Graduate School of
Business Administration

KOBE
UNIVERSITY

ROKKO KOBE JAPAN

2010-48

Does Vertical Separation Reduce Cost?
An Empirical Analysis of the Rail Industry
in OECD Countries

Fumitoshi Mizutani   Shuji Uranishi

Discussion Paper Series

Does Vertical Separation Reduce Cost? An Empirical Analysis of the Rail Industry in OECD Countries*

by

Fumitoshi Mizutani (Kobe University)
Shuji Uranishi (Fukuyama Heisei University)

Correspondent Author: Fumitoshi Mizutani
Kobe University, Graduate School of Business Administration
2-1 Rokkodai, Nada-ku, Kobe 657-8501
(Tel): +81-78-803-6905
(Fax):+81-78-803-6977
(E-mail): toshi@kobe-u.ac.jp

[Abstract]: The main purpose of this study is to analyze structural separation policies, especially vertical (i.e. operation-infrastructure) separation and functional (i.e. passenger-freight service) separation. Using the total cost function of a railway organization, we evaluate whether or not vertical separation and/or functional separation can reduce costs. For this analysis, we select 25 railway organizations from 23 OECD countries over 11 years, from 1997 to 2007. Our findings show that because the functional separation dummy has a negative sign with statistical significance, functional separation can be seen to reduce the cost of a railway. The effect of the vertical separation changes according to the train density of a railway organization. With lower train density, vertical separation tends to reduce cost, while with higher train density vertical separation increases cost.

[JEL Classification]: L23, L33, L51, L92, R48
[Key Words]: Vertical Separation, Functional Separation, Total Cost Function, Railway

---

* An earlier version of this paper was presented at the 12th World Conference on Transport Research in Lisbon, Portugal, July 11-15, 2010. We would like to thank participants for valuable comments and suggestions. For providing valuable information and materials, we would especially like to thank Simon Fletcher (International Union of Railways: UIC), Vincent Vu (International Union of Railways: UIC), Stephen Perkins (Joint Transport Research Centre of the OECD and the International Transport Forum), Siebe Riedstra (Dutch Ministry of Infrastructure and Transport), and Bastin Zibrandtsen (Danish Ministry of Transport).

Does Vertical Separation Reduce Cost?
An Empirical Analysis of the Rail Industry in OECD Countries

1 Introduction

Since the Japan National Railway (JNR) was privatized and subdivided into six passenger JR companies and one nationwide freight JR company in 1987, privatization and regulation of railways have been effected in many countries, each according to its own railway regulation and competition policies. For example, while vertical separation (i.e. operation-infrastructure separation) is a common policy in the European Union, vertical integration is still the structure of choice in the Japanese rail industry[1]. Among vertical separation options, there are many variations. For example, accounting might be separated from other functions, or there might be organizational separation of rail operations and infrastructure, or there might be organizational separation involving a holding company. Massive horizontal separation of former state railways was adopted in the UK and Japan, but in some countries the descendent organization of the former state railway has a vital role in the market. As for the ownership structure, a commercial organization with private ownership is common in the UK and Japan, in contrast to Denmark, where Danish Railway is still a publicly owned organization.

Competition policy is a vitally important issue in regulatory reform. Jensen (1998), by using a model in an empirical study of the Swedish railway sector, finds that external competitive pressure is strong in most supply segments. However, competition is handled in different ways in different countries. For example, direct competition in the railway market, in which the rail operator is selected by competitive tendering, is favored in many European countries while in Japan, rather than allowing direct market competition to occur, regulators apply yardstick regulation (i.e. the benchmark competition policy) to existing railway organizations (see for example, Mizutani et al (2009)). There are various railway regulations and competition policies, with much empirical and descriptive research having been carried out on individual countries' railway regulations. Although some studies such as Lodge (2002) explore the notion of regulatory failure in the railway domain by taking an analytical and a comparative perspective, there are few studies analyzing regulatory and competition policies across the international board. While some studies such as Oum and Yu (1994) and Lan and Lin (2006) analyze a rail organization's performance by using a cross-sectional data set, these studies do not focus on regulatory policy. Oum and Yu (1994) undertake an international comparison of economic efficiency among OECD countries' railways. Lan and Lin (2006) present an international comparison of performance measurements for railways by using stochastic distance functions.

[1] A series of regulatory reforms and regulation policies of each country is summarized, for example, by the ECMT (1998, 2001, 2005).

This study focuses mainly on structural separation policy, the most controversial among various regulatory policies in the rail industry, with our main purpose being to analyze how vertical separation policy affects each individual rail operator's performance. Among performance measures, we pay special attention to cost structure changes. There already exist many empirical studies on vertical separation's effect on cost, but their results vary, with some studies supporting the idea that vertical separation improves efficiency (e.g. Shires et al., Kim and Kim (2001), Ivaldi and McCullough (2001)); some suggesting the opposite (e.g. Cantos Sanchez (2001), Bitzan (2003), Jensen and Stelling (2007) and Growitsch and Wetzel (2009)); and one showing no effect (e.g. Mizutani and Shoji (2004)). Because studies have shown such differing, inconclusive results, the separation issue needs further analysis. In this study, we explain the effect of vertical separation policy on cost, by considering the differences in the degree of train density in the empirical cost model.

This paper consists of five sections after the introduction. In the second section, we summarize the previous literature, including both theoretical and empirical studies related to the vertical separation policy. In the third section, we explain theoretical background by applying Williamson's transaction cost economics. For the conceptual argument here, we are indebted to Preston (2002) and Hori (1996). In the fourth section, we explain the empirical cost model for this analysis. The cost model is specified as translog total cost function. In the cost model, both vertical separation dummy and functional separation dummy variables are included. The cost model is specified as to what extent vertical separation's effects are changed by the degree of train density of a rail organization. Furthermore, in order to control the output qualities, hedonic specification for output measures is used. In the fifth section, the empirical results are shown, after and explanation of the sample selection and data. Rail operators and infrastructure managers in OECD countries for the years from 1997 to 2007 are chosen. The main data source is a compilation of railway statistics issued by the International Union of Railways (UIC). The observations in the analysis cover, for example, JRs in Japan, SNCF in France, NS in Holland, SJ in Sweden, KORAIL in South Korea, and so on. By using empirical results, we evaluate whether or not vertical separation and functional separation can reduce the cost of railways. Last, we outline important points garnered from this analysis.

The main results of this study are as follows. First, because the functional separation (i.e. passenger and freight service) dummy has a negative sign with statistical significance, functional separation can be seen to reduce the cost of a railway. Second, the effect of the vertical separation changes according to the train density of a railway organization. With lower train density, vertical separation tends to reduce costs, while with higher train density, it would increase costs.

