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

by

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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 horizontal (i.e. passenger-freight service) separation. Using the total cost function of a railway organization, we evaluate whether or not vertical separation and/or horizontal separation can reduce costs. For this analysis, we select 30 railway organizations from 23 OECD countries over 14 years, from 1994 to 2007. Our findings show that because the horizontal separation dummy has a negative sign with statistical significance, horizontal 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.

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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. Possibilities include a functional accounting separation, an organizational separation of rail operations and infrastructure, or organizational separation involving a holding company. Massive horizontal (regional) 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, while direct competition, defined as "competitive tendering/competition for the market" in regional passenger transport and "open access/competition in the market" in freight transport and long distance passenger segments, is common in many European countries, regulators in Japan, rather than allowing direct market competition to occur, apply indirect competition schemes such as 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

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

an international comparison of performance measurements for railways by using stochastic distance functions.

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)); some suggesting the opposite (e.g. Cantos Sanchez (2001), Bitzan (2003), Jensen and Stelling (2007), Ivaldi and McCullough (2008) 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 horizontal (passenger-freight) 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 1994 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 horizontal (passenger-freight) 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 horizontal (passenger-freight) separation (i.e. passenger and freight service) dummy has a negative sign with statistical significance, horizontal (passenger-freight) 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

[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 for 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.

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) 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.

Pittman (2003) evaluates the desirability of certain forms of restructuring in the rail industry as well as in the electricity and telecommunication industries in transaction economies. There are three potential forms of restructuring: a vertically integrated monopoly, vertical separation, and vertical integration with competition. Pittman believes that one possible solution would be to create on-track competition between integrated and nonintegrated train operators, but that due to both economies of density and intermodal competition, it seems unlikely the benefits of on-track competition would be very great, except perhaps for the largest shippers. Pittman concludes that the vertically integrated monopoly form might be the best model for creating competition and attracting private investment.

Kurosaki (2008, 2009) evaluates vertical separation policies that have been effected in the world's rail industries, classifying 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. He summarizes appropriate forms of vertical separation policy according to differing market structures (e.g. with/without within-rail competition, or 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 conclusion remains 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 operations from infrastructure; 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. and Kim and Kim (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.

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. Although this study does not clearly uncover the effects of vertical separation policy alone, the authors find that regulatory reforms increase efficiency.

On the other hand, some studies such as Cantos Sánchez (2001), Bitzan (2003), Jensen and Stelling (2007), Ivaldi and McCullough (2008) 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 costs deriving from freight transport and infrastructure, while the effects are substitutable between costs deriving from passenger transport and infrastructure. Sanchez 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.

Ivaldi and McCullough (2001) apply the cost function to Class I U.S. railways and evaluate the effects of vertical separation. They find modest cost complementarities between general freight operations and infrastructure maintenance, but anti-complementarities between bulk and infrastructure and between intermodal and infrastructure maintenance. However, in more recent empirical results by Ivaldi and McCullough (2008) for U.S. freight railways for the period 1978-2001, they find both vertical and horizontal economies of scope. According to the authors, there would be a 20 to 40% loss of technical efficiency if railway freight operations were separated from infrastructure and an additional 70% loss of operational efficiency if on-rail operations were separated.

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/Integration in the Rail Industry

In this section, we explain the rationale for the vertical separation/integration policy in the rail industry. Our plausible conclusion is that the vertical separation/integration depends on the level of train density. These theoretical arguments on vertical separation/integration 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). Although we use the framework of transaction cost economics, we also explain the effects of vertical separation by looking at train density rather than asset specificity, and by assuming that the degree of asset specificity is related to 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 ΔPC as the difference between the production costs of internal governance ($PC_B(k)$) and the production costs of market governance ($PC_M(k)$). Williamson (1985) assumes that the production costs of market governance, $PC_M(k)$ are always lower than the production costs of internal governance, $PC_B(k)$. However, as the potential for scale economies across firms is reduced as the degree of asset specificity, k, increases, the production cost difference becomes smaller. After all, when the degree of asset specificity is too high, the production cost of market governance becomes larger than that of internal governance. Therefore, the production cost difference, ΔPC, declines as the degree of asset specificity increases.

