A Private-Public Comparison of Labor Productivity and Utilization in Japanese Urban Railways

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Abstract

As of 1990, there were 183 rail operators in Japan. Of these railways, private railways accounted for 89 percent, almost all owned and operated by the private sector. And, especially in urban rail transportation, the role of private railways is very important. In contrast to publicly owned railways, private railways are considered by Japanese researchers to be more efficient than public railways. This paper analyzes the performance difference of private and public urban railways in Japan, especially focussing on labor productivity and labor utilization and investigates how much more efficient private railways truly are than public. After summarizing labor productivity and labor utilization by activity basis, regression analysis is used to specify the relationship between labor productivity by activity basis and factors such as service output level, network characteristics, and contracting-out. After controlling for these factors, private railways are found to be about 31 percent more productive than public railways.

1. Introduction

A distinctive fact about the Japanese rail industry is that privately owned railways (private railways) play such an important role. Moreover, if we equate private railways with Nihon Tetsudo (established in 1883), the private rail industry has a history of 110 years. Since Japan National Railways was privatized in 1987 and became the JR group (whose equity holders are nevertheless still the national government), there has been no national railway. Even if we consider JR, Eidan (Teito Rapid Transit Authority), and public operators of local governments as publicly owned railways (public railways), in 1990, private railways accounted for 89 percent of operators, 24 percent of route-km for passengers, and 31 percent of passenger-km. When we consider that JRs have intercity rail services as well as urban rail services, we recognize just how important private railways are in urban transportation. Furthermore, private railways operate even in smaller metropolises, a situation very different from that in other industrialized countries. And Japanese urban private railways are generally recognized to be more efficient than other publicly owned railways or the former Japan National Railways. The fact that the former Japan National Railways was privatized in 1987 reflects the belief in Japan that the private sector is more efficient than the public. In fact, Sekiguchi (1987) reports that the labor productivity of private railways was higher than for Japan National Railways in terms of both car-km per employee and passenger per employee based on 1984 statistics.[1]

As for urban railways, Miyajima and Lee (1984) analyzed the productivity difference using eleven urban railways, of which six are public subways and five private railways, for the five years from 1977 to 1981. They concluded that the public sector is less efficient than the private.[2] In fact, in 1990, the labor productivity measured by car-km per employee of large private railways was 2.08 times that of public (excluding Eidan subway). Even compared with Eidan, labor productivity was 54 percent higher. But the productivity of small private railways was 18 percent lower than for Eidan, while it was 11 percent higher than for public (excluding Eidan).[3] In other industrialized countries, popular opinion is that private railways are more efficient than public. However, there is no clear evidence that there is a significant difference in productivity. Caves and Christensen (1980) compare the postwar productivity performance of the Canadian National (public) and Canadian Pacific Railroads (private) using the total factor productivity index (TFP). And they conclude that there is no evidence of inferior performance by the government-owned railroad.[4] More recent studies suggest that the ownership difference is only one of many factors causing a difference in productivity.[5]

The main purpose of this paper is to investigate whether or not there is any significant difference in productivity and input utilization. Among the inputs, this paper focuses on labor and labor productivity because labor cost accounts for about 60 to 67 percent of operating cost and labor could be the main cause for inefficient input utilization.

There are several points to discuss here. First, how much difference is there in productivity between private and public railways in selected samples? Second, if productivity between the two sectors is different and private railways' is higher, is the private more efficient in any activity or simply limited to some activity, for example, administration? Third, even if we set up the same conditions in terms of service output, such as passenger-km and network factors such as route-km, stations, and number of lines, is private still more efficient? How much more efficient? Fourth, how do other factors affect labor productivity, such as the practice of contracting-out and the advanced technology of the Automated Ticket Taker?

Sample selection for urban railways is important to set up conditions equally. In this analysis, urban railways are defined as railways which operate in major metropolitan areas (with a population of more than 0.5 million). Public railways are rail organizations owned by local governments including Teito Rapid Transit Authority (Eidan), but JRs (the former Japan National Railways) are excluded from the sample selection because they operate intercity rail services in addition to urban rail service. A total of 56 urban railways (46 private and 10 public) are selected for 1987, 1988, and 1989, and total sample size is 166 (136 private and 30 public).[6]

2. Characteristics of Urban Railways in Japan

The Japanese urban rail industry is a mixed structure of privately owned and publicly owned railways with most railways belonging to the private sector. The urban rail industry in Japan is highly regulated by the national government, which imposes regulations mainly on entry and exit, fares, and safety. There is no clear evidence showing that these regulations overprotect the urban rail industry, and, in fact, in the last three decades, some unprofitable railways or lines have had to be switched to bus transportation.

Urban private railways are mainly commuter railways which connect a central city and its suburbs, while urban public railways are rapid railways whose role is downtown distribution. The most distinguishing difference is that public railways are mainly subway systems. The image of Japanese private railways as commuter rails is far from the image of commuter rails in the U.S. The real picture of private railways is closer to rapid rail transit (or semi-rapid rail transit), because there is more traffic volume in the off-peak period.

There is almost no subsidy available for private railways. Strictly speaking, some small private railways in small communities can get subsidies, but the amount is limited. Urban private railways as defined here are considered almost subsidy-free. Fares are regulated by the government to cover the cost, so there is almost no subsidy. On the other hand, all public railways get subsidies from both the national and local governments. Most subsidies are capital subsidies, but some public operators get operating subsidies. As the fare box recovery ratio shows, both private and public railways are profitable in terms of operating cost.