2 Previous Studies

There are many studies regarding structural separation in the rail industry, most aiming to discuss the advantages and disadvantages of vertical separation based on both theory and empirical evidence. In this section, we will give an overview of studies regarding the theoretical effects of vertical separation, such as Nash (1997), Hori (1996), Preston (2002), Ksoll (2004) and Drew (2009). Other studies, such as Nash and Rivera-Trujillo (2004) and Di Pietrantonio and Pelkmans (2004), summarize and discuss regulatory reforms, including vertical separation, in the EU railway industry. Pittman (2003, 2005) discusses structural separation with a focus on developing countries. There are studies on the unbundling issue by Affuso and Newbery (2004) and infrastructure quality by Buehler et al. (2004)[2].

First, Nash (1997) cites the potential advantages of separation: (1) promotion of a variety of operators; (2) clarification of intra-industry relationships; (3) specialization in both operation and infrastructure. On the other hand, he notes that separation has adverse effects on (1) pricing and performance; (2) timetabling and slot allocation; (3) investment; (4) safety; and integrated information and ticketing. These advantages and disadvantages are summarized in order to formulate a practical policy for the rail industry.

Hori (1996) and Preston (2002) apply Oliver Williamson's framework of transaction cost economics to the railway industry. These studies are not theoretical and do not involve, for example, model building. However, they consider this issue as a trade-off between market governance, which implies vertical separation, and bureaucratic internal governance, which implies vertical integration. For example, Preston (2002) evaluates the advantages and disadvantages of the operation-infrastructure separation. He mentions that the rail industry may well be thought of as one in which there is site-specific transfer of intermediate product across successive stages and hence unified governance (i.e. vertical integration) might be preferred, but this would need to be validated by empirical results. Although Hori (1996) mentions in his study that the degree of asset specificity increases in urban rapid rail systems compared with local rail systems, he does not explain why the degree of asset specification increases.

Like Nash (1997), Ksoll (2004) explores the arguments both in favor of and against vertical integration in railways. There are eight advantages: (1) lower complexity of interfaces simplifies operational co-ordination and conflict settlement; (2) comprehensive investment incentives and avoidance of holdups strengthen capacity, quality, safety and innovation; (3) private

---

[2] Affuso and Newbery (2004) investigate whether or not the investment pattern of the rail passenger franchisees responds to structural and contractual characteristics using a unique panel data on privatized railways in Britain. Their results suggest that unbundling and competition for franchises combined with commercial objectives can provide strong incentives towards better performance, as is the case for investment behavior. Buehler et al. (2004) investigate how various institutional settings affect a network provider's incentives to invest in infrastructure quality. In their analysis, with suitable non-linear access prices, investment incentives under separation become identical to those under integration.

infrastructure provision within an integrated firm ensures higher productivity levels and market driven allocation; (4) integration yields cost savings and synergies in shared facilities and services; (5) co-existence of integration and competition drives technological and product innovation; (6) encouragement of staff identification and responsibility increases quality and safety; (7) partial avoidance of double marginalization increases consumer welfare; (8) strategic behavior of the integrated firm can counteract excessive entry. On the other hand, there are four disadvantages of vertical integration: (1) integration involves the risk of discriminatory behavior by the infrastructure provider against downstream competition; (2) integration complicates regulation of the infrastructure monopoly; (3) there is a conflict between public infrastructure obligations and private infrastructure management; (4) integration may go along with lower and/or misguided performance incentives in internal compared to fully external transactions.

Kurosaki (2008, 2009) classify and evaluate the vertical separation policies which have been effected in the world's rail industries. He classifies vertical separation options into four groups: (1) vertical separation without within-rail competition (e.g. Vietnam, Indonesia and Tunisia), (2) vertical separation with competition among operators (e.g. Sweden, U.K., Germany, France and Australia), (3) vertical separation for passenger or freight traffic (e.g. Japan (JR Freight), US (Amtrack)), (4) concession of long-run access to infrastructure (e.g. Mexico). He summarizes appropriate forms of vertical separation policy based on different market structure (e.g. with/without within-rail competition, the market share of passenger and freight service. Kurosaki's contribution is his recognition that there is more than one feasible form of vertical separation. However, the empirical evidence by which he reaches his conclusions remain weak.

Drew (2009) reviews and analyses the benefits for rail freight customers of the two principal models for introducing competition in main line railway networks: (1) the vertical separation of infrastructure from operations; and (2) the introduction of competition providing other operators with open access to the network. He concludes that vertical separation benefits freight customers more than open access does alone.

Thus, there exists no definitive theoretical study of vertical separation in the railway industry. If we review existing literature from a theoretical point of view, we must say it is not clear whether or not a separation policy (i.e. vertical separation or vertical integration) is desirable.

As for empirical studies, there are many, but their results are not consistent. Some studies such as Shires et al., Kim and Kim (2001), and Ivaldi and McCullough (2001) show that vertical separation is better than vertical integration in terms of efficiency.

First, a study by Shires et al. shows that rail operating costs in Sweden are reduced by about 10% after vertical separation, although this separation was also accompanied by the gradual introduction of tendering (Preston, 2002, p.12).

Kim and Kim (2001) analyze the cost structure of Seoul's subway systems by using the stochastic frontier cost function. Their calculation results show that the total cost of the vertically separated system was about 3.6% lower than that of the vertically integrated system in 1998.

Ivaldi and McCullough (2001) apply the cost function to Class I U.S. railways and evaluate the effects of vertical separation. They find there are no cost complementarities between operations and infrastructure. This result implies that at all levels of output characterizing freight rail operations in the U. S., there may be no inherent technological advantages from vertical integration.

Although their study does not focus only on structural reforms, Friebel et al. (2010) apply a production frontier model for railways in EU countries over a period of 20 years in order to analyze the effect of regulatory reforms such as vertical separation, the introduction of third-party access, and the creation of independent regulatory institutions. They find that regulatory reforms increase efficiency.

On the other hand, some studies such as Cantos Sánchez (2001), Bitzan (2003), Jensen and Stelling (2007) and Growitsch and Wetzel (2009) show that vertical separation is inferior to vertical integration.

Cantos Sánchez (2001) analyzes the vertical relationship by applying translog total cost function for a data set of 12 European state railways for the period 1973 – 1990. He obtains the result that there are complementary effects between the costs deriving from freight transport and infrastructure, while the effects between the costs deriving from passenger transport and the infrastructure are substitute. He concludes that infrastructure and operations must be coordinated both in order to maintain the coordination effect and to avoid possible inefficiencies.

Bitzan (2003) examines the cost implications of competition over existing US freight rail lines by testing for the condition of cost subadditivity. He finds that there are economies associated with vertically integrated roadway maintenance and transport. This result suggests that vertical separation of infrastructure from operations increases costs.