Furthermore, governance costs, ΔGC, are defined as the difference between internal governance costs ($GC_B(k)$) and market governance costs ($GC_M(k)$). 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 total cost, ΔC, which is the sum of ΔPC and ΔGC, we can see the crossover point at k^{**}. To the left of point k^{**}, the market will be cost effective because ΔC (=ΔPC+ ΔGC) are positive. This means that vertical separation could be reasonable. On the other hand, to the right of point k^{**}, internal organization will be cost effective. Therefore, vertical integration could be reasonable.

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Figure 1

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Finally, we will explain how the degree of asset specificity of the rail infrastructure is related to the train density of a rail organization. This train density variable is considered a proxy variable for asset specificity. We do not mean to imply that focusing on train density necessarily leads to perfect decision making about whether to self-supply infrastructure maintenance and train control activities,[3] but we can use train density to understand more easily how vertical separation can affect the production and governance costs of train operation and track maintenance activities.

First, as for production costs, maintenance activity of rail infrastructure is divided into two components, one related to track length and the other to train density. As the maintenance

[3] U.S. freight railways often rely on independent firms to supply important traffic related maintenance activities such as tamping and grinding services. In Japan, some private railways use outside independent firms for track maintenance.

activities of the 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, with regard to the second component of maintenance activities (e.g. rail and electric wire inspection, signal system maintenance), the situation is different. When a railway's train density is very low and its schedule relatively simple, it would be more efficient for that railway to use maintenance offered on the market than to hold its own staff and machinery. However, when train density is very high and train operations much more complex, daily maintenance activities become more frequent and demanding. For high-density organizations, internal ownership of maintenance staff and machinery is preferable because it reduces the difference in production costs between internal governance and market use. The production cost difference decreases as train density increases.

A more important point is governance cost. Cost differences decrease more rapidly as train density increases. Governance costs by market governance include labor costs related to the coordination of divisions between two organizations, material costs such as those associated with documents related to maintenance activity plans, legal costs, and insurance costs. When train density is very low, market governance costs would be low because a simple maintenance activity contract would suffice. However, such costs would clearly be formidable under conditions of heavy train density because of the necessity to conduct safe train operations. Further increasing costs of high-density organizations is the need for adequate insurance and legal documentation in case of accidents. Also increasing governance costs would be the minutely detailed contracts necessary to prevent outside service-supplying companies from engaging in opportunistic behavior. 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 make decisions about priorities and management power hierarchy among different internal divisions. Therefore, as train density becomes larger, the degree of the asset specificity becomes larger, increasing the governance costs of high-density railway organizations.

Therefore, 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 is true because the degree of the asset specificity in the rail infrastructure is highly related to the train density of the rail organization. Although there is systematic empirical evidence, in particular, the experience of JR Freight relative to JR passenger companies after the privatization of JNR shows support for our argument (see for example, Mizutani and Nakamura (2004)). Moreover, in Japan, some small railway companies with low train density operating in rural areas have delegated maintenance of their privately held rail tracks to extra-mural, mostly public organizations.

Issues remain. The current vertical separation policy is based on a belief in competition policy. As the rail industry in general tends to have strong economies of scale, the government seeks to stimulate competition by separating rail infrastructure from operations. However, if the train industry's economies of scale are too strong, the result of vertical separation may be two monopolies instead of one, as Pittman (2003) and Thomas (2003) point out. In fact, Ivaldi and McCullough (2001) note that even if railways are separated into operations and infrastructure, the firms still experience operational returns to density and enjoy large market share, so that an open access regime would not necessarily lead to competitive outcomes.

While this may be true, our main interest is in whether vertical separation can reduce total railway costs. There is also the fact that the separation policy creates at least two separated companies (i.e. an operations and an infrastructure company), and that governance costs will be created to coordinate the two companies. The framework of Williamson's transaction cost economics clarifies separation/integration issues. We will investigate these issues from an empirical point of view.

4 Empirical Cost Model

Based on our arguments in the previous section, we investigate the vertical separation issues related to total cost. Our hypothesis is that cost reduction associated with vertical separation changes with the degree of train density. At low train density, vertical separation works to reduce costs, but as train density increases, vertical separation increases costs. To investigate this hypothesis, the most important characteristic of our cost model is specified such that the effect of vertical separation varies by train density.

In this study we employ a translog total cost function,[4] in which we include two kinds of institutional variables: a vertical separation dummy (D_{VS}) and a horizontal (passenger-freight) separation dummy (D_{HS}). 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 output conditions.