As for fare level measured as yield, private railways are lower than public railways. However, the situation

Table 1

Summary of Urban Railways in Japan		
	Private Railways	Public Railways
(1) service characteristics (location)	commuter rails (central city and suburbs)	rapid transit (central city)
(2) rail structure	surface train (underground = 5.5%)	subway (underground = 91.6%)
(3) subsidy	almost no subsidy available	all public getting capital subsidy/ most getting operating subsidy
(4) average fare as yield (yen/passenger-km)	19.1	23.3
(5) average operating cost (yen/passenger-km)	6.26	11.43
(6) average fare box recovery ratio		
(a) without depreciation	1.31 (all), 1.56 (large)	1.47 (all), 1.45 (large)
(b) with depreciation	1.09 (all), 1.28 (large)	0.90 (all), 1.11 (large)
(7) service quality		
(a) av. load factor	0.40 (all), 0.63 (large)	0.51 (all), 0.64 (large)
(b) peak load factor	1.70 - 1.91	1.73 - 2.06
(c) speed (km/hr)	32.3 (regular) - 51.0 (express)	33.5 (regular only)
(d) headway (peak)	9.5 min(all), 2.2 min(large)	3.2 min
(e) service hour per day	18 hour 16 min	18 hour 47 min
(Note): "All" and "large" in parentheses mean all urban and large urban railways.		

is not as simple as the result shows. In fact, for shorter distances private railways' fare is less expensive, but for longer distances, public railways' fare becomes less expensive. As for operating cost, clearly private railways are less expensive than public. There is no significant difference in service quality measured by load factor, speed, headway, and so on.

3. Labor Productivity Comparison

Several previous researchers report that labor productivity is significantly lower in Japan's public than its private railways. This is generally borne out by the figures in Table 2, which show simple comparisons of labor productivity for the two sectors and for different size firms.

Labor productivity is substantially higher in the average private than public railway, no matter which measure of productivity is used. Using passenger-km or car-km as an output measure, the productivity of all private railways is 47 percent or 44 percent higher than for all public railways. Using train-km as an output measure, on average, the productivity of all private railways is twice as large as that of all public railways. These differences in productivity do not disappear, moreover, if large and small railway firms are analyzed separately. Large private railways are approximately twice as productive as large public railways with all three measures of productivity. Compared to their public counterparts, small private

Table 2

Labor Productivity						
	(1) private (all)	(2) public (all)	(3) private (large)	(4) public (large)	(5) private (small)	(6)public (small)
(a) total employee	1,369 (0.45)	3,039 (1.00)	3,866 (0.60)	6,445 (1.00)	253 (0.33)	769 (1.00)
(b)passenger-km p.a/ employee (1000)	1,111 (1.47)	758 (1.00)	1,978 (2.21)	897 (1.00)	724 (1.09)	665 (1.00)
(c) car-km p.a./ total employee (1000)	22.16 (1.44)	15.40 (1.00)	29.68 (1.98)	15.01 (1.00)	18.80 (1.20)	15.67 (1.00)
(d) train-km / total employee (1000)	5.94 (2.20)	2.70 (1.00)	5.13 (2.23)	2.30 (1.00)	6.30 (2.13)	2.96 (1.00)
sample size	136	30	42	12	94	18

(Note): 1) The number in parentheses is the ratio to the number of public railways.
2) Sample is from 1989, 1988, and 1987.

Table 3

Proportion of Permanent Employee by Activity						
	(1) Private (all)	(2) Public (all)	(3) Private (large)	(4) Public (large)	(5) Private (small)	(6) Public (small)
(a) total permanent employees	1,369 (0.45)	3,039 (1.00)	3,866 (0.60)	6,445 (1.00)	253 (0.33)	769 (1.00)
(b) operators & conductors/ total employees	30.7% (1.70)	18.1% (1.00)	26.3% (1.45)	18.2% (1.00)	32.6% (1.80)	18.1% (1.00)
(c) station employees/ total employees	29.6% (0.74)	39.8% (1.00)	32.9% (0.81)	40.5% (1.00)	28.1% (0.72)	39.3% (1.00)
(d) employees of track etc/ total employee	13.3% (0.94)	14.1% (1.00)	13.9% (0.97)	14.3% (1.00)	13.1% (0.94)	14.0% (1.00)
(e)employees of rolling stock/ total employees	9.2% (0.90)	10.2% (1.00)	10.2% (0.78)	13.1% (1.00)	8.7% (1.06)	8.2% (1.00)
(f) admin. staff/ total employees	17.2% (0.97)	17.8% (1.00)	16.7% (1.20)	13.9% (1.00)	17.4% (0.85)	20.4% (1.00)
Sample size	136	30	42	12	94	18

(Note): 1) The number in parentheses is the ratio to the number for public railways
2) Sample is from 1989, 1988, and 1987.

railways have 9 percent more passenger-km per employee, 20 percent more car-km per employee, and 113 percent more train-km per employee.

4. Labor Productivity by Employee Type

Some suggestions as to the sources of the productivity differences can be gleaned by calculating separate labor productivity measures for different types of employees. Table 3 shows the number and proportion of five different groups of employees: 1) station employees (EMPs); 2) operators and conductors (EMPo); 3) maintenance employees of track and electricity (EMPt); 4) maintenance employees of rolling stock (EMPc); and 5) engineering and administrative staff at headquarters (EMPh).[7]

The major difference between the public and private railways is that the public railways have a much smaller proportion of operators and conductors and a much higher proportion of station employees (see Table 3). These differences in workforce composition are reflected in the productivity measures. For the average railway (regardless of size), for example, the private sector produces 47 percent more passenger-km per total employee, but 13 percent less passenger-km per operator and conductor, and 158 percent more passenger-km per station employee (Table 4). Among large railways, private railways are 121 percent more productive per total employee than public railways, but only 54 percent more productive per operator and 176 percent more productive per station employee. Among small railways, private firms have 50 percent lower productivity per operator and conductor but 155 percent higher productivity per station employee.