Jensen and Stelling (2007), by using data from the railway industry in Sweden, explore how deregulation has affected cost efficiency. In their cost estimation, they evaluate the effect of vertical separation and conclude that it increases costs.

Growitsch and Wetzel (2009) investigate the performance of European railways with a particular focus on economies of vertical integration. They apply data envelopment analysis (DEA) to a data set of 54 railway companies from 27 European countries over 5 years from 2000 to 2004. From their analysis, they conclude that for a majority of European railways, there exist economies of scope.

One study shows no difference in efficiency. Mizutani and Shoji (2004) apply the translog cost function to maintenance activities in the Japanese rail industry and evaluate whether or not the vertical separation of operation and infrastructure activities would reduce cost. The results indicate that vertically separated systems might not be significantly different from vertically integrated ones.

Thus, previous empirical analysis has produced inconsistent results. It remains unclear whether vertical separation yields efficiency or inefficiency with regard to cost.

3 Theoretical Background of Vertical Separation in the Rail Industry

In this study, we assume that vertical separation can be explained by both the framework of transaction cost economics by Williamson (1985) and the application to the rail industry by Hori (1996) and Preston (2002). We also assume that the degree of asset specificity is changed by train density.

Based on Hori (1996) and Preston (2002), the application of Williamson's transaction cost economics to the rail industry is as follows. The key concept is the trade-off between the cost associated with market governance, which implies vertical separation, and internal governance, which implies vertical integration. We define ΔC as the difference between the production costs of internal governance ($C_B(k)$) and the production costs of market governance ($C_M(k)$). The production costs of market governance, $C_M(k)$ are always lower than the production costs of internal governance, $C_B(k)$ because the specialized company can expect economies of scale in infrastructure management at any degree of asset specificity, k. However, if the degree of asset specificity is too high, the production cost difference becomes small because the specialized company cannot enjoy scale economies. Therefore, the production cost difference ΔC is positive but declines as the degree of asset specificity increases.

Furthermore, governance costs, ΔG, are defined as the difference between internal governance costs ($G_B(k)$) and market governance costs ($G_M(k)$). If the degree of asset specificity is very low, the railway organization can purchase infrastructure management services from anybody in the market. Therefore, internal governance costs are much higher than market governance costs. On the other hand, if the degree of asset specificity is very high, market governance costs become larger than internal governance costs because the railway company cannot find a safe infrastructure management company.

When we consider the sum of ΔC and ΔG, we can see the crossover point at k^{**}. To the left of point k^{**}, market governance will be cost effective because ΔC and ΔG are positive. This means that vertical separation could be reasonable. On the other hand, to the right of point k^{**}, bureaucratic internal governance will be cost effective. Therefore, vertical integration could be reasonable.

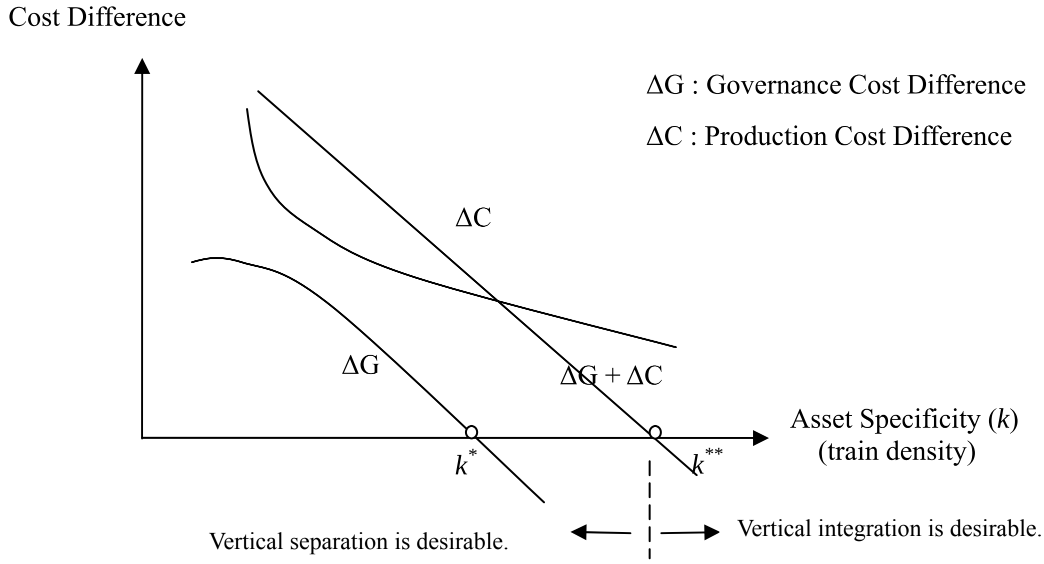

Figure 1 Concept of Production and Governance Costs and Asset Specificity

Finally, we will explain how the degree of asset specificity of the rail infrastructure is related to the train density of a rail organization. First, as for production costs, the maintenance of rail infrastructure is divided into two components: maintenance activity related to track length and maintenance activity related to train density. As the maintenance activities of first component are fixed regardless of the degree of train density, we can expect a railway to make use of resources available on the market. However, as for the second component of maintenance activities (e.g. rail and electric wire inspection), when train density is very high, daily maintenance activities become more frequent and demanding. Under these circumstances, it is better that maintenance staff and machinery be owned by the internal organization. Such ownership would reduce the difference in production costs between internal governance and market use. Therefore, the production cost difference decreases as the train density increases.

A more important point is governance cost. Cost differences decrease more rapidly as train density increases. Governance costs by market governance are for example, labor cost related to coordination divisions between two organizations, material costs such as documents related to maintenance activity plans, legal costs, and insurance costs. These costs are clearly huge under the condition of heavy train density because safe train operations are necessary. Of course, with internal governance, these costs are to some degree necessary but coordination and legal costs become much smaller because the top manager can decide who has more priority and management power among different internal divisions. Therefore, as the train density becomes larger, the degree of the asset specification becomes larger. As a result, governance costs by market governance become much larger with heavy train density.

From these arguments, the plausible conclusion is that vertical integration is more cost effective than vertical separation, if the rail organization's train density is very heavy. On the other hand, vertical separation is more cost effective than vertical integration under low train density. This happens because the degree of asset specification in the rail infrastructure is highly related to the train density of the rail organization. Although there is systematic empirical evidence, in particular, the claims by JR Freight company to JR passenger companies after the privatization of JNR shows support for our argument (see for example, Mizutani and Nakamura (2004)).

4 Empirical Cost Model

The most important characteristic of our cost model is specified such that the effect of the vertical separation varies by train density. As explained above, we expected the effect of vertical separation on cost to be positive because the coordination costs between two organizations would be higher than the cost saved by specializing in different activities (i.e. rail operation and infrastructure management).

