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Effects of Regulatory and Competition Policy on Performance: An Empirical Analysis of OECD Members' Rail Industries

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Effects of Regulatory and Competition Policy on Performance: An Empirical Analysis of OECD Members' Rail Industries[*]

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[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 the 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 reduce the cost of a railway. The vertical separation dummy generally shows a negative sign, indicating that vertical separation tends to reduce rail costs, but some results show that the vertical separation dummy is not statistically significant.

[JEL Classification]: L23, L33, L51, L92, R48

[Key Words]: Vertical Separation, Functional Separation, Total Cost Function, Railway

1 Introduction

Since the Japan National Railway (JNR) was privatized and subdivided into 6 passenger JR companies and 1 nationwide freight JR company in 1987, the privatization and regulation of railways have been carried out in many countries, each according to its own railway regulation and competition policies. For example, while vertical separation (i.e.

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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]. Massive horizontal separation of the former state railway 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 the 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. There are a wide variety of 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.

This study focuses mainly on the 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.

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

This paper consists of five sections after the introduction. In the first section, we summarize the previous literature, including both theoretical and empirical studies related to the vertical separation policy. In the second 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. Furthermore, in order to control the output qualities, hedonic specification for output measures is used. In the third section, we explain the sample selection and data. Rail operators and infrastructure managers in the OECD countries for the years 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. In the fourth section, 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.

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 about the theoretical effects of vertical separation, such as Nash (1997), 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

[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 the 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.

integrated information and ticketing.

Preston (2002) applies Oliver Williamson's framework of transaction economics to the railway industry, in which he considers this issue as a trade-off between market governance, which implies vertical separation, and bureaucratic internal governance, which implies vertical integration. He evaluates the advantages and disadvantages of the operation-infrastructure separation.

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 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) embracing 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 for vertical integrations: (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.

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 just open access does.

There exists no definitive theoretical study of vertical separation in the railway industry. However, if we review existing literature from a theoretical point of view, we must say that it is uncertain as to 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 Empirical Cost Model

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 translog cost model used here is shown as follows:

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

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

where
TC: total cost
Y: output measure
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),
D_{VS}: vertical separation dummy (vertical separation =1, otherwise = 0),
D_{FS}: functional separation dummy (functional separation = 1, otherwise = 0).

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[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.
[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).

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:

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

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

As for the estimation technique, we apply the full information maximum likelihood (FIML) 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.

4 Sample Selection and Data

4.1 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 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 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.

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	-	-

4.2 Main Data Source and Definition of Variable

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.

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%.

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
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

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.

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 otherwise is 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 otherwise is zero.

5 Empirical Results

We estimate the total cost function shown in equation-(1) and (2) with equation-(3). For our estimation, we use the full information maximum likelihood (FIML) method by the total cost function and input share equations. The estimation results of the total cost function are summarized in Table 5.

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, 94.55 to 96.73% of observations satisfy the concavity condition. Therefore, we conclude that it is acceptable to use this cost model.

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 the negative sign. However, this does not always hold. In a case where we take time trend as technology variable, the coefficient of the vertical separation dummy is not statistically significant at 10%, although the sign of the coefficient is negative. Therefore, vertical separation would be slightly better than vertical integration in terms of cost reduction.

Last, as Case 3 and Case 4 show, the coefficient of the cross effect of these separations ($D_{VS} \cdot D_{FS}$) is positive. Therefore, the cost reducing effect by each separation gradually becomes smaller because of the other separation policy.

Our results support 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) but inconsitent with studies such as Cantos Sanchez (2001), Bitzan (2003), Jensen and Stelling (2007), and Growitsch and Wetzel (2009). Unlike many previous studies, ours includes observations from former eastern European countries' state railways, whose less densely operated train systems may have made it cost advantageous for them to separate infrastructure management from train operation.