The translog cost model used here is shown as follows:

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

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

[4] 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.

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), FRC (number of freight cars per train))

w_j: input factor price [5] (j (or k) = L (labor), M (material), K (capital)),

N: total route length,

T: technology [6] (T: percentage of electrified length),

V: train density,

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

D_{HS}: horizontal (passenger-freight) separation dummy (horizontal 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.

In this study, we apply Shephard's Lemma to the cost function. This implicitly assumes that the rail company minimizes its costs. Most railway companies used in this study are public organizations, and there might be skepticism about whether such public organizations actually minimize costs, but if the cost-minimizing assumption is not held, there is the possibility that the

5 We estimate the cost function with three input factor prices (labor, material and capital). However, some train companies do not separate the information of material and capital expenditures. Therefore, we also estimate the case of the cost function with two input factor prices in order to check the estimation bias.

6 In this study, as for technology variable (T), we take the natural logarithm for percentage of electrified length (i.e. ln T). We also estimate the cost function by using time trend for T. However, the overall results by time trend are inferior to these by percentage of electrified length. Therefore, we chose this variable.

estimation results of the input share equations could be faulty. This approach allows us to check our results.

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 horizontal (passenger-freight) 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). In Japan, we count each JR company separately in order to avoid the estimation bias that would result from combining the JRs into one huge rail organization. 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 30 railway organizations from 23 OECD countries for the 14 years from 1994 to 2007, giving us 420 observations (i.e. 30 railways times 14 years).

We follow the definition of structural reform[7] 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 horizontal (passenger-freight) separation since 2001. KORAIL in Korea was neither vertically nor horizontally separated between 1994 and 2007, so that KORAIL is classified as an integrated system. Therefore, 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.

There are potential problems related to data. First, most railway companies belong to the public sector, with infrastructure possibly supported by the government. We know that each country's accounting system is different and that all infrastructure investment might not be recorded in the UIC data, but due to a lack of other data sources, we are compelled to use what might be incomplete information.

[7] 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 organizational separation. The standard data are well organized in the UIC data set. Therefore, we follow the definition of the UIC.

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Table 1

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5.2 Main Data Source and Definition of Variables

The main data source for this study is *International Railway Statistics*, issued annually by the UIC. In this source, however, some railway organizations' data are incomplete, and to fill in these information gaps, we have used data from several other sources. Table 2 shows our main data sources.

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Table 2

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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 cost structure. In the case of integrated rail systems, we can use the reported total cost itself. However, 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. In general, the separated rail company's infrastructure costs are included as service costs, which are paid as infrastructure fees.

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Table 3

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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 including tax expenditures. In rail operation companies with vertically separated systems, service costs for infrastructure service are included in the total costs. In the integrated rail system, infrastructure costs are included as depreciation and maintenance activity costs for infrastructure.

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 four kinds of variables of output characteristics: passenger revenue share (H_{PR}), load factor of passenger service (H_{LF}), passenger travel length (H_{PTL}) and number of freight cars per train (H_{FRC}). 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. Last, number of freight cars per train is obtained by dividing gross-ton-km of freight service by train-km of freight service. We assume that the weight of a freight car is 50 tons per vehicle. As we explained before, these output measures and output characteristics measures are specified as a hedonic function.

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Table 4

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There are three kinds of input factor prices. First, labor price (w_L) is obtained by dividing labor costs by the total number of employees. Material price (w_M) is obtained by dividing service and material expenditures by rolling stock. Capital costs are considered mostly as a portion of expenditures and financial expenditures. In this study, we allocated 75% of depreciation expenditures as capital cost for integrated rail organizations. Capital price (w_M) is defined as capital cost per route length. In order to check for estimation bias, we also estimate the cost function by two input factor prices models. In this case, material and capital costs are combined. Material and capital price ($w_{M\&K}$) 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 24% and the route length's weight is 76%. 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*). As for the technology (*T*) variable, there are two possibilities. First, there are two possible proxy variables that would show technological progress, such as the percentage of ATS (Automatic Train Stop) or ATC (Automatic Train Control), control systems for maintaining safe train operation, and electrified line length. In this study, we define technology as the percentage of electrified lines (*T*). 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. In this specification, all railway organizations can progress technologically in a linear fashion and can obtain technology on an equal basis. Although we estimate the cost function by using time trend, the results of the percentage of electrified lines are better. Therefore, we report the case of the percentage of electrified lines only.