In this study we employ a translog total cost function,[3] in which we include two kinds of institutional variables: a vertical separation dummy (*Dvs*) and a functional separation dummy (*Dfs*). The cost model is specified such that the effect of vertical separation on the cost varies by the degree of train density. The output measure is specified as a hedonic function of output characteristics in order to control the differences in the output conditions.

The translog cost model used here is shown as follows:

$$\begin{aligned}\ln TC =\; & \alpha_0 + \alpha_Y \ln Y + \Sigma_j \beta_j \ln w_j + \gamma_N \ln N + \tau_T\, T + (1/2)\alpha_{YY} (\ln Y)^2 + \Sigma_j \alpha_{Yj} (\ln Y)(\ln w_j) + \\ & \alpha_{YN} (\ln Y)(\ln N) + \alpha_{YT} (\ln Y)(T) + (1/2)\, \Sigma_k \Sigma_j \beta_{jk} (\ln w_j)(\ln w_k) + \\ & \Sigma_j \beta_{jN} (\ln w_j)(\ln N) + \Sigma_j \beta_{jT} (\ln w_j)(T) + (1/2)\, \gamma_{NN} (\ln N)^2 + \gamma_{NT} (\ln N)(T) + \\ & (1/2)\tau_{TT} T^2 + (\delta_{VS1} + \delta_{VS2} \ln V) D_{VS} + \delta_{FS} D_{FS} \qquad (1)\end{aligned}$$

$$\ln Y = \ln Q + \Sigma_f\, \eta_f \ln H_f, \qquad (2)$$

where TC: total cost

Y: output measure

[3] Several studies (e.g. Savage (1997), Mizutani (2004), Mizutani and Uranishi (2007)) use the variable cost function. However, as the main purpose of this study is to evaluate the effect of infrastructure management on cost, we use the total cost function.

Q: quantity of output

H_f: characteristics of output ($f = PR$ (passenger revenue share),

LF (load factor of passenger service), PTL (passenger travel length))

w_j: input factor price (j (or k) = L (labor), K (material and capital)),

N: total route length,

T: technology [4] (T_1: percentage of electrified length, or T_2 : time trend),

V: train density,

D_{VS}: vertical separation dummy (vertical separation =1, otherwise = 0),

D_{FS}: functional separation dummy (functional separation = 1, otherwise = 0).

In this model, we impose the restriction on input factor prices such that $\Sigma_j\beta_j = 1$, $\Sigma_k\beta_{jk} = 0$, $\Sigma_j\beta_{jN} = 0$, $\Sigma_j\beta_{jT} = 0$, $\Sigma_j\alpha_{Yj} = 0$, $\beta_{jk} = \beta_{kj}$, $\beta_{jN} = \beta_{Nj}$, $\beta_{jT} = \beta_{Tj}$. Furthermore, we apply Shephard's Lemma to the total cost function. Then we can obtain the input share equations as follows:

$$S_j = \beta_j + \alpha_{Yj}(\ln Y) + \Sigma_k\beta_{jk}(\ln w_k) + \beta_{jN}(\ln N) + \beta_{jT}(T), \qquad (3)$$

where S_j: input j's share of total cost.

As for the estimation technique, we apply the seemingly unrelated regression (SUR) method by the total cost function and the input share equations. For the estimation, we will divide all observations of each variable by the sample mean, except for time trend.

5 Empirical Analysis

5.1 Sample Selection

The main purpose of this study is to examine how differences in structural reform affect cost structure; that is, we evaluate how differences in unbundling methods, such as vertical separation and functional separation, affect cost difference. In order to evaluate the structural factor only, we selected railway organizations with relatively similar conditions. As a sample selection, we chose railway organizations from OECD countries, excluding those of OECD railway organizations in the US, Canada and Australia, however, because their network conditions are generally different (e.g. long line hauls). And while there exist cost studies, for example that of Smith (2006), which do use data from the UK rail industry, we unfortunately have to forgo including the UK because of the overall lack of data. As Table 1 shows, we collected data on 25 railway

[4] In this study, as for technology variable (T), we take the natural logarithm for percentage of electrified length (i.e. ln T_1) but do not take it for time trend (i.e. T_2).

organizations from 23 OECD countries for the 11 years from 1997 to 2007, giving us 275 observations (i.e. 25 railways times 11 years).

We follow the definition of structural reform[5] of the UIC, which classifies railway organizations into five categories: (1) integrated company, (2) railway undertaking, (3) passenger operator, (4) freight operator, and (5) infrastructure manager. For example, as for operation-infrastructure management, DSB in Denmark was separated from its infrastructure organization (BDK) in 1997, so that DSB is classified as having had vertical separation since 1997. However, the freight service of DSB, which became Railion DK, was separated in 2001, so that DSB is also classified as having had functional separation since 2001. KORAIL in Korea was neither vertically nor functionally separated between 1997 and 2007, so that KORAIL is classified as an integrated system. Therefore, the vertical separation here means that the activities of rail operations and infrastructure management are provided by completely separate organizations. Two different organizations under the same holding company are not separated bodies.

Table 1 Railway Operators for Our Study

No.	Railway Operator	Country	Vertical Separation	Functional Separation
1	ÖBB (Österreichische Bundesbahnen)	Austria	-	-
2	SNCB/NMBS (Société Nationale des Chemins de fer Belges)	Belgium	-	-
3	BLS (BLS AG)	Switzerland	-	2003~
4	SBB CFF FFS (Schweizerische Bundesbahnen)	Switzerland	-	-
5	CD (České Dráhy)	Czech Rep.	-	2003~
6	DB AG (Deutsche Bahn AG)	Germany	-	-
7	DSB (Danske Statsbaner)	Denmark	1997~	2001~
8	RENFE (Red Nacional de los Ferrocarriles Españoles)	Spain	2005~	-
9	VR (VR-Group Ltd)	Finland	1995~	-
10	SNCF (Société Nationale des Chemins de fer Français)	France	1997~	-
11	OSE (Hellenic Railway Organization)	Greece	-	-
12	GySEV/RÖEE (Györ-Sopron-Ebenfurti Vasút Részvénytarsasag)	Hungary	-	-
13	MAV (Magyar Államvasutak Rt.)	Hungary	2007~	2006~
14	CIE (Coras Iompair Éireann)	Ireland	-	-
15	FS (Ferrovie dello Stato SpA)	Italy	-	-
16	JR (JR Group)	Japan	-	1987~
17	KOREAIL (Korean National Railroad)	South Korea	-	-
18	CFL (Société Nationale des Chemins de fer Luxembourgeois)	Luxembourg	-	2007~
19	NS (N. V. Nederlandse Spoorwegen)	Netherlands	1998~	2000~
20	NSB (Norges Statsbaner AS)	Norway	1996~	2002~
21	PKP (Polskie Koleje Państwowe S. A.)	Poland	-	-
22	CP (Caminhos de Ferro Portugueses, E. P)	Portugal	1997~	-
23	SJ (Statens Jämvägar AB)	Sweden	1988~	2002~
24	ZSSK (Slovak Rail)	Slovakia	2002~	2005~
25	TCDD (Türkiye Cumhuriyeti Deviet Demiryollari Isletmesi)	Turkey	-	-

5.2 Main Data Source and Definition of Variable

[5] There are some studies on classifications of structural reforms (e.g. ECMT (1998, 2001) and Kurosaki (2008, 2009). In this study, we focus on the effect of the organizational separation. And the standard data are well organized from the data set by the UIC. Therefore, we follow the definition of the UIC.

