VC})	Total Cost (R_{TC})
	VC2 VC function with K=fixed capital	TC2 Transformed TC function used by VC2
Less efficient private (Upper 10%)	0.594	0.970
Average private	0.852	1.391
More efficient private (Lower 10%)	1.222	1.996

(Note):
(1) Each type of private is defined as follows:
Average private: the estimated point on the line of cost function
Less efficient private: the upper limit of 10% confidence in the cost function
More efficient private: the lower limit of 10% confidence in the cost function

6 CONCLUSION

This paper has aimed to estimate the cost function of privately owned passenger railways, to calculate minimum average cost by using the cost function, and to evaluate the cost differences between private and public railways. This analysis is relevant to the work of policy makers as they restructure state railways into private organizations of an optimal size for achieving efficiency. We have seen that private ownership indeed does produce rail service more cheaply than public ownership. As for the organization size, we have attained the specific following results: the optimal size of a railway organization, that which attains minimum average costs, is the organization with 194 million vehicle-km annually and a total network of about 85km, which is a route-km per line of 4 km, with 21 lines. In this case, the average costs are 287 yen per vehicle-km in 1990 values. Second, in terms of total costs, the costs of public railways are certainly higher than for private railways. On average, the costs of full public ownership are 39.1% higher than those for full private ownership. However, in terms of variable costs, there are no differences between two sectors. Therefore, ownership is one factor showing cost difference, but could not be the absolute factor. Last, based on my calculations, the variable cost function should be used because railway organizations fail to optimize their facilities in the short-run.

NOTES

[1] As for the entrepreneurial behavior of private railways, see, for example, Van de Velde, D., F. Mizutani, J. Preston and S. Hulten (1998).

[2] In this study, the cost function is long-run cost function. In theory, the capital stock is not fixed in the long-run cost function. However, because the data set of the empirical cost study is pooled data, the cost function necessarily includes such network variables as capital stock in order to control for heterogeneous network conditions.

[3] Strictly speaking, each railway organization might use differing technology, especially for maintaining safety. However, I assume that production technology is the same among railways per given year. Therefore, technology changes by time only.

[4] Based on data from a previous study (Pushkarev, Zupan and Cumella, 1982), I used the following formula to translate oil consumption to equivalent consumption:

$ELCe = 10526.9\ OIL$

where ELCe : equivalent electricity consumption (kwh)

OIL : actual light oil consumption (kl)

[5] Most material expenditure is related to rail tracks, including electric wires and rolling stock. In general, the expenditure is price times quantity, so that if we know the “quantity” of material, then we can know the “price.” In this study, I assume that the main quantity of materials is related to rail track and rolling stock. And I assume that quantity in each category depends on the expenditure of material in that category, as there is data on material expenditure regarding track and rolling stock for each rail company. I use these expenditures as weight to construct the aggregate index of materials. I define the aggregate material index (AMI) as follows:

$AMI = w_1 RKM + w_2\ TV$

Where RKM: total route kilometer

TV: total number of train car

w_1, w_2: weight (defined as expenditure of tracks and rolling stock).

[6] Capital price (w_F) is defined as follows:

$w_F = PI\ (r + \delta\ )$

where PI : price index of capital (base year : 1990) r : interest rate of short-term government bonds

δ : depreciation.

[7] According to Jara-Diaz and Cortes (1996), the weight of vehicle-km is smaller than that of passenger-km by γ. I assume that this difference is shown in the difference of coefficients of these variables. As a result, I obtain the number as 0.1851 (= 0.9271 – 0.7420). Therefore, this is used for the weight of load factor.

[8] All coefficients of passenger-km and attributes are multiplied by 0.7420.

[9] The calculation results are as follows:

$RTD = [\delta_Q \delta_{Qd} + 0.1851\ \delta_Q (\zeta_P + \zeta_L)]^{-1}$

$RTS = [\delta_Q \delta_{Qd} + 0.1851\ \delta_Q (\zeta_P + \zeta_L) + \gamma_N + \gamma_S + \gamma_R\ ]^{-1.}$

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REFERENCES

Berndt, E. R., A. F. Friedlaender, J. S. W. Chiang and C. A. Vellturo (1993) "Cost Effects of Mergers and Deregulation in the U.S. Rail Industry," *Journal of Productivity Analysis,* Vol.4, No.1-2, pp.123-144

Borts, G. H. (1960) "The Estimation of Rail Cost Functions," *Econometrica*, Vol.28, No.1, pp.108-131

Braeutigam, R. R., A. F. Daughety and M. A. Turnquist (1982) "The Estimation of a Hybrid Cost Function for a Railroad Firm," *Review of Economics and Statistics,* Vol.64, No.3, pp.394-404

Braeutigam, R. R., A. F. Daughety and M. A. Turnquist (1984) "A Firm Specific Analysis of Economies of Density in the U.S. Railroad Industry," *Journal of Industrial Economics,* Vol.33, No.1, pp.3-20