The differences in station, operator, and conductor productivity may be partly due to differences in technology. In the first place, public railways may have more station employees in part because they have shorter station spacing and thus more stations than private railways given line-haul length. Moreover, some of the private railways, particularly the smallest, may have more operators and conductors per passenger-km because they rely more heavily on conductors than station employees to sell and check tickets on lightly patronized lines.

Another major difference between public and private railways is in the productivity of their maintenance employees. Large private railways have much higher productivity per track or car maintenance employee than their public sector counterparts. Among small railways, by contrast, maintenance employee productivity is actually slightly lower in private than public railways. This pattern does not seem related to differences in network conditions, but to the tendency of large private railways to contract out the maintenance of track and rolling stock. Very high productivity per maintenance employee in large private railways suggests the possibility of contracting-out.

Finally, on average, it is interesting to note that there is no clear evidence that public is less efficient than private in the productivity of administration and engineering staff (headquarters employees), while private railways are slightly more productive than public railways. Large private railways produce 66 percent more passenger-km per headquarters staff than their public sector counterparts, but small private railways are only six percent more efficient than their public counterparts.

5. Regression Analysis of Productivity

5.1 Potential Reasons for Productivity Difference

The results of the labor productivity comparison agree with previous researchers' results showing that the productivity of private railways is higher than that of public railways. However, this result does not distinguish the ownership factor from other factors. There are several factors besides ownership.

Service Output Level:

The unequal output level in both private and public railways might be a factor in the productivity difference, with large private railways having 13 percent more passenger-km than their public counterparts as Table 5 shows. Clearly, if other conditions such as network factors (route length, number of lines, etc.)

Table 4

Labor Productivity by Activity						
	(1) Private (all)	(2) Public (all)	(3) Private (large)	(4) Public (large)	(5) Private (small)	(6) Public (small)
(a) passenger-km per total employee (1000)	1,111 (1.47)	758 (1.00)	1,978 (2.21)	897 (1.00)	724 (1.09)	665 (1.00)
(b) passenger-km per operator etc (1000)	3,677 (0.87)	4,212 (1.00)	7,656 (1.54)	4,971 (1.00)	1,840 (0.50)	3,706 (1.00)
(c) passenger-km per station employee (1000)	4,918 (2.58)	1,915 (1.00)	6,145 (2.76)	2,225 (1.00)	4,371 (2.55)	1,709 (1.00)
(d) passenger-km per track maintenance employee (1000)	8,063 (1.41)	5,728 (1.00)	15,116 (2.44)	6,198 (1.00)	4,807 (0.89)	5,414 (1.00)
(e) passenger-km per car maintenance employee (1000)	10,773 (1.40)	7,685 (1.00)	19,620 (2.89)	6,791 (1.00)	6,853 (0.83)	8,281 (1.00)
(f) passenger-km per administration staff (1000)	6,464 (1.25)	5,156 (1.00)	12,305 (1.66)	7,416 (1.00)	3,854 (1.06)	3,649 (1.00)
(Note): Same as Table 3.						

are the same, a railway with more service output would have advantages in labor utilization, because employees do not always increase proportionally with the increase in service output. However, service output difference is not the only factor because small private railways attain higher productivity than their public counterparts in spite of the fact that their service output level is much smaller than public railways.

Network Difference:

Network conditions would affect productivity and labor utilization. The two sectors have very different network conditions which could significantly affect the productivity level of each sector. First, shorter station spacing or having more stations per line reduces productivity because more station employees are required, even if service output is the same. Public railways with shorter station spacing than private railways are at a disadvantage in productivity comparisons. Second, the number of lines could also affect productivity. Having more lines creates a need for more operators and conductors as well as car maintenance employees, because rail operation and car maintenance shops would be done on a line-basis. Third, a higher proportion of elevated and underground route might require more track maintenance employees. While Miyajima and Lee's 1984 study does not control for this effect at all, limited working space in underground railways makes the maintenance work more difficult. In fact, the Eidan subway argued that its extensive underground route is one of the reasons it has more maintenance employees for its track and electric system than large private railways. Furthermore, underground stations would require more station employees than at-grade stations, because underground stations provide more entrance gates than at-grade stations. Thus, it is important to distinguish network differences when assessing the cause for any productivity difference between the sectors.

Table 5

Service Output and Network Characteristics Comparison

	(1) Private (all)	(2) Public (all)	(3) Private (large)	(4) Public (large)	(5) Private (small)	(6) Public (small)
(a) passenger-km (1000)	2,445,700 (0.84)	2,928,500 (1.00)	7,399,500 (1.13)	6,544,500 (1.00)	232,260 (0.45)	517,740 (1.00)
(b) route-km	78.5 (1.58)	49.6 (1.00)	195.4 (2.07)	94.4 (1.00)	26.3 (1.33)	19.8 (1.00)
(c) line numbers	3.2 (1.00)	3.2 (1.00)	7.4 (1.42)	5.2 (1.00)	1.4 (0.78)	1.8 (1.00)
(d) route-km per line (=b/c)	21.1 (1.53)	13.8 (1.00)	26.1 (1.43)	18.3 (1.00)	18.9 (1.77)	10.7 (1.00)
(e) station numbers	52 (1.08)	48 (1.00)	121 (1.33)	91 (1.00)	21 (1.05)	20 (1.00)
(f) station spacing (=b/(e-1))	1.56 (1.47)	1.06 (1.00)	1.52 (1.48)	1.03 (1.00)	1.58 (1.46)	1.08 (1.00)
(g) % of under-ground-km	5.5 (0.06)	91.6 (1.00)	5.8 (0.06)	90.5 (1.00)	5.3 (0.06)	92.3 (1.00)
(h) % of bridge-km	8.7 (1.78)	4.9 (1.00)	13.4 (1.63)	8.2 (1.00)	6.6 (2.44)	2.7 (1.00)
sample size	136	30	42	12	94	18