The main data source for this study is *International Railway Statistics*, annually issued by the UIC, in which, however, some railway organizations' data is incomplete, so that we were compelled to supply missing data from several other sources. Table 2 shows our main data sources.

Table 2 Major Data Sources for Our Study

Items	Source
Costs, Output measures, Wage, Number of employees, Rolling stock, Route length etc.	(1) International Railway Statistics by the UIC (2) Jane's World Railways (3) Annual reports by each individual railway organization (4) Danish Ministry of Transport for missing data of DSB and BDK (5) Annual Railway Statistics for JR
Exchange rate	Eurostat
GDP deflator	(1) World Development Indicators by the World Bank (2) Economic Outlook 83 Database by OECD

Before we explain the definition of variables, we must explain the treatment of total cost in the structurally separated organization. In this study, we analyze the structural separation effect on the cost structure. In the case of structurally separated companies, we combine these organizations, as Table 3 shows. It is worth noting that input factors such as labor and rolling stock are also combined in cases where organizations are combined.

Table 3 Total Costs in the Structurally Separated Organization

Structure	Type of railway organization	Definition of total costs	Structural dummy variable
Vertical structure	Vertical integration	Vertically integrated company's total cost	D_{VS} =0
	Vertical separation	Operation company's total cost + Infrastructure company's total cost	D_{VS} =1
Functional structure	Functional integration	Functionally integrated company's total cost	D_{FS} =0
	Functional separation	Passenger company's total cost + Freight company's total cost	D_{FS} =1
(Note): (1) D_{VS} : vertical separation dummy, D_{FS} : functional separation dummy			

Table 4 shows the definition of all variables used for the estimation of total cost function. First, total costs (TC) in this study are defined as the sum of labor, energy, material costs and capital costs. Service costs for the rail organization whose infrastructure service is separated from rail operation are included in the total costs.

As for output measure, we use the total number of train kilometers (Q) for both passenger services and freight services. In order to avoid estimation bias based on different kinds of output, we also include three kinds of variables of output characteristics: passenger revenue share (H_{PR}), load factor of passenger service (H_{LF}) and passenger travel length (H_{PTL}). First, passenger revenue share is defined as the ratio of passenger service revenue to total rail service revenues. Second, passenger load factor is defined as the ratio of the number of passengers per train to the designated capacity of a passenger vehicle. The designated capacity of a passenger vehicle is calculated by multiplying the number of vehicles per train by the number of seats per passenger vehicle. The number of passengers per train is obtained by dividing revenue passenger kilometers by passenger train kilometers. Third, passenger travel length is measured as the ratio of revenue passenger kilometers to the total number of passengers. As we explained before, these output measures and output characteristics measures are specified as a hedonic function.

Table 4 Definition of Variables Used for the Estimation of Cost Function

Variable	Definition	Unit	Mean	Standard Deviation	Minimum	Maximum
TC (Total cost)	Sum of labor, energy energy and capital cost	million euro	4,572	7,637	78	37,148
Q (Output)	Total train-km(1)	thousand km	167,031	227,878	1,747	936,714
w_L (Wage)	Labor costs per employee	euro	35,277	20,193	4,203	100,731
w_K (Material and capital price)	Material and capital costs per composite material index(2)	euro	213,689	190,915	11,295	919,693
N (Total route length)	Total route km	km	8,524	9,197	220	38,450
T_1 (Technology index 1)	Percentage of electrified line	%	53.91	27.12	0.01	100.00
T_2 (Technology index 2)	Time trend (Year 1997=1)	-	6.000	3.168	1.000	11.000
H_{PRS} (Passenger revenue share)	Share of passenger revenue to total revenue(3)	-	0.5812	0.2399	0.0541	0.9677
H_{LF} (Load factor of passenger)	Passenger per train to capacity(4)	-	0.3661	0.1424	0.1264	0.9355
H_{PTL} (Passenger travel length)	Revenue passenger-km per passenger	km	54.46	31.45	14.64	190.21
V (Train density)	Train-km per route length per day	Train/day	55.4475	32.3542	12.2569	142.6948
D_{VS} (Vertical separation)	Vertical separation dummy (Vertical separation = 1)	-	0.3309	0.4714	0.0000	1.0000
D_{FS} (Functional separation)	Functional separation dummy (Functional separation = 1)	-	0.1418	0.3495	0.0000	1.0000
S_L (Share of labor)	Share of labor input expenditure	-	0.3937	0.1320	0.1155	0.7434
S_K (Share of material etc)	Share of material and capital expenditure	-	0.6063	0.1320	0.2566	0.8845

(Note):
(1) Total train-km (Q) = passenger train-km + freight train-km
(2) Composite material index (M) = 0.28 * rolling stock + 0.72* total route lengths
(3) Passenger revenue share(H_{PRS}) = Passenger service turnover / Passenger and freight service turnover
(4) Load factor of passenger (H_{LF}) = Passengers per train / Capacity
Where Capacity = Number of wagons per train * Number of seats per passenger wagon
Number of wagons per train = Passenger gross hauled ton-km / Passenger train-km / 50 ton *1000
Passengers per train = Revenue passenger-km / Passenger train-km * 1000
(5) Train density (V) = train-km/route-km/365

There are two kinds of input factor prices. First, labor price (w_L) is obtained by dividing labor costs by the total number of employees. Material and capital price (w_K) is obtained by dividing material and capital costs by the composite material index. The composite material index is the weighted share of rolling stock and route length. In this study, we assume that the rolling stock's weight is 28% and the route length's weight is 72%. We should note that due to a lack of data we are unable to include energy prices. These are included in the price of material and capital.

As for the network variable, we include the total route length (N). We consider two kinds of technology (T). First, in determining which variables to use, we considered possible proxy variables that would show technological progress, such as the percentage of ATS or ATC, electrified line length. In this study, we define technology as the percentage of electrified lines (T_1). Although we considered using the ratio of ATS or ATC as variables, we were forced to forgo their use due to a lack of data availability. Alternatively, technology is used as a measure of time trends (T_2), in which the year 1997 is equal to one. In this specification, all railway organizations can progress technologically in a linear fashion and can obtain technology on an equal basis.