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 horizontal (passenger-freight) separation dummy (D_{HS}) 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 seemingly 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 input factor prices model (i.e. two input factor (combined material and capital price) or three input factor (separated material and capital price) and whether 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 is 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, two-input-factor-price models show very high: about 90% of observations satisfy the concavity condition. However, three-input-factor-price models produce a moderate result: about 51% satisfy the concavity condition. Furthermore, the goodness-of-fit in the regressions is acceptably high for the input share equations so that the assumption of cost minimization can be accepted.

Among these cases, Case 2 is the best based on the log likelihood statistics. If we consider the three-input-factor-price model, Case 4 is better than Case 3. Therefore, we conclude that these cases are all acceptable but Case 2 is the best and Case-4 is an alternative for the three-input-factor-price model.

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Table 5

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We evaluate the effects of structural reform based on empirical results. First, because the coefficients of the horizontal (passenger-freight) 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 horizontal (passenger-freight) 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 ($\ln V \cdot D_{VS}$) shows the positive sign with a significance of 1%. This can hold in both Case 2 and Case 4, regardless of whether the two-input-factor-price or three-input-factor-price model is used. From these results, it can be seen that 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. and Kim and Kim (2001). 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).

What accounts for this result? As explained in the previous section, the framework of Williamson (1985) and Preston (2002) is helpful. 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 meetings for maintenance scheduling, maintaining safety under a busy train operation schedule, and so on. Therefore, any costs saved by vertical separation specialization would be canceled out by high coordination costs between two different organizations.

If we consider the component of vertical separation only (i.e. $(\delta_{VS1} + \delta_{VS2}\ln V)D_{VS}$ in Equation (1)), the effect on cost can be seen clearly. Figure 2 shows how cost reduction changes according to the degree of train density based on the estimation results of Case 2 and Case 4. The cost reduction rate due to vertical separation decreases as train density increases, when other conditions are fixed. If train density reaches about 2 times the sample mean, vertical separation begins to increase costs, as Figure 2 shows.

The train density level of each railway company in 2007 is shown in Table 6. Among our observations in 2007, railway organizations with higher train density are BLS (Switzerland), SBB CFF FFS (Switzerland), JR East, JR Central and JR West (Japan), KOREAIL (South Korea) and NS (Netherlands).[8] Except for NS, a vertical integration policy has been taken in these rail organizations.

These empirical results show that the European Commission's policy to apply the vertical separation policy to all organizations is not appropriate in terms of costs, but may be appropriate only for the railway organizations with less train density. For railway organizations with higher train density, vertical separation is more costly than integration.

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Figure 2

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Table 6

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[8] The railway organization with the higher train density is a railway organization whose value of train density (V) is 1.5 times the value of the sample mean.

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 and is being undertaken in Eastern Europe as well, vertical integration is still standard practice in East Asia, especially in Japan. The main purpose of this study has been to analyze structural separation policy, especially vertical (i.e. operation-infrastructure) separation and horizontal (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 horizontal (passenger-freight) separation could reduce costs. We selected 30 railway organizations from 23 OECD countries for the 14 years between 1994 and 2007.

Our main findings are as follows. First, because the coefficients of the horizontal (passenger-freight) separation dummy in any case of our analysis show the negative sign with a statistical significance of 1%, horizontal (passenger-freight) separation appears to lower a railway's costs. Because of diseconomies of scope between passenger service and freight service, horizontal (passenger-freight) 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 ($\ln V \cdot D_{VS}$) 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, 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 might be reasonable. However, a rail organization with higher train density should take a vertical integration policy. Therefore, the European Commission's policy applying universal vertical separation policy is not appropriate in terms of costs. Evidence suggests that vertical separation is more costly than the vertical integration for the railway organizations with higher train density.