Brown, R. S., D. W. Caves and L. R. Christensen (1979) "Modeling the Structure of Cost and Production for Multiproduct Firms," *Southern Economic Journal,* Vol.46, No. 1, pp.256-273

Caves, D. W. and L. R. Christensen (1980) "The Relative Efficiency of Public and Private Firms in a Competitive Environment: The Case of Canadian Railroads," *Journal of Political Economy,* Vol.88, No.5, pp.958-976

Caves, D. W., L. R. Christensen and J. A. Swanson (1980) "Productivity in U.S. railroads, 1951-1974," *Bell Journal of Economics,* Vol.11, No.1, pp.166-181

Caves, D. W., L. R. Christensen and J. A. Swanson (1981a) "Productivity Growth, Scale Economies, and Capacity Utilization in U.S. Railroads, 1955-74," *American Economic Review,* Vol.71, No.5, pp.994-1002

Caves, D. W., L. R. Christensen and J. A. Swanson (1981b) "Economic Performance in Regulated and Unregulated Environments: A Comparison of U.S. and Canadian Railroads," *Quarterly Journal of Economics,* Vol.96, No.4, pp.559-581

Caves, D. W., L. R. Christensen, M. W. Tretheway and R. J. Windle (1985) "Network Effects and the Measurement of Returns to Scale and Density for U.S. Railroads," in Daughety, A. F. (ed.) *Analytical Studies in Transport Economics,* Cambridge University Press, New York, U.S.A., pp.97-120

De Borger, B. (1991) "Hedonic Versus Homogeneous Output Specifications of Railroad Technology: Belgian Railroads 1950 - 1986," *Transportation Research,* Vol.25A, No.4, pp.227-238

De Borger, B. (1992) "Estimating a Multiple-output Generalized Box-Cox Cost Function: Cost Structure and Productivity Growth in Belgian Railroad Operations, 1950-1986," *European Economic Review,* Vol.36, No.7, pp.1379 - 1398

Dodgson, J. S. (1993) "British Railway Cost Functions and Productivity Growth," *Explorations in Economic History*, Vol.30, pp.158-181

Filippini, M. and R. Maggi (1992) "The Cost Structure of the Swiss Private Railways, *International Journal of Transport Economics,* Vol.19, No.3, pp.307 – 327

Filippini, M. and R. Maggi (1993) "Efficiency and Regulation in the Case of the Swiss Private Railways," *Journal of Regulatory Economics,* Vol.5, No.2, pp.199-216

Friedlaender, A. F., E. R. Berndt, J. S. W. Chiang, M. Showalter and C. A. Vellturo (1993) "Rail Costs and Capital Adjustments in a Quasi-Regulated Environment," *Journal of Transport Economics and Policy,* Vol.27, No.2, pp.131-152

Friedlaender, A. F. and R. H. Spady (1981) *Freight Transport Regulation,* MIT Press, Cambridge, U.S.A.

Griliches, Z. (1972) "Cost Allocation in Railroad Regulation," *Bell Journal of Economics and Management Science,* Vol.3, No. 1, pp.26-41

Harris, R. G. (1977) "Economies of Traffic Density in the Rail Freight Industry," *Bell Journal of Economics,* Vol.8, No.2, pp.556-564

Harris, R. G. and C. Winston (1983) "Potential Benefits of Rail Mergers: An Econometric Analysis of Network Effects on Service Quality," *Review of Economics and Statistics,* Vol.65, No.1, pp.32-40

Hasenkamp, G. (1976) "A Study of Multiple-output Production Functions: Klein's Railroad Study Revised," *Journal of Econometrics,* Vol.4, No. 3, pp.253-262

Hensher, D. A., R. Daniels and I. Demellow (1995) "A Comparative Assessment of the Productivity of Australia's Public Rail Systems 1971/72 - 1991/92," *Journal of Productivity Analysis*, Vol.6, No.3, pp.201 – 223

Jara-Diaz, S. R. and C. E. Cortes (1996) "On the Calculation of Scale Economies from Transport Cost Functions," *Journal of Transport Economics and Policy,* Vol.30, No.2., pp.157-170

Keeler, T. E. (1974) "Railroad Costs, Returns to Scale, and Excess Capacity," *Review of Economics and Statistics,* Vol.56, No.2, pp.201-208

Killeen, B. J. and K. Shoji (1997) "Diversification Strategy and Urban Transportation: The Case of Japan," *Presented Paper at the 5th International Conference on Competition and Ownership in Land Passenger Transport,* Leeds, UK, 27-30 May

Kim, H. Y. (1987) “Economies of Scale and Scope in Multiproduct Firms: Evidence from U.S. Railroads,” Applied Economics, Vol.19, No.6, pp.733-741

Levin, R. C. and D. H. Weinberg (1979) “Alternatives for Restructuring the Railroads: End-toEnd or Parallel Mergers?” *Economic Inquiry,* Vol.17, No.3, pp.371-388

Loizides, I. and B. Giahalis (1995) "The Performance of Public Enterprises: A Case Study of the Greek Railway Organization," *International Journal of Transport Economics,* Vol.22, No.3, pp.283 – 306