Train density (V) is obtained by dividing the number of train-km by the total route length of a railway. This variable is measured as per-day so that it is divided by 365. This variable is used with the vertical separation dummy in order to measure the multiple effects of vertical separation and train density, as explained above.

Finally, two kinds of structural dummy variables are defined. First, the vertical separation dummy (D_{VS}) is defined as a binary measure, in which the vertically separated railway company is equal to one but is otherwise zero. The functional separation dummy (D_{VS}) is also defined as a binary measure. If a railway company's passenger and freight services are separated, this measure is equal to one but is otherwise zero.

5.3 Empirical Results

We estimate the total cost function shown in equation-(1) and (2) with equation-(3). For our estimation, we use the seeming unrelated regression (SUR) method by the total cost function and input share equations. The estimation results of the total cost function are summarized in Table 5. We show four cases in Table 5: two kinds of technology variable (i.e. percentage of electrified line or time trend) and whether the train density is considered in the vertical separation dummy (i.e. with/without the cross-term of train density and vertical separation dummy).

The goodness-of-fit in the regressions is acceptably high for these models because pseudo R^2 are very high. As for the required properties in the cost function, first, symmetry and homogeneity conditions in input factor prices are satisfied, because we imposed restrictions on the cost model. Second, as for monotonicity conditions, it is necessary that the cost function be a non-monotone decreasing function in both output and input factor prices. Whether or not the monotonicity conditions are satisfied was evaluated by checking that the partial derivative of the cost function with respect to output and input factor prices is not negative (i.e. $\partial \ln C/\partial \ln Y \geq 0$, $\partial \ln C/\partial \ln w_j \geq 0$). Around the sample mean, these conditions are satisfied. Determining whether or not the Hessian matrix holds negative semi-definite can test for the concavity condition in input factor prices. In our test results, 93.45% of observations satisfy the concavity condition. Among these cases, Case 3 is the best based on the log likelihood statistics. Therefore, we conclude that these cases are all acceptable but Case 3 is the best.

Table 5 Estimation Results of the Total Cost Function

Variable	Case 1	Case 2	Case 3	Case 4	Variable	Case 1	Case 2	Case 3	Case 4
Y	0.5743*** (0.0461)	0.6072*** (0.0637)	0.5541*** (0.0493)	0.5253*** (0.0587)	$Y \cdot T_2$	-	0.0000 (0.0028)	-	-0.0041 (0.0063)
H_{PRS}	-0.5556*** (0.0531)	-0.7487*** (0.0516)	-0.5860*** (0.0556)	-0.7973*** (0.0579)	$w_L \cdot N$	-0.1338*** (0.0131)	-0.0988*** (0.0132)	-0.1332*** (0.0137)	-0.0946*** (0.0128)
H_{LF}	-0.2701*** (0.0776)	-0.2173** (0.0905)	-0.2989*** (0.0855)	-0.3194*** (0.0997)	$w_L \cdot T_1$	-0.0347*** (0.0051)	-	-0.0330*** (0.0054)	-
H_{PTL}	0.2289*** (0.0478)	0.3141*** (0.0496)	0.2817*** (0.0515)	0.3291*** (0.0529)	$w_L \cdot T_2$	-	-0.0079*** (0.0019)	-	-0.0077*** (0.0019)
w_L	0.3681*** (0.0065)	0.4161*** (0.0134)	0.3684*** (0.0068)	0.4152*** (0.0136)	$w_K \cdot N$	0.1338*** (0.0131)	0.0988*** (0.0132)	0.1332*** (0.0137)	0.0946*** (0.0128)
w_K	0.6319*** (0.0065)	0.5839*** (0.0134)	0.6316*** (0.0068)	0.5848*** (0.0136)	$w_K \cdot T_1$	0.0347*** (0.0051)	-	0.0330*** (0.0054)	-
N	0.3791*** (0.0464)	0.3508*** (0.0630)	0.3981*** (0.0492)	0.4404*** (0.0590)	$w_K \cdot T_2$	-	0.0079*** (0.0019)	-	0.0077*** (0.0019)
T_1	-0.2794*** (0.0521)	-	-0.2551*** (0.0529)	-	$N \cdot T_1$	-0.1237*** (0.0127)	-	-0.2436*** (0.0868)	-
T_2	-	-0.0138 (0.0172)	-	-0.0145 (0.0164)	$N \cdot T_2$	-	-0.0792*** (0.0125)	-	0.0003 (0.0065)
$Y \cdot Y$	-0.3680** (0.1478)	-0.1738* (0.0895)	-0.2127 (0.1470)	-0.1270* (0.0762)	$T_1 \cdot T_1$	0.4090*** (0.1467)	-	-0.0090 (0.0089)	-
$N \cdot N$	0.1237*** (0.0127)	0.0792*** (0.0125)	-0.4278*** (0.1608)	-0.2895*** (0.0872)	$T_2 \cdot T_2$	-	0.2570*** (0.0896)	-	0.0006 (0.0026)
$w_L \cdot w_L$	0.1528*** (0.0104)	0.1556*** (0.0109)	0.1514*** (0.0109)	0.1550*** (0.0112)	D_{VS}	-0.2051*** (0.0375)	-0.2013*** (0.0359)	-0.1849*** (0.0377)	-0.1644*** (0.0370)
$w_L \cdot w_K$	-0.1528*** (0.0104)	-0.1556*** (0.0109)	-0.1514*** (0.0109)	-0.1550*** (0.0112)	$V \cdot D_{VS}$	-	-	0.1378*** (0.0523)	0.2199*** (0.0451)
$w_K \cdot w_K$	0.1528*** (0.0104)	0.1556*** (0.0109)	0.1514*** (0.0109)	0.1550*** (0.0112)	D_{FS}	-0.2246*** (0.0435)	-0.2454*** (0.0445)	-0.2654*** (0.0438)	-0.3009*** (0.0437)
$Y \cdot w_L$	0.0948 (0.0597)	-0.0058 (0.0070)	0.1204*** (0.0132)	0.0740*** (0.0121)	Constant	8.6248*** (0.0260)	8.6724*** (0.0500)	8.6208*** (0.0249)	8.6701*** (0.0476)
$Y \cdot w_K$	-0.5362*** (0.1629)	-0.3785*** (0.0996)	-0.1204*** (0.0132)	-0.0740*** (0.0121)	Log of likelihood	44.8827	31.2916	50.8841	48.5389
$Y \cdot N$	-0.3029*** (0.0856)	0.0017 (0.0072)	0.2808* (0.1455)	0.1895 (0.0773)	Pseudo R^2	0.9786	0.9763	0.9795	0.9791
$Y \cdot T_1$	-0.0205** (0.0087)	-	0.0428 (0.0607)	-	Satisfied concavity condition	93.45%	93.45%	93.45%	93.45%

(Note):
(1) *** Significant at 1 percent, ** 5 percent, * 10 percent.
(2) Number of observations: 275

We evaluate the effects of structural reform based on empirical results. First, because the coefficients of the functional separation dummy (D_{FS}) in any case of our analysis show the negative sign with a statistical significance of 1%, it seems clear that companies can reduce cost when they functionally separate passenger and freight services. In fact, Kim (1987) finds that there are diseconomies of scope between passenger and freight service. If this is true, a functional separation policy is advisable.

