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Kitamura, Tomohiro

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利用者のタイプが鉄道事業者の効率性に与える影響：距離関数アプローチ

Effect of Passengers' Types on Railroad Efficiency: Distance Function Approach

神戸大学大学院経済学研究科講師
北村　友宏
Lecturer, Graduate School of Economics, Kobe University
Tomohiro KITAMURA

ABSTRACT:

We examine the effect of the types of passengers on the efficiency of Japanese regional small and medium-sized passenger railroad companies by estimating the input distance function and inefficiency function. The empirical results are as follows. First, railroad companies that mainly transport passengers whose trip distance per operating distance is long are more technically efficient. Second, railroad companies that mainly transport commuters are more technically efficient than those that transport mainly non-commuters, such as tourists.

キーワード：鉄道、技術効率性、距離関数、確率的フロンティア、真の固定効果モデル
Keywords: Railroad, Technical Efficiency, Distance Function, Stochastic Frontier, True Fixed Effect Model

1. Introduction

Japanese regional small and medium-sized passenger railroad companies face operational difficulties due to the decreasing the number of passengers and high facility costs. As the birth rate in Japan continues to decline and the population ages, the population along the railroad routes has decreased. The decrease in passengers is compounded by greater levels of private car ownership. Continuing to operate inefficiently in this situation will make supplying transport services difficult in the future. Therefore, we need to discuss ways to improve their financial situation and long-term viability. Hence, we need to investigate the factors affecting the efficiency of railroad companies.

Efficiency or inefficiency can be measured by estimating, for example, a distance function. We explain the distance function later. Many previous studies have investigated the efficiency of railroads by estimating distance functions. For example, Lan and Lin (2006) conducted international comparisons among 39 railroad systems worldwide and revealed that a higher national income, higher percentage of electrified lines, and higher ratio of lines' length to the area of a country increase the efficiency of railroads in countries. Bougna and Crozet (2016) used data on European railroads to investigate the relationship between the railroad liberalization process and efficiency. They revealed that competition tendering for tracks improves the efficiency of railroads.

As for passenger railroad companies, the types of passengers to be transported may also affect the railroad company's efficiency. However, the efficiency of Japanese regional small and medium-sized passenger railroad companies or the relationship between the types of passengers and the efficiency of railroad companies has received little attention.

Therefore, we investigate the effect of the types of passengers on the efficiency of Japanese regional small and medium-sized passenger railroad companies by estimating a distance function for these companies.

We tested the following two hypotheses empirically. The first hypothesis is that railroad companies that transport mainly passengers with long trip distance per operating distance are more technically efficient than those that transport mainly passengers with short trip distance per operating distance. Here, the longer the distance per passenger boarding, the higher is the value of passenger kilometers (the output in this study). This may make transportation more efficient.

The second hypothesis is that railroad companies that transport mainly commuters are more technically efficient than those that transport mainly other types of passengers (e.g., tourists, shoppers, and outpatients). If there is stable demand for the transportation services of companies that transport mainly commuters, they may be more efficient (Nakanishi, 2008).

The number of commuters is assumed to be given for railroad companies because it depends on the number of offices and schools along their lines. On the other hand, railroad companies may change the number of non-commuters by the measures to increase tourists such as operating special trains for tourists. In Japan, more and more regional small and medium-sized passenger railroad companies have advanced in such measures. However, this study uses data from FY 1994 to FY 2013, the period that few railroad companies operated such the special tourist trains. Furthermore, the number of non-commuters depends on that of tourist sites along the railroad companies' lines and thus changing the number of non-commuters is difficult for railroad companies during that period. Therefore, this study assumes that the number of non-commuters is also given for railroad companies.

The empirical results suggest that railroad companies that transport mainly passengers with long trip distance per operating distance have higher technical efficiency (TE) than those that transport passengers with short trip distance per operating distance do. Furthermore, we find that railroad companies that transport mainly commuters are more technically efficient than are those that transport mainly non-commuters, such as tourists.

The remainder of this study is structured as follows. Section 2 describes the input distance function as an empirical model. Section 3 explains the data used in the empirical analysis. Then, Section 4 presents our estimation results using the input distance function, and Section 5 discusses the empirical results. Lastly, Section 6 concludes the study.

2. Model

This study estimates the railroad companies' input distance function and inefficiency function. An input distance function can be used when companies have more control over their inputs than they do over their outputs (Coelli et al., 2005). We assume that railroad companies produce one output (passenger kilometers) from three inputs (fixed assets, electricity consumption, and number of employees). Because this output is affected by demand factors such as population along their lines, companies find it difficult to control their output. Thus, using an input distance function may be supported in this study.