(Note): 1) The number in parentheses is the ratio to the number for public.
2) Sample is from data in 1987, 1988, and 1989.

Contracting-Out:

The significant difference in maintenance productivity, especially in large railways, could not be explained by ownership or network difference only. Whether or not a railway is using a contracting-out scheme might also account for the productivity difference. In fact, the Management and Coordination Agency (1987) found this effect when it audited the Eidan subway.

Private railways could attain higher labor productivity partially because of the practice of contracting-out. It is true that public railways are also more or less involved in contracting-out but the problem is that there is no clear data as to how much each individual railway is contracting-out. However, in general, private railways are more likely to contract-out than public railways. For example, the Management and Coordination Agency (Somu-cho) reports that the ratio of contracting-out in Eidan (public) is smaller than for large private railways. The Management and Coordination Agency compares the contracting-out ratio for 25 items in rolling stock maintenance activities at the factory, between a large unnamed Tokyo-based private railway, and Eidan. Of 25 items, there were 23 items with more than 90 percent contracting-out for the large private railway but only 17 items for Eidan. Only two items for the private were less than 50 percent contracting-out, but Eidan had seven out of the 25 items with less than 50 percent contracting-out.[8]

Evidence showing that private railways have more contracting-out can be inferred from another source. If a railway has more contracting-out than other railways, then the ratio of the labor cost of the railway is smaller than for other railways, but the railways face a relatively higher proportion of material and service costs because the cost of contracting-out is included in this category. For example, the Management and Coordination Agency also gave the labor cost and the contracting-out cost in rolling stock maintenance in Tokyo based large railways, as shown in Table 6. From this table, it can be seen that even if there are variations among private railways, they are contracting-out more than public railways.

Contracting-out is used for the maintenance of the track as well as for the maintenance of rolling stock. For example, Meitetsu in Nagoya metropolis has reduced maintenance employees by 57.5 percent over 30 years, mostly by contracting-out and by modernizing maintenance equipment. Meitetsu has attained a reduction of 478 maintenance employees from 1960 to 1991. During this period, about 65 percent of the reduction in maintenance employees of track is considered due to contracting-out.[9] Other private railways are considered to have the same tendency, while there is no precise data. However, it is possible to guess the degree of contracting-out by using the proportion of labor cost in the total maintenance cost as Table 6 shows. If a railway has a lower proportion of labor cost, then the railway could be considered to be contracting-out. There is much variation among private and public railways. However, in general private railways face a lower proportion of labor cost for track maintenance than public railways. For example, in the sample average for 1987 to 1989, the proportion of non-labor cost to total cost in track maintenance was 52.7 percent in all private and 48.8 percent in all public railways. This is considered evidence that private railways are more likely using the contracting-out scheme. However, even among public railways, there are some operators that have a small proportion of labor cost in track maintenance, among them small public railways such as Sapporo, Sendai, and Fukuoka. These public railways might be considered to be contracting-out, just as private railways do. However, most public railways and certainly large public railways are not contracting-out their track maintenance as private railways do, because the proportion of non-labor cost in track maintenance of large private railways was 60.9 percent but large public railways was only 35.7 percent.

Advanced Technology:

The introduction of, or an eagerness to pursue, advanced technologies might also create higher labor productivity and reduce the labor force. Several researchers suggest that this is the reason for the efficiency of private railways (e.g. Sekiguchi, 1987; Management and Coordination Agency, 1989).

The reason public railways are less productive at stations than private railways might be related to advanced technology. Some researchers suggest that private railways, especially large private railways, are more aggressive in cutting employees. For example, Sekiguchi notes that large private railways have made an effort to reduce employment. And for the decade between 1975 and 1984, total employees in the 14 large private railways were reduced to 54,700 from 60,000. He noted that the introduction of automated machines such as the Automated Ticket Taker (hereafter referred to as ATT) and the Automated Ticket Purchasing Machine(ATPM) contributed to the reduction of employees.[10]

Management and Coordination Agency (Somu-cho)'s audit of the current rail industry reports how aggressively large private and public railways are providing ATTs in their stations. Table 7 shows the

Table 6

The Magnitude of Contracting-Out in the Maintenance Cost of Rolling Stock (1986)			
ownership	operator	labor cost for own-- employee (%)	contracting-out etc cost(%)
public	Eidan	62.8	37.2
	Tokyo Metropolitan	76.8	23.2
private	Tobu	59.6	40.4
	Seibu	30.4	69.6
	Keisei	58.3	41.7
	Keio	48.6	51.4
	Tokyu	40.9	59.1
	Odakyu	46.3	53.7
	Keikyu	49.7	50.3

(Source): Management and Coordination Agency (Somu-cho), *Present Conditions and Problems of Rail Industry (Tetsudo Jigyo no Genjo to Mondaiten)*, Ministry of Finance, p.119 (1989) (in Japanese)

results. From this table, it seems that public railways are more aggressive. Compared with railways in Osaka, railways in Tokyo are rather passive about providing ATTs. Thus, it is not clear how providing ATTs affects the difference in employee numbers between the two sectors or whether there is a relationship at all. Probably, advanced technology could certainly reduce employees and increase productivity, but it is not the sole reason for the difference in productivity at stations.