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	0.5866***	0.6345***	0.5341***	0.5463***	$Y \cdot T_2$	-	-0.0082	-	-0.0029
	(0.0826)	(0.1143)	(0.0657)	(0.1033)			(0.0112)		(0.0108)
H_{PRS}	-0.5622***	-0.7847***	-0.5612***	-0.7716***	$w_L \cdot N$	-0.1310***	-0.0909***	-0.1201***	-0.0817***
	(0.0680)	(0.0643)	(0.0663)	(0.0673)		(0.0171)	(0.0199)	(0.0159)	(0.0189)
H_{LF}	-0.2590***	-0.1911*	-0.3689***	-0.3097**	$w_L \cdot T_1$	-0.0355***	-	-0.0373***	-
	(0.0938)	(0.1135)	(0.0851)	(0.1219)		(0.0050)		(0.0052)	
H_{PTL}	0.2276***	0.3032***	0.1331**	0.2356***	$w_L \cdot T_2$	-	-0.0079***	-	-0.0075***
	(0.0650)	(0.0842)	(0.0677)	(0.0898)			(0.0022)		(0.0022)
w_L	0.3686***	0.4186***	0.3674***	0.4165***	$w_K \cdot N$	0.1310***	0.0909***	0.1201***	0.0817***
	(0.0085)	(0.0197)	(0.0084)	(0.0195)		(0.0171)	(0.0199)	(0.0159)	(0.0189)
w_K	0.6314***	0.5814***	0.6326***	0.5835***	$w_K \cdot T_1$	0.0355***	-	0.0373***	-
	(0.0085)	(0.0197)	(0.0084)	(0.0195)		(0.0050)		(0.0052)	
N	0.3647***	0.3237***	0.4429***	0.4201***	$w_K \cdot T_2$	-	0.0079***	-	0.0075***
	(0.0766)	(0.1038)	(0.0575)	(0.0890)			(0.0022)		(0.0022)
T_1	-0.2659***	-	-0.2732***	-	$N \cdot T_1$	-0.2524**	-	-0.1728	-
	(0.0919)		(0.0905)			(0.1267)		(0.1131)	
T_2	-	-0.0161	-	-0.0187	$N \cdot T_2$	-	0.0038	-	-0.0014
		(0.0189)		(0.0184)			(0.0104)		(0.0098)
$Y \cdot Y$	-0.3086	-0.1626	-0.1998	-0.1070	$T_1 \cdot T_1$	-0.0160	-	-0.0210	-
	(0.2128)	(0.1566)	(0.2030)	(0.1385)		(0.0217)		(0.0199)	
$N \cdot N$	-0.4641**	-0.3494***	-0.1677	-0.1978*	$T_2 \cdot T_2$	-	0.0000	-	0.0005
	(0.1973)	(0.1310)	(0.1976)	(0.1186)			(0.0029)		(0.0028)
$w_L \cdot w_L$	0.1481***	0.1435***	0.1446***	0.1390***	D_{VS}	-0.1713**	-0.0973	-0.2031**	-0.1269
	(0.0125)	(0.0141)	(0.0121)	(0.0139)		(0.0859)	(0.1000)	(0.0900)	(0.0925)
$w_L \cdot w_K$	-0.1481***	-0.1435***	-0.1446***	-0.1390***	D_{FS}	-0.2201***	-0.2310***	-0.5866***	-0.4623***
	(0.0125)	(0.0141)	(0.0121)	(0.0139)		(0.0581)	(0.0678)	(0.01087)	(0.1188)
$w_K \cdot w_K$	0.1481***	0.1435***	0.1446***	0.1390***	$D_{VS} \cdot D_{FS}$	-	-	0.4552***	0.2962***
	(0.0125)	(0.0141)	(0.0121)	(0.0139)				(0.1310)	(0.1358)
$Y \cdot w_L$	0.1220***	0.0738***	0.1140***	0.0654***	Constant	8.6059***	8.6450***	8.5807***	8.6421***
	(0.0153)	(0.0175)	(0.0142)	(0.0163)		(0.0395)	(0.0664)	(0.0360)	(0.0624)
$Y \cdot w_K$	-0.1220***	-0.0738***	-0.1140***	-0.0654***	Log of likelihood	40.8750	16.4281	47.1361	15.1197
	(0.0153)	(0.0175)	(0.0142)	(0.0163)					
$Y \cdot N$	0.3456*	0.2400*	0.1496	0.1352	Pseudo R squared	0.9779	0.9735	0.9789	0.9733
	(0.1901)	(0.1338)	(0.1875)	(0.1179)					
$Y \cdot T_1$	0.0647	-	0.0324	-	Satisfied concavity condition	94.55%	96.73%	96.00%	96.73%
	(0.1012)		(0.1005)						

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

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 shows 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, in general, vertical separation tends to reduce the costs of railways, but this does not always hold. When we take time trend as a technology variable, the coefficient of the vertical separation dummy is not statistically significant at 10%, although the sign of the coefficient shows the negative. Therefore, vertical separation would be slightly better than vertical integration in terms of cost reduction. Last, the relationship between vertical separation and functional separation is complementary, because the coefficient of the cross-effect of these variables shows the positive sign.

In conclusion, our results regarding vertical separation support studies such as Shires et al., Kim and Kim (2001), Ivaldi and McCullough (2001), but the effect is still weak. In a future study, in which we hope to obtain more conclusive results, we must distinguish noise factors from structural factors (i.e. vertical separation).

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