[2011.5.13 1045]

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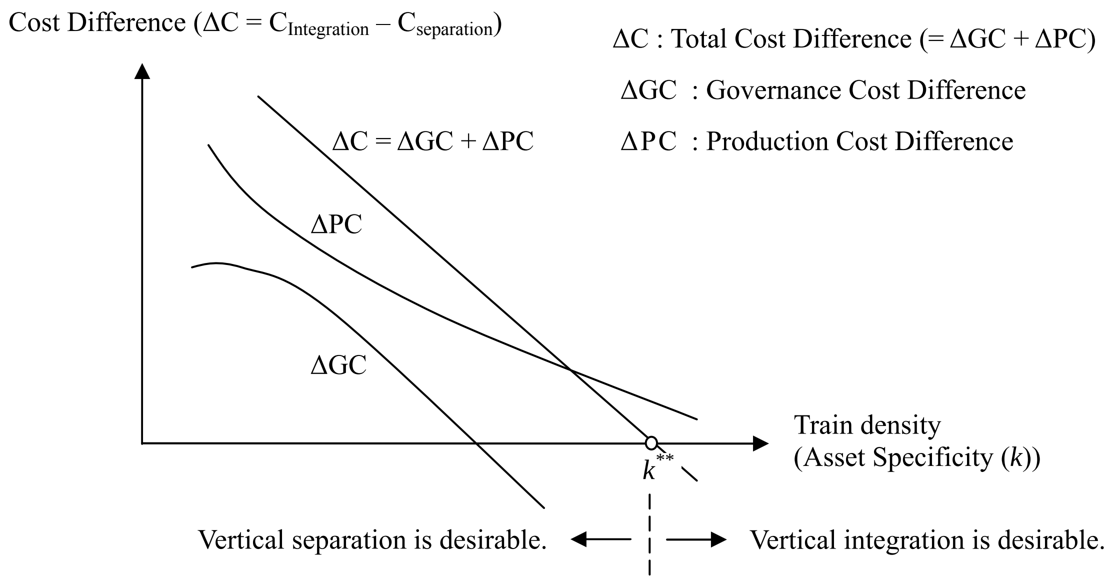

Figure 1 The Relationship between Cost Difference and Train Density:
Application for Concept of Production and Governance Costs and Asset Specificity