5.2. Regression Results of Labor Productivity

The main purpose of this section is to examine how the factors previously explained affect labor productivity and to evaluate whether there is a difference between the two sectors in labor productivity or the number of employees after these factors are controlled using regression analysis. Of several factors, service output, network factors, and contracting-out are examined with the ownership factor, because data is available on them.

In the regression analysis, five kinds of labor productivity by activity difference are directly estimated. As dependent variables, productivity per operator and conductor (PRDo), per station employee (PRDs), per track maintenance employee (PRDt), per car maintenance employee (PRDc), and per engineering and administration (PRDh) are chosen. As explanatory variables, passenger-km as service and network variables such as route-km, number of line and number of stations, and contracting-out indices are chosen with the ownership dummy (PUB).[11]

In this analysis, samples are obtained from 1987 to 1989. In general, Japanese companies have the reputation of not laying off their employees even if demand changes. Three years is short enough for demand conditions to change, but there might be an effect on productivity or the number of employees

Table 7

Stations with Automated Ticket Takers, 1987

(a) metropolis	(b) ownership	(c) total station	(d) station with ATT	(e) (d/c)
Tokyo	private	648	32	4.9 %
	public	217	23	10.6 %
Osaka	private	668	216	32.3 %
	public	116	116	100.0 %
Nagoya	private	341	47	13.8 %
	public	61	61	100.0 %
Others	private	76	16	21.1 %
	public	65	65	100.0 %
total	private	1,950	311	15.9 %
	public	459	265	57.7 %

(Source): Management and Coordination Agency (Soumu-cyo), *Present Condition and Problems of Rail Industry (Tetsudo Jigyo no Genjo to Mondaiten)*, Ministry of Finance, p.88, (1989) (in Japanese)

(Note): 1) Private railways are the 14 large private railways.
2) Others are Sapporo, Sendai, and Fukuoka.
3) ATT represents Automated Ticket Taker.

of each railway. However, time (year) has no significant effect, even if the time effect is considered in the regression analysis.[12] Furthermore, in regression analysis, three sets of sample of urban railways (i.e. all urban railways, large and medium urban railways, and large urban railways only) are examined separately to maintain as much as possible the homogeneity in uncontrolled conditions.

Table 8 shows the most reasonable results of several regressions. Most regressions have high R**2. These are expected results, because there is a linear relationship between the natural logarithm of productivity for each activity and the natural logarithm of service output (passenger-km).

First of all, most regression results show a negative sign in the ownership dummy (PUB). This result suggests that public railways are less productive or use more employees than private railways under the same conditions in service output, network factors, and so on. However, there is much variation in the magnitude of coefficients of the ownership dummy. The most striking point is that the regression result for operator and conductor shows a very small number in the ownership dummy even if it is still a negative sign. In fact, some regression results for productivity of operator and conductor have the coefficient of almost zero in the ownership dummy. It is considered that there is not much a difference in productivity of operators and conductors between private and public railways. However, someone might claim that a reasonable number for operators and conductors depends on the operating schedule (speed of train, headway, service hours, and so on) of each railway. If we specify these operating schedules precisely, the result might be different. However, even if we use another method to evaluate productivity and the number of operators and conductors, there is not much difference, while private railways have a tendency to be more productive and to have fewer operators and conductors.[13] Therefore, a more

Table 8

Regression Results for Productivity: Coefficients and Standard Error

	PRDo (operator)	PRDs (station)	PRDt (track main.)	PRDc (car main.)	PRDh (admin.)
Q (passenger-km)	0.478 (0.034)	0.576 (0.022)	0.433 (0.060)	0.423 (0.026)	0.502 (0.095)
N1 (route-km)			- 0.364 (0.076)		
N2 (number of line)	- 0.378 (0.063)			- 0.558 (0.076)	- 0.028 (0.314)
N3 (route-km per line)	- 0.284 (0.059)				0.272 (0.258)
N4 (number of station)		- 0.658 (0.037)			- 0.307 (0.319)
N5 (% of underground route length)			- 0.088 (0.063)		- 0.104 (0.122)
N6 (% of underground station)		- 0.127 (0.029)			
N7 (load factor)	0.196 (0.094)				
CT1 (contracting-out for track maintenance)			0.869 (0.112)		
CT2 (contracting-out for car maintenance)				0.636 (0.077)	
PUB (ownership dummy) (public=1)	- 0.164 (0.079)	- 0.412 (0.087)	- 0.160 (0.205)	- 0.405 (0.083)	- 0.118 (0.348)
a1 (constant)	5.725 (0.405)	5.704 (0.380)	5.089 (1.141)	5.629 (0.492)	5.686 (1.895)
R**2	0.8747	0.9482	0.8251	0.7888	0.6509

<u>specification of regression model :</u>

$$\ln(PRDi) = a0 + a1 * \ln(Q) + \Sigma bj * \ln(Nj) + c * \ln(CTk) + d * PUB$$

where,
- PRDi = labor productivity in activity - i (= Q/EMPi)
- Q = service output(passenger-km)
- Nj = network and service characteristics
- CTk = contracting-out index
- PUB = ownership dummy (public = 1)

appropriate interpretation would be that the productivity difference in operators and conductors is, at most, 18 percent.