Marumo, A. (1984) “Costs of Passenger Rail Transportation (Ryokaku Yuso Jigyo no Hiyo ni Tsuite),” *Shogaku Kenkyu,* Vol.32, No.2, pp.35-66 (in Japanese)

McGeehan, H. (1993) “Railway Costs and Productivity Growth: The Case of the Republic of Ireland, 1973-1983,” *Journal of Transport Economics and Policy,* Vol.27, No.1, pp.19-32

Meyer, J. R. and A. L. Morton (1975) “The U.S. Railroad Industry in the Post-Eorld War II Period: A Profile,” *Explorations in Economic Research,* Vol.2, No.4, pp.449-501

Ministry of Transport, Railway Bureau (ed.) (1999) *Rail Fact Book 2000 (Suji de Miru Tetsudo 2000),* Institute of Transportation Policy Research, Tokyo, Japan (in Japanese)

Miyajima, M. and S. D. Lee (1984) "A Study Comparing the Efficiency of Local Public Enterprises and Private Enterprise: Railway Industry (Chiho Koei Kigyou to Minkan Kigyo no Koritsusei no Hikaku ni Kansuru Kenkyu: Tetsudogyo wo Reitoshite," *Journal of Public Utilityt Economics (Koeki Jigyo Kenkyu),* Vol.36, No.1, pp.79-100 (in Japanese)

Mizutani, F. (1994) *Japanese Urban Railways: A Private-Public Comparison,* Avebury, Ashgate Publishing, Aldershot U.K./Brookfield U.S.A.

Mizutani, F. (1997) "Empirical Analysis of Yardstick Competition in the Japanese Railway Industry," *International Journal of Transport Economics,* Vol.24, No.3, pp.367-392

Mizutani, F. (1999a) "Changing Trains: Japan," in D. M. van de Velde (ed.), *Changing Trains: Railway Reform and the Role of Competition,* Aldershot U.K./Brookfield U.S.A., pp.255-306

Mizutani, F. (1999b) "An Assessment of the Japan National Railway Companies Since Privatization: Performance, Local Rail Service and Debts," *Transport Reviews,* Vol.19, No.2, pp.117-139

Mizutani, F. (2000) "Private Provision and Privatization in the Public Utility Industries (Koeki Jigyo ni okeru Kinkankyokyu to Mineika)," *Journal of Economics and Business Administration (Kokumin Keizai Zasshi),* Vol.182, No.3, pp.57-76 (in Japanese)

Mizutani, F. and K. Nakamura (1997) "Privatization of the Japan National Railway: Overview of Performance Change," *International Journal of Transport Economics,* Vol.24, No.1, pp.75-99

Mizutani, F. and K. Shoji (1997) "A Comparative Analysis of Financial Performance: U.S. and Japanese Urban Railways," *International Journal of Transport Economics,* Vol.24, No.2, pp.207-239

Nakamura, R. (1994) "Economies of Scale and Density for the Private Railroad Firms (Mintetsu Kigyo no Hiyo Kozo)," *Transportation and Economies (Unyu to Keizai),* Vol.54, No.12, pp.36-44 (in Japanese)

Preston, J. and C. Nash (1993) "European Railway Comparisons: Lessons for Policy," *Proceedings of the Third International Conference on Competition and Ownership in Surface Passenger Transport,* September 26-29, Toronto, Canada, pp.439-452

Preston, J. (1996) "The Economics of British Rail Privatization: An Assessment," *Transport Reviews,* Vol.16, No.1, pp.1-21

Pushkarev, B. S., J. M. Zupan and R. S. Cumella (1982) *Urban Rail in America: An Exploration of Criteria for Fixed-Guideway Transit,* Indiana University Press, Bloomington, USA

Savage, I. (1997) "Scale Economies in United States Rail Transit Systems," *Transport Research-A*, Vol.31, No.6, pp.459-473

Small, K. A. (1992) *Urban Transportation Economics,* Harwood Academic Publishers, Philadelphia, USA

Tittenbrun, J. (1995) *Private Versus Public Enterprise: In Search of the Economic Rationale for Privatisation,* Janus Publishing Company, London, U.K.

Uekusa, M. (1991) *Economics of Public Regulation (Koteki Kisei no Keizaigaku),* Chikuma Syobo, Tokyo, Japan (in Japanese)

Van de Velde, D., F. Mizutani, J. Preston and S. Hulten (1998) "Railway Reform and Entrepreneurship: A Tale of Three Countries," *The 1998 European Transport Conference,* Loughborouugh, U.K.

Vellturo, C. A., E. A. Berndt, A. F. Friedlaender, J. S. W. Chiang and M. H. Showalter (1992) "Deregulation, Mergers, and Cost Savings in Class I U.S. Railroads, 1974-1986," *Journal of Economics and Management Strategy,* Vol.1, No.2, pp.339-370

Viton, P. A. (1980) "On the Economics of Rapid-Transit Operation," *Transportation Research-A,* Vol.14A, No.4, pp.247-253

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