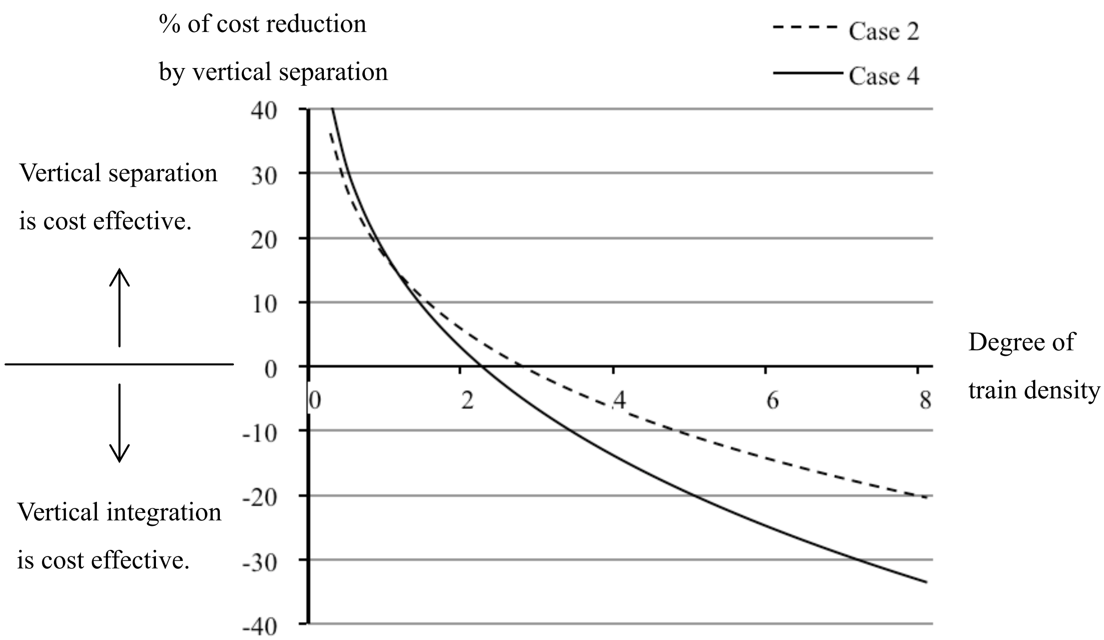

Figure 2 Cost Reduction Rate by The Degree of Train Density

Table 1 Railway Operators Included in Our Study

No.	Railway Operator	Country	Vertical Separation	Horizontal 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 Hokkaido	Japan	-	1987~
17	JR East	Japan	-	1987~
18	JR Central	Japan	-	1987~
19	JR West	Japan	-	1987~
20	JR Shikoku	Japan	-	1987~
21	JR Kyushu	Japan	-	1987~
22	KOREAIL (Korean National Railroad)	South Korea	-	-
23	CFL (Société Nationale des Chemins de fer Luxembourgeois)	Luxembourg	-	2007~
24	NS (N. V. Nederlandse Spoorwegen)	Netherlands	1998~	2000~
25	NSB (Norges Statsbaner AS)	Norway	1996~	2002~
26	PKP (Polskie Koleje Państwowe S. A.)	Poland	-	-
27	CP (Caminhos de Ferro Portugueses, E. P)	Portugal	1997~	-
28	SJ (Statens Jämvägar AB)	Sweden	1988~	2002~
29	ZSSK (Slovak Rail)	Slovakia	2002~	2005~
30	TCDD (Türkiye Cumhuriyeti Deviet Demiryollari Isletmesi)	Turkey	-	-

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

Table 3 Total Costs in Structurally Separated Organizations

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
Horizontal (passenger-freight) structure	Horizontal integration	Horizontally integrated company's total cost	D_{HS} =0
	Horizontal separation	Passenger company's total cost + Freight company's total cost	D_{HS} =1
(Note): (1) D_{VS} : vertical separation dummy, D_{HS} : horizontal separation dummy			

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	4,063	5,841	80	32,524
Q (Output)	Total train-km(1)	thousand km	137,887	178,241	1,648	936,714
w_L (Wage)	Labor costs per employee	euro	40,595	22,751	4,203	107,479
w_M (Material price)	Material costs(2) per rolling stock	euro	115,616	117,683	5,749	580,032
w_K (Capital price)	Capital costs(3) per route length	euro	180,651	321,904	292	2,322,617
$w_{M\&K}$ (Material and capital price)	Material and capital costs per composite material index(4)	euro	312,455	402,805	14,889	2,655,127
N (Total route length)	Total route km	km	7,172	8,607	220	41,718
T (Technology index)	Percentage of electrified line	%	52.45	26.93	0.01	100.00
H_{PRS} (Passenger revenue share)	Share of passenger revenue to total revenue(5)	-	0.7837	0.1152	0.4334	0.9875
H_{LF} (Load factor of passenger)	Passenger per train to capacity(6)	-	0.3730	0.1371	0.1264	0.9355
H_{PTL} (Passenger travel length)	Revenue passenger-km per passenger	km	52.03	30.09	14.64	190.21
H_{FRC} (Average freight car)	Number of freight car per train	car	17.30	4.31	5.37	30.74
V (Train density)(7)	Train-km per route length per day	Train/day	61.44	36.17	12.26	165.12
D_{VS} (Vertical separation)	Vertical separation dummy (Vertical separation = 1)	-	0.2405	0.4279	0.0000	1.0000
D_{FS} (Horizontal separation)	Horizontal separation dummy (Horizontal separation = 1)	-	0.2929	0.4556	0.0000	1.0000
S_L (Share of labor)	Share of labor input expenditure	-	0.3886	0.1233	0.1058	0.6850
S_M (Share of material)	Share of material expenditure	-	0.3739	0.1021	0.1326	0.7359
S_K (Share of capital)	Share of capital expenditure	-	0.2375	0.1438	0.0029	0.6743
$S_{M\&K}$ (Share of material & capital)	Share of material and capital expenditure	-	0.6114	0.1232	0.3148	0.8942

(Note):
(1) Total train-km (Q) = Passenger train-km + Freight train-km
(2) Material costs = Purchases of material and external services + 0.25 * Depreciation
(3) Capital costs = Tax + Other operating expenses + 0.75 * Depreciation + Financial expenses + Total costs of Infrastructure Manager
(4) Composite material index (M) = 0.24 * Rolling stock + 0.76* Total route lengths
(5) Passenger revenue share(H_{PRS}) = Passenger service turnover / Passenger and freight service turnover
(6) 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
(7) Train density (V) = Train-km/Route-km/365