Of these activities, previous sample statistics show station and maintenance (of track and car) activity creates more difference between the two sectors in productivity. As for stations, even if we control the network difference (more stations and a higher percentage of underground stations for public railways), public railways are still less productive and use more station employees. However, the productivity difference becomes smaller. The regression result shows that the existence of underground stations reduces the productivity or requires more station employees.

Both track and car maintenance activity shows a very different structure between the two sectors. First, the coefficients of the contracting-out index are very large (0.869 in track and 0.636 in car maintenance). As the sample comparison shows (Table 4), there was much difference in productivity of maintenance, but the ownership difference becomes smaller in the regression results after controlling contracting-out, especially track maintenance. The weakest point is that the coefficient of the percentage of underground (N5) is still smaller than in reality, while it shows a negative sign. The reason the coefficient of underground (N5) is smaller than expected is that it is correlated to the ownership dummy to some degree. In fact, in the case of the regression analysis without ownership dummy, the coefficient of underground effect increases.[14]

As for engineering and administration, the productivity of private railways is still about 13 percent higher. This means that public railways employ more labor than private given service output level. In general, the number of administrative employees is obtained by assuming that they are some proportion of employees in other activities, so it is natural that the number for public railways becomes larger than for private railways, because the number of employees in other activities of public railways is larger than in private railways.

6. Evaluation of Productivity and Employee Difference

From the previous regression analysis, it would be interesting to see how much more productive private railways are while using fewer employees than public railways, if we could control service output, network and other factors such as contracting-out. But it is also important to notice that the previous equations do not control all factors affecting labor productivity and employees because of statistical limits. For example, the speed difference, which would affect the labor productivity of operators and conductors, is not controlled. A factor affecting the control system of rail operation based on technological difference (subway vs. surface rails) might affect the number of station employees. Furthermore, maintenance employees will be affected by the age, the number of repair shops, and the technological type of rolling stock. Under the condition that these factors are not controlled, private and public railways are compared in labor productivity and employees for each activity. As an evaluation case, the average railways of the sample are chosen. In other words, by substituting parameters for the "average railway" to estimated equations, both labor productivity and employees for each activity are obtained.

Table 9 shows the results of productivity and employee. Case-A1 and case-A2 are both sample averages from each private and public railway. These are the cases that **do not control any factors** such as service output level, network, and so on. From case-B1 to case-B5 are the results from the regression formula. Case-B1 is the result obtained by taking all private variables. Case-B5 is, on the other hand, the result for all public variables. Between case-B2 and case-B4 are results obtained by changing variables from private to public one by one. For example, case-B2 is the result with public service output but private other variables. The true comparison of private and public railways by holding conditions the same are between case-B4 and case-B5.

First, as for labor productivity, the sample average comparison (case-A1 and case-A2) creates much more productivity difference than in reality, especially for large railways. Private railways are about 47 percent more productive than public railways.

Table 9

Comparison of Estimated Labor Productivity and Employees

(1) productivity							
method A:(sample average) B:(regression analysis)							
case	case-A1	case-A2	case-B1	case-B2	case-B3	case-B4	case-B5
private variable =	all private		Q, N, CT PUB	N, CT PUB	CT PUB	PUB	—
public variable =		all public	—	Q	Q,N	Q, N, CT	Q, N, CT PUB
PRDo (operator & conductor)	3,677 (0.86)	4,212 (1.00)	5,243 (0.91)	5,714 (0.99)	6,811 (1.18)	6,811 (1.18)	5,780 (1.00)
PRDs (station)	4,918 (2.58)	1,915 (1.00)	4,959 (1.99)	5,501 (2.20)	3,771 (1.51)	3,771 (1.51)	2,498 (1.00)
PRDt (track maintenance)	8,063 (1.41)	5,728 (1.00)	10,186 (1.26)	11,013 (1.36)	10,156 (1.25)	9,511 (1.17)	8,105 (1.00)
PRDr (car maintenance)	10,773 (1.40)	7,685 (1.00)	15,474 (1.49)	16,700 (1.61)	16,879 (1.63)	15,567 (1.50)	10,383 (1.00)
PRDh (admin. etc)	6,464 (1.25)	5,156 (1.00)	8,410 (1.51)	9,206 (1.60)	6,256 (1.13)	6,256 (1.13)	5,560 (1.00)
(2) permanent employees							
case	case-A1	case-A2	case-B1	case-B2	case-B3	case-B4	case-B5
EMPo (operator & conductor)	420 (0.76)	550 (1.00)	466 (0.92)	513 (1.02)	430 (0.85)	430 (0.85)	507 (1.00)
EMPs (station)	405 (0.33)	1,210 (1.00)	493 (0.42)	532 (0.45)	777 (0.66)	777 (0.66)	1,173 (1.00)
EMPt (track maintenance)	182 (0.43)	428 (1.00)	240 (0.66)	261 (0.72)	288 (0.80)	308 (0.85)	361 (1.00)
EMPr (car maintenance)	126 (0.41)	310 (1.00)	158 (0.56)	175 (0.62)	174 (0.62)	188 (0.67)	282 (1.00)
EMPh (admin & engin. staff)	235 (0.43)	541 (1.00)	291 (0.55)	318 (0.60)	468 (0.89)	468 (0.89)	527 (1.00)
EMP (total employees)	1,369 (0.45)	3,039 (1.00)	1,648 (0.58)	1,799 (0.63)	2,137 (0.75)	2,171 (0.76)	2,850 (1.00)

(Note): (1) Equations for estimation of labor productivity are used in Table 8.
(2) Equations for estimation of permanent employees are modified from the results of Table 8:
$\ln(EMPi) = - a0 + (1 - a1) * \ln(Qpkm) - \Sigma bj * \ln(Nj) - c*\ln(CTk) - d *PUB$
(3)The number in parenthesis is the ratio to the number of public.