Second, as for vertical separation, in general, vertical separation tends to reduce the costs of railways, as the coefficient of the vertical separation dummy (D_{VS}) shows only the negative sign. These have a statistical significance of 1%. However, the cross-tem with train density ($V \cdot D_{VS}$) shows the positive sign with a significance of 1%. From these results, it can be seen that the vertical separation effects with lower train density tend to reduce the total costs of a railway organization. But as train density increases, vertical separation causes an increase in a railway's total costs.

Our results could explain why previous studies have produced differing results. In the case of lower train density, our result supports that vertical separation contributes to cost reduction in the railway industry, which is consistent with studies by Shires et al., Kim and Kim (2001), Ivaldi and McCullough (2001) and Friebel et al. (2010). However, in the case of higher train density, our result shows that the vertical separation causes an increase in costs, which is consistent with studies such as Cantos Sanchez (2001), Bitzan (2003), Jensen and Stelling (2007), and Growitsch and Wetzel (2009).

Why does this kind of result appear? We can explain by using the framework of Williamson (1985) and Preston (2002). In the case of lower train density, as trains are operated on tracks, the coordination cost is low between the operating company and the infrastructure company. Therefore, production costs can be saved by specializing in activities (i.e. train operation and infrastructure management). On the other hand, in the case of higher train density, coordination between the train operating company and the infrastructure management company is expensive because there are necessarily a lot of costs for such things as meeting for maintenance scheduling, maintaining safety under busy train operation, and so on. Therefore, any costs saved by vertical separation specialization would be canceled out by high coordination costs between two different organizations.

In our calculation, if train density reaches about 2.11 to 3.83 times the sample mean, vertical separation starts to increase the costs, as Figure 2 shows. Among our observations in 2007, railway organizations with the higher train density are BLS (Switzerland), SBB CFF FFS (Switzerland), JR (Japan), KOREAIL (South Korea) and NS (Netherlands).[6] Except for NS, a vertical separation

[6] The railway organization with the higher train density is a railway organization whose value of train density (V) is 1.7 times the value of the sample mean.

policy has not been taken in these rail organizations.

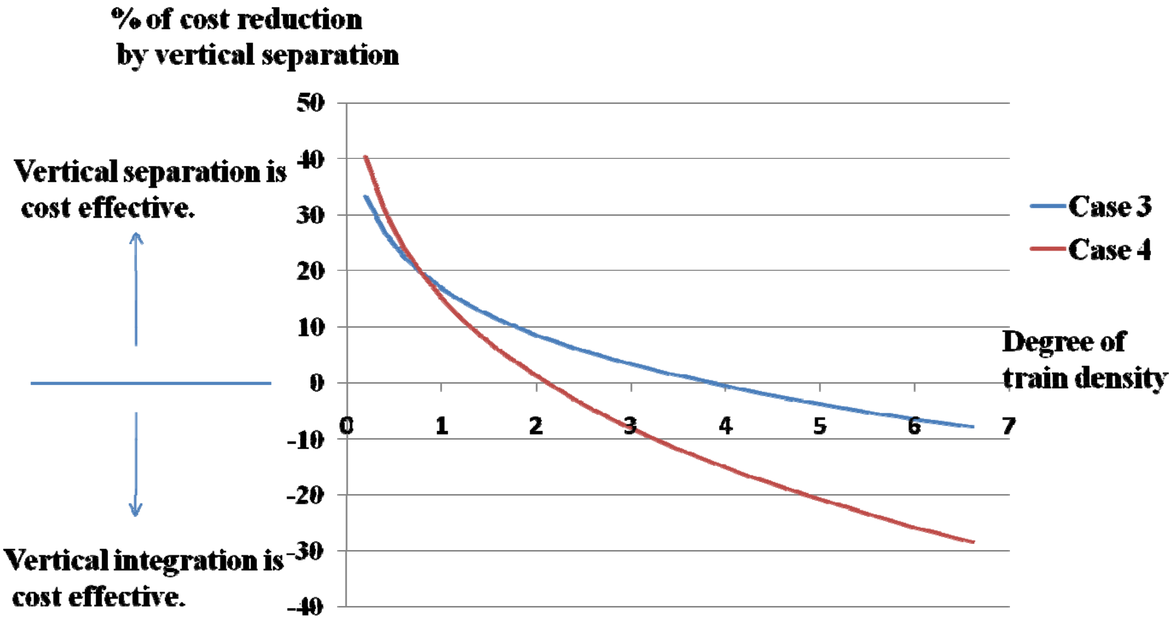

Figure 2 Cost Reduction Rate by The Degree of Train Density

6 Conclusion

Regulatory reforms, including privatization and deregulation in the rail industry, have been carried out in many countries, each with its own regulation and competition policies. Especially noticeable is that while vertical separation is common in Western Europe, vertical integration is still standard in East Asia and Eastern Europe. The main purpose of this study has been to analyze structural separation policy, especially vertical (i.e. operation-infrastructure) separation and functional (i.e. passenger-freight service) separation. By using the total cost function of a railway organization, we evaluate whether or not vertical separation and/or functional separation could reduce its costs. We selected 25 railway organizations from 23 OECD countries for the 11 years between 1997 and 2007.

Our main findings are as follows. First, because the coefficients of the functional separation dummy in any case of our analysis show the negative sign with a statistical significance of 1%, functional separation appears to lower a railway's costs. Because of diseconomies of scope between passenger service and freight service, functional separation is a better policy than the alternative. Second, as for vertical separation, in general, vertical separation tends to reduce the costs of railways, as the coefficient of the vertical separation dummy shows only the negative sign.

However, the cross-term with train density ($V \cdot D_{VS}$) shows the positive sign with significance of 1%. From these results, the overall vertical separation effects with lower train density tend to reduce the total cost of a railway organization. But as train density increases, the vertical separation causes total costs to increase.

In conclusion, our results regarding vertical separation show that the effects on cost reduction depend on the magnitude of train density. If a rail organization has lower train density, the vertical separation policy is reasonable. However, a rail organization with higher train density should take a vertical integration policy.

[2010.9.21 998]

References

Affuso, L. and D. Newbery (2002) "The Impact of Structural and Contractual Arrangements on a Vertically Separated Railway," *The Economic and Social Review,* Vol.33, No.1, pp.83-92.