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	0.6187***	0.5588***	0.7629***	0.6981***	$Y \cdot w_M$	-	-	0.0327***	0.0419***
	(0.0351)	(0.0388)	(0.0366)	(0.0400)				(0.0102)	(0.0107)
H_{PRS}	-1.3293***	-1.5508***	-1.2888***	-1.7110***	$Y \cdot w_K$	-	-	-0.1417***	-0.1550***
	(0.1603)	(0.1718)	(0.1472)	(0.1556)				(0.0144)	(0.0150)
H_{LF}	-0.2000***	-0.2816***	-0.0795	-0.1616***	$Y \cdot w_{M\&K}$	-0.1147***	-0.1137***	-	-
	(0.0640)	(0.0714)	(0.0528)	(0.0569)		(0.0100)	(0.0103)		
H_{PTL}	0.1220***	0.1352***	0.1675***	0.1787***	$Y \cdot N$	0.5094***	0.5304***	0.4468***	0.5033***
	(0.0441)	(0.0453)	(0.0417)	(0.0421)		(0.1112)	(0.1116)	(0.1029)	(0.1042)
H_{FRC}	0.2871***	0.2062**	0.3568***	0.2006**	$Y \cdot T$	0.1785***	0.1604***	0.1646***	0.1219***
	(0.0853)	(0.0886)	(0.0780)	(0.0789)		(0.0409)	(0.0421)	(0.0381)	(0.0398)
w_L	0.3312***	0.3305***	0.3085***	0.3061***	$w_L \cdot N$	-0.1288***	-0.1283***	-0.1133***	-0.1169***
	(0.0050)	(0.0051)	(0.0051)	(0.0052)		(0.0103)	(0.0106)	(0.0099)	(0.0102)
w_M	-	-	0.3805***	0.3789***	$w_L \cdot T$	-0.0293***	-0.0293***	-0.0296***	-0.0311***
			(0.0052)	(0.0053)		(0.0040)	(0.0041)	(0.0038)	(0.0039)
w_K	-	-	0.3111***	0.3150***	$w_M \cdot N$	-	-	-0.0202**	-0.0260**
			(0.0068)	(0.0068)				(0.0102)	(0.0106)
$w_{M\&K}$	0.6688***	0.6695***	-	-	$w_M \cdot T$	-	-	0.0004	-0.0029
	(0.0050)	(0.0051)						(0.0041)	(0.0042)
N	0.3638***	0.4148***	0.2331***	0.2779***	$w_K \cdot N$	-	-	0.1334***	0.1429***
	(0.0386)	(0.0416)	(0.0403)	(0.0430)				(0.0141)	(0.0146)
T	-0.3029***	-0.2721***	-0.3523***	-0.3123***	$w_K \cdot T$	-	-	0.0292***	0.0340***
	(0.0378)	(0.0390)	(0.0375)	(0.0381)				(0.0058)	(0.0059)
$Y \cdot Y$	-0.4208***	-0.4355***	-0.2508**	-0.2718***	$w_{M\&K} \cdot N$	0.1288***	0.1283***	-	-
	(0.1094)	(0.1102)	(0.1008)	(0.1045)		(0.0103)	(0.0106)		
$N \cdot N$	-0.6951***	-0.7296***	-0.7350***	-0.8390***	$w_{M\&K} \cdot T$	0.0293***	0.0293***	-	-
	(0.1282)	(0.1279)	(0.1229)	(0.1223)		(0.0040)	(0.0041)		
$w_L \cdot w_L$	0.1632***	0.1612***	0.1543***	0.1543***	$N \cdot T$	-0.4698***	-0.4513***	-0.5249***	-0.4866***
	(0.0073)	(0.0075)	(0.0062)	(0.0062)		(0.0543)	(0.0558)	(0.0515)	(0.0529)
$w_L \cdot w_M$	-	-	-0.0661***	-0.0651***	$T \cdot T$	-0.0317***	-0.0217**	-0.0238**	-0.0037
			(0.0047)	(0.0048)		(0.0104)	(0.0107)	(0.0100)	(0.0105)
$w_L \cdot w_K$	-	-	-0.0882***	-0.0892***	D_{VS}	-0.1946***	-0.1711***	-0.2005***	-0.1717***
			(0.0044)	(0.0045)		(0.0264)	(0.0279)	(0.0264)	(0.0273)
$w_L \cdot w_{M\&K}$	-0.1632***	-0.1612***	-	-	$V \cdot D_{VS}$	-	0.1713***	-	0.2218***
	(0.0073)	(0.0075)					(0.0449)		(0.0431)
$w_M \cdot w_M$	-	-	0.1060***	0.1078***	D_{HS}	-0.3117***	-0.3093***	-0.3831***	-0.3621***
			(0.0052)	(0.0052)		(0.0266)	(0.0258)	(0.0267)	(0.0252)
$w_M \cdot w_K$	-	-	-0.0399***	-0.0427***	Constant	8.7276***	8.7449***	8.7861***	8.8028***
			(0.0045)	(0.0046)		(0.0220)	(0.0215)	(0.0216)	(0.0207)
$w_K \cdot w_K$	-	-	0.1282***	0.1318***	Log of likelihood	63.6081	73.7701	21.2133	34.7842
			(0.0064)	(0.0065)					
$w_{M\&K} \cdot w_{M\&K}$	0.1632***	0.1612***	-	-	Pseudo R^2	0.9751	0.9762	0.9700	0.9717
	(0.0073)	(0.0075)							
$Y \cdot w_L$	0.1147***	0.1137***	0.1091***	0.1132***	Satisfied concavity condition	89.52%	90.48%	51.67%	51.19%
	(0.0100)	(0.0103)	(0.0099)	(0.0103)					