Among the activity difference, the productivity of operators and conductors shows the least difference but the productivity of station employees shows the biggest percentage difference. In the productivity of station employees, the network factor (especially underground effect) is most important in creating a productivity difference. Before controlling network factors, private railways were about 120 percent more productive (see case-B2). But after controlling network factors, it drops to 51 percent(see case-B3).

As for maintenance, contracting-out significantly affects productivity. In the case of all railways, the effect of contracting-out is not large, or about 10 percent difference in productivity (see case-B3 and case-B4). However, in large railways, before controlling for contracting-out, the productivity difference was 86 percent in track and 131 percent in car maintenance, but controlling contracting-out, these become 17 percent and 50 percent respectively. Thus, the effect of contracting-out is a more important factor than the ownership difference in creating productivity difference, especially for large railways.

As for employee for each activity, the tendency is the same as for labor productivity. As the sample average comparison shows, private railways' employee figures are underestimated at 45 percent of public railways'. The most likely result is that private railways' employees is about 76 percent that of public.

7. Conclusion

Compared with the results of the sample average, which does not control any factors, the productivity difference becomes smaller, but private railways are still more productive than public railways. The most likely difference is that private railways were 13 percent (administration staff) to 51 percent (station employees) more productive than public railways based on regression results. Overall, private railways were about 31 percent more productive than public (or 76 percent of public in total employees).

The productivity difference between the two sectors can be accounted for mainly by the station employees and maintenance employees. The main factor in the productivity of station employees is technological differences such as underground stations and the number of stations. About 70 percent of the productivity difference in station employees can be explained largely by these technological differences. However, even if we control factors other than ownership difference, private railways are still 51 percent more productive than public railways. The use of advanced technology such as the Automated Ticket Taker does not significantly boost productivity, as public railways use more of these machines.

The primary reason productivity per maintenance employee of private railways is much higher than public railways is the exercise of contracting-out. Large private railways especially are using this scheme more than large public railways. However, private railways are still 17 percent more productive in track maintenance and 50 percent more productive in car maintenance than public railways, even after controlling service output, network factors, and contracting-out.

Productivity per operator and conductor, as well as per administrative staff, does not differ as much between the two sectors. At most, private railways are 18 percent more productive than public railways.

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References

Anderson, S. C.(1983), "The Effect of Government Ownership and Subsidy on Performance: Evidence from the Bus Transit Industry," *Transportation Research* Vol.17A, pp.191-200.

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, pp.958-976.

Eidan (1990), *'90 Eidan Chikatetsu Handbook*, December, Tokyo (in Japanese).

Yamauchi H. (1989), "Management of Private Railways: Rail Sector (Shitetsu Keiei: Tetsukido Bumon)," in Y. Fujii(ed), *Shitetsu Gyokai (Private Rail Industry),* Kyoikusya, Tokyo (in Japanese).

Gomez-Ibanez, J. A. and J. R. Meyer (1990), "Privatizing and Deregulating Local Public Services: lessons from Britain's Buses," *Journal of American Planning Association*, Vol.56, No.1, pp.9-21.

Hankyu (1991), *Handbook Hankyu '90*, July, Osaka (in Japanese).

Hensher, D. A. (1987), "Productive Efficiency and Ownership of Urban Bus Services," *Transportation*, Vol.14, pp.209-225.

Isoura, K, S. Sakamoto, Y. Suda, and T. Ito (1992), " Railway Management and Track Maintenance(Tetsudo Keiei to Senro Hosyu)," *Transport and Economy (Unyu to Keizai)*, February, Vol.52, No.2 , pp.4-38. (in Japanese).

Lave, C. A. (1985), "The Private Challenge to Public Transportation: An Overview," in C. A. Lave(ed), *Urban Transit: The Private Challenge to Public Transportation*, Pacific Institute for Public Policy Research, San Francisco, CA, pp.1-29.

Levinson, H, S (1992), " Urban Mass Transit Systems," in J. D. Edwards, Jr.(ed), *Transportation Planning Handbook*, Prentice Hall, N.J, 1992, pp.156.

Management and Coordination Agency (Somu-cho) (1989), *Present Condition and Problem of Rail Industry (Tetsudo Jigyo no Genjo to Mondaiten)*, Ministry of Finance, pp.108 (in Japanese).

Meyer, J. R. and J. A. Gomez-Ibanez (1980), "Measurement and Analysis of Productivity in Transportation Industries," in J. W. Kendrick and B. N. Vaccara(eds), *New Development in Productivity Measurement and Analysis*, The University of Chicago Press, Chicago, IL, pp.295-332.

Meyer, J. R., J. F. Kain and M. Wohl (1965)," *The Urban Transportation Problem*," Harvard Univ. Press, Cambridge, Mass.

Ministry of Transportation (1990), *Present Conditions of Private Railways (Minei Tetsudo no Genkyo)*, Unpublished Report, December (in Japanese).