Bitzan, J. D. (2003) "Railroad Costs and Competition: The Implications of Introducing Competition to Railroad Networks," *Journal of Transport Economics and Policy,* Vol.37, No.2, pp.201-225.

Buehler, S., A. Schmutzler and M. Benz (2004) "Infrastructure Quality in Deregulated Industries: Is There an Underinvestment Problem?" *International Journal of Industrial Organization,* Vol.22, No.2, pp.253-267.

Cantos Sánchez, P. (2001) "Vertical Relationships for the European Railway Industry," *Transport Policy,* Vol.8, No.2, pp.77-83.

Di Pietrantonio, L. and J. Pelkmans (2004) *The Economics of EU Railway Reform,* Bruges European Economic Policy Briefings, College of Europe, The Hague, Holland.

Drew, J. (2009) "The Benefits for Rail Freight Customers of Vertical Separation and Open Access," *Transport Reviews,* Vol.29, No.2, pp.223-237.

ECMT (1998) *Rail Restructuring in Europe,* OECD, Paris, France.

ECMT (2001) *Railway Reform: Regulation of Freight Transport Markets,* OECD, Paris, France.

ECMT (2005) *Railway Reform and Charges for the Use of Infrastructure,* OECD, Paris, France.

Friebel, G., M. Ivaldi and C. Vibes (2010) "Railway (De)Regulation: A European Efficiency Comparison," *Economica,* Vol.77, No.305, pp.77-99.

Growitsch, C. and H. Wetzel (2009) "Testing for Economies of Scope in European Railways: An Efficiency Analysis," *Journal of Transport Economics and Policy,* Vol.43, No.1, pp.1-24.

Hori, M. (1996) "Separation of Infrastructure and Operations and Open Access: From the Viewpoint of Internal Organization Theory (Joge Bunri to Opun Akusesu)," *Transportation and Economy (Unyu to Keizai),* Vol.56, No.6, pp. 79-87 (in Japanese).

Ivaldi, M. and G. J. McCullough (2001) "Density and Integration Effects on Class I U.S. Freight Railroads," *Journal of Regulatory Economics,* Vol.19, No.2, pp.161-182.

Jensen, A. (1998) “Competition in Railway Monopolies,” *Transportation Research-E,* Vol.34, No.4, pp.267-287.

Jensen, A. and P. Stelling (2007) “Economic Impacts of Swedish Railway Deregulation: A Longitudinal Study,” *Transportation Research-E,* Vol.43, No. 5, pp.516-534.

Kim, H. Y. (1987) “Economies of Scale and Scope in Multiproduct Firms: Evidence from US Railroads,” *Applied Economics,* Vol.19, pp.733-741.

Kim, M. and S. Kim (2001) “An Analysis of the Cost Structure of a Seoul’s Rail Transit Property: Stochastic Frontier Approach,” *A Paper Presented to Ninth World Conference on Transport Research,* Seoul, Korea, July 22-27, 2001.

Ksoll, M. (2004) “Integration of Infrastructure and Transport: An Assessment from Industrial Economics and Railway Perspectives,” *Paper Presented at the 2nd Conference on Railroad Industry Structure, Competition and Investment,* October 8-9, 2004, Evanston, IL, USA.

Kurosaki, F. (2008) *An Analysis of Vertical Separation of Railways,* Unpublished Doctor of Philosophy Dissertation, Institute for Transport Studies, the University of Leeds.

Kurosaki, F. (2009) “An Analysis of Vertical Separation of Railways (Tetsudo no Joge Bunri ni Kansuru Bunseki),” *Annual Report on Transportation Economics (Kotsugaku Kenkyu),* No.53, pp.65-74 (in Japanese).

Lan, L. W. and E. T. J. Lin (2006) “Performance Measurement for Railway Transport: Stochastic Distance Functions with Inefficiency and Ineffectiveness Effects,” *Journal of Transport Economics and Policy,* Vol.40, No.3, pp.383-408.

Lodge, M. (2002) “The Wrong Type of Regulation? Regulatory Failure and the Railways in Britain and Germany,” *Journal of Public Policy,* Vol.22, No.3, pp.271-297.

Mizutani, F. (2004) “Privately Owned Railways’ Cost Function, Organization Size and Ownership,” *Journal of Regulatory Economics,* Vol.25, No.3, pp.297-322.

Mizutani, F. and K. Shoji (2004) “Rail Operation-Infrastructure Separation: the Case of Kobe Rapid Transit Railway,” *Transport Policy,* Vol.11, pp.251-263.

Mizutani, F. and K. Nakamura (2004) “The Japanese Experience with Railway Restructuring,” in T. Ito and A. O. Krueger (eds.) *Governance, Regulation and Privatization*, The University of Chicago Press, Chicago, pp. 305-336.

Mizutani, F. and S. Uranishi (2007) “The Effects of Privatization on Productivity and Capital Adjustment,” *International Journal of Transport Economics,* Vol.34, No.2, pp.197-224.

Mizutani, F., H. Kozumi and N. Matsushima (2009) “Does Yardstick Regulation Really Work? Empirical Evidence from Japan’s Rail Industry,” *Journal of Regulatory Economics,* Vol.36, No.3, pp.308-323.

Nash, C. (1997) “The Separation of Operation from Infrastructure in the Provision of Railway Services: The British Experience,” in ECMT (ed.) *The Separation of Operation from*

Infrastructure in the Provision of Railway Service, OECD, Paris, France, pp.53-89.

Nash, C. and C. Rivera-Trujillo (2004) "Rail Regulatory Reform in Europe: Principles and Practice," *Paper Presented at the Conference on Competition in the Rail Industry,* September 2004, Madrid, Spain.

Oum, T. H. and C. Yu (1994) "Economic Efficiency of Railways and Implications for Public Policy: A Comparative Study of the OECD Countries' Railways," *Journal of Transport Economics and Policy,* Vol.28, No.2, pp.121-138.

Pittman, R. (2003) "Vertical Restructuring (or Not) of the Infrastructure Sectors of Transition Economies," *Journal of Industry, Competition and Trade,* Vol.3, No.1/2, pp.5-26.

Pittman, R. (2005) "Structural Separation to Create Competition? The Case of Freight Railways," *Review of Network Economics,* Vol.4, No.3, pp.181-196.

Preston, J. (2002) "The Transaction Cost Economics of Railways," *Trasporti Europei,* Vol.8, No.20/21, pp.6-15.

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

Smith, A. S. (2006) "Are Britain's Railways Costing Too Much?: Perspectives Based on TFP Comparisons with British Rail 1963-2002," *Journal of Transport Economics and Policy,* Vol.40, No.1, pp.1-44.

Williamson, O. (1985) *The Economic Institutions of Capitalism,* The Free Press, New York.