(Note):
(1) *** Significant at 1 percent, ** 5 percent, * 10 percent.
(2) Number of observations: 420
(3) R^2 of the Cost Share Function
Case 1 (Labor: 0.6001), Case 2 (Labor 0.5974),
Case 3 (Labor: 0.6363, Material: 0.6538), Case 4 (Labor: 0.6343, Material: 0.6478)

Table 6 Train Density Level in 2007

No.	Railway Operator	Country	Train Density	Ratio
1	ÖBB (Österreichische Bundesbahnen)	Austria	66.6	1.08
2	SNCB/NMBS (Société Nationale des Chemins de fer Belges)	Belgium	77.1	1.26
3	BLS (BLS AG)	Switzerland	132.2	2.15
4	SBB CFF FFS (Schweizerische Bundesbahnen)	Switzerland	142.7	2.32
5	CD (České Dráhy)	Czech Rep.	43.6	0.71
6	DB AG (Deutsche Bahn AG)	Germany	72.7	1.18
7	DSB (Danske Statsbaner)	Denmark	80.4	1.31
8	RENFE (Red Nacional de los Ferrocarriles Españoles)	Spain	36.4	0.59
9	VR (VR-Group Ltd)	Finland	24.4	0.40
10	SNCF (Société Nationale des Chemins de fer Français)	France	44.9	0.73
11	OSE (Hellenic Railway Organization)	Greece	21.4	0.35
12	GySEV/RÖEE (Györ-Sopron-Ebenfurti Vasút Részvénytarsasag)	Hungary	48.7	0.79
13	MAV (Magyar Államvasutak Rt.)	Hungary	37.0	0.60
14	CIE (Coras Iompair Éireann)	Ireland	26.9	0.44
15	FS (Ferrovie dello Stato SpA)	Italy	55.9	0.91
16	JR Hokkaido	Japan	46.0	0.75
17	JR East	Japan	93.3	1.52
18	JR Central	Japan	165.1	2.69
19	JR West	Japan	118.4	1.93
20	JR Shikoku	Japan	68.7	1.12
21	JR Kyushu	Japan	88.8	1.45
22	KOREAIL (Korean National Railroad)	South Korea	94.7	1.54
23	CFL (Société Nationale des Chemins de fer Luxembourgeois)	Luxembourg	72.0	1.17
24	NS (N. V. Nederlandse Spoorwegen)	Netherlands	116.6	1.90
25	NSB (Norges Statsbaner AS)	Norway	22.7	0.37
26	PKP (Polskie Koleje Państwowe S. A.)	Poland	27.2	0.44
27	CP (Caminhos de Ferro Portugueses, E. P)	Portugal	37.6	0.61
28	SJ (Statens Jämvägar AB)	Sweden	22.1	0.36
29	ZSSK (Slovak Rail)	Slovakia	35.1	0.57
30	TCDD (Türkiye Cumhuriyeti Deviet Demiryollari Isletmesi)	Turkey	12.6	0.20

(Note)
(1) "Train density" is defined as train-km per route length per day.
(2) "Ratio" means that each company's train density to the sample mean of train density.