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

Miyajima, M. and S. D. Lee (1985), " Management and Efficiency in Local Public and Private Enterprises: A Comparison in the Case of Railways (Chiho Koei Kigyo to Minkan Kigyo no Koritsusei to Kigyo Kodo ni Kansuru Kenkyu: Tetsudogyo wo Reitoshite)," *Journal of Public Utility Economics (Koeki Jigyo Kenkyu)*, Vol.36, No.3, pp.69-103 (in Japanese).

Morlok, E. K. and P. A. Viton (1985), "The Comparative Costs of Public and Private Providers of Mass Transit," in C. A. Lave(ed), *Urban Transit: The Private Challenge to Public Transportation*, Pacific Institute for Public Policy Research, San Francisco, CA, pp.233-253.

Oka, K.(1989),"Present Condition and Future Goals of Eidan Subway (Eidan Chikatetsu no Genkyo to Kongo no Kadai)," in H. Hirooka and Y. Watanabe (eds), *Urban Transportation (Toshi Kotsu),* Seizando, Tokyo, pp,119-136. (in Japanese).

Pashigian, B. P. (1976), "Consequences and Causes of Public Ownership of Urban Transit Facilities," *Journal of Political Economy*, Vol.84, pp.1239-1259.

Perry, J., T. Babitsky, and H. Gregersen (1988), "Organizational Form and Performance in Urban Mass Transit," *Transport Reviews*, Vol.8, No.2, pp.125-143.

Pucher, J. and A. Markstedt (1983), "Consequences of Public Ownership and Subsidies for Mass Transit: Evidence from Case Studies and Regression Analysis," *Transportation,* Vol.11, pp.323-345.

Sekiguchi, M (1987), *Private Railways (Shitetsu)*, Nihon Keizai Shinbun, Tokyo (in Japanese).

Shoji, K (1991), "The Japanese Experience with Urban Private Rail Companies: Idiosyncratic or Exemplary?", *The 2nd International Conference on Privatization and Deregulation in Passenger Transportation*, Tempere, Finland, June 16-20.

Yamashita, T (1992), " Track Maintenance at the Nagoya Railways(Nagoya Tetsudo no Senro Hosyu wo Kataru)," *Transportation and Economy (Unyu to Keizai)*, April, Vol.52, No.4, pp.58-63. (in Japanese).

Endnotes

1. All private railways were about 20% more and large private railways were 53% more productive than the Japan National Railways in terms of car-km per employee in 1984. (Sekiguchi, M, *Private Railways (Shitetsu)*, Tokyo, Nihon Keizai Shinbun, especially pp.113-116 (1987) (in Japanese))

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

3. Labor productivity (thousand car-km per employee) was 30.2 for large private, 16.1 for small private, 19.6 for Eidan (public), and 14.5 for public (excluding Eidan) in 1989 (Unyu Keizai Kenkyu Senta, *Rail Fact Book '91 (Suji de Miru Tetsudo)*, Tokyo, pp.92-93 (1991)).

4. Caves, D. W. and L. R. Christensen, "The Relative Efficiency of Public and Private Firms in a Competitive Environment: The Case of Canadian Railroads," *Journal of Political Economy*, Vol.88, pp.958-976 (1980).

5. For example, Lave(1985) and Morlok and Viton (1985) mention that the competition factor is important.

6. These railways as samples are all electric, heavy rail, passenger service operators. Operators with different propulsion (diesel etc), different technology (light rails etc), and service type (freight service, etc.) are excluded from the sample.

7. Station employees includes the category of others in "transport section" (which consists of station, operator, conductor, and others) and engineering and administrative staff includes the construction sector, too.

8. Management and Coordination Agency, *Present Condition and Problem of Rail Industry (Tetsudo Jigyo no Genjo to Mondaiten)*, Ministry of Finance, pp.120-122 (1989) (in Japanese)

9. About Meitetsu's case, see Yamashita, T. " Track Maintenance at the Nagoya Railways(Nagoya Tetsudo no Senro Hosyu wo Kataru)," *Transportation and Economy (Unyu To Keizai)*, Vol.52, No.4, pp.58-63 (1992) (in Japanese)

10. For example, Sekiguchi, M, *Private Railways (Shitetsu)*, Tokyo, Nihon Keizai Shinbun (1987) (in Japanese)

11. Two kinds of contracting-out index are defined here: for track maintenance (CT1) and for car maintenance (CT2). These are defined as the percentage of non-labor cost to total maintenance cost in each activity (track or car maintenance) as shown in Table-5.2.

12. A priori a time dummy, t87(1987) and t88(1988), is employed as a fixed effect in regression models, but neither is statistically significant.

13. Productivity of operator and conductor and number of operator and conductor by a different approach are done for selected private and public operators. The difference between private and public railways is not much, while private railways use less operators and conductors and are more productive than public. The evaluation method is based on the following equation:
PRDo = Q/EMPo
EMPo = no* (2 * lr / V + t) * (60 / h) * Nl * (H / w) where
EMPo = total number of operators and conductors
no = number of operators and conductors per train
lr = route-km per line (one way)
V = operating speed of train (km/hr)
t = break time for next boarding
h = headway (minute)
Nl = number of lines of a railway
H = rail service hours a day
w = working hours per day of operator & conductor

14. This regression result is as follows:

In(PRDt)	4.533 +	0.460 *	ln(Q) -	0.392 *	ln(N1) -	0.134 *	ln(N5) +	0.909 *	ln(CT1)
(0.889)	(0.049		(0.066)		(0.025)		(0.100)	R**2 = 0.8234	

where EMPt = track maintenance employees CT1 = contracting-out index of track maintenance
N5 = % of underground N1 = route-km Q = passenger-km