We express the input distance function as an empirical model. With reference to Atkinson et al. (2003), Bogart and Chaudhary (2013), and Deshpande and Weisskopf (2014), we assume that the railroad companies use three inputs to produce one output as a passenger transportation service, and that there is one output attribute. The Cobb-Douglas input distance function for company i at year t is expressed as follows:

$$\ln d_{it} = \beta_0 + \beta_Y \ln y_{it} + \beta_{OA} \ln OA_{it} + \beta_K \ln k_{it} + \beta_M \ln m_{it} + \beta_L \ln l_{it} + \beta_T t + v_{it}, \quad (1)$$

$$v_{it} \sim N(0, \sigma_v^2), \quad (2)$$

where d_{it} is the input distance, y_{it} is the output, OA_{it} is the output attribute, k_{it} is capital, m_{it} is an intermediate input, l_{it} is labor, and v_{it} is a two-sided disturbance term.

The input distance function must be non-decreasing, homogeneous of degree one, and concave in the inputs (Coelli et al., 2005; Kumbhakar et al., 2015). Because (1) is a Cobb–Douglas type function, it is non-decreasing and concave in inputs when β_K, β_M, and β_L are all non-negative. After the estimation, we check whether the estimated input distance function satisfies these two properties. For the homogeneity property, we impose the following linear restriction on the function before the estimation:

$$\beta_K + \beta_M + \beta_L = 1. \quad (3)$$

The input distance, the dependent variable of (1), is unobservable. Therefore, the distance function needs to be rearranged by moving $\ln d_{it}$ to the right-hand side and moving one of the observable variables in the right-hand side of (1) (e.g., $\ln k_{it}$ in this paper) to the left-hand side.

Substituting (3) into (1), rearranging (1), and assuming a probability distribution on unobservable $\ln d_{it}$, we obtain the following model to be estimated:

$$-\ln k_{it} = \beta_0 + \beta_Y \ln y_{it} + \beta_{OA} \ln OA_{it} + \beta_M \ln \tilde{m}_{it} + \beta_L \ln \tilde{l}_{it} + \beta_T t + v_{it} - u_{it}, \quad (4)$$

$$v_{it} \sim N(0, \sigma_v^2), \quad (5)$$

$$u_{it} \sim N^+(\alpha_{it}, \sigma_u^2), \quad (6)$$

$$u_{it} = \alpha_{it} + w_{it} = \alpha_0 + \alpha_{PRU} \ln PRU_{it} + \alpha_{NRP} \ln NRP_{it} + \alpha_T t + w_{it} \geq 0, \quad (7)$$

$$w_{it} \geq -\alpha_{it}, \quad (8)$$

where $\tilde{m}_{it} = m_{it} / k_{it}$, $\tilde{l}_{it} = l_{it} / k_{it}$, and $u_{it} = \ln d_{it}$. The logarithm of the input distance, u_{it}, is a one-sided random variable that takes non-negative values. This random variable is distributed according to a truncated normal distribution, with the truncation point at zero: the (before-truncation) mean is α_{it}, and the (before-truncation) variance is σ_u^2. Furthermore, u_{it} is affected by several factors: a passengers' route-use ratio (PRU_{it}), the non-rail-pass passenger ratio (NRP_{it}), and the time trend t. The α_{it} equation also has a disturbance term, w_{it}, which is distributed according to a truncated normal distribution, with the truncation point at $-\alpha_{it}$: the (before-truncation) mean is zero, and the (before-truncation) variance is σ_u^2, as is the variance of u_{it}.

The model composed of (4)–(8) shows the input distance of a railroad company as inefficient, and it is expressed as a stochastic frontier model. This is in line with the model proposed by Battese and Coelli (1995): u_{it} is assumed to be a function of some variables. See Coelli et al. (2005) for details of the Cobb–Douglas input distance function. We jointly estimate (4), called the input distance function, and (7), called the inefficiency function, based on the assumptions of the random variables' distribution, (5), (6), and (8), using the maximum likelihood method.

3. Data

This study adopts panel data on Japanese small and medium-sized passenger railroad companies that had routes in regional areas from FY 1994 to FY 2013; the companies include private and third-sector companies. In Japan, third-sector companies are those with both private and public stakeholders. The data are taken from the "Annual Rail Statistics," published by the Ministry of Land, Infrastructure, Transport and Tourism and the "Domestic Corporate Goods Price Index, All Commodities," published by Bank of Japan.

We omit some companies from the data to obtain better econometric results. For example, we omit companies that use diesel vehicles that run on oil, third-sector railroad companies that operate routes that run along high-speed lines and that were operated by private companies before the high-speed lines opened (called ***heiko zairaisen***), and other companies. Kitamura (2017) provides further details.

The final sample includes 45 companies. However, our data comprise an unbalanced panel: of the 45 companies, only 32 existed from FY 1994 to FY 2013.

We handle several missing and obviously incorrect values. Kitamura (2017) gives more details. Furthermore, we divide fixed assets by the domestic corporate goods price index, with a base year of 2010, deflating the values to 2010 prices.

The descriptive statistics and definitions of variables used in this study are shown in Tables 1 and 2, respectively.(1) We constructed these variables following Atkinson et al. (2003), Mizutani and Uranishi (2007), Mizutani et al. (2009), Bogart and Chaudhary (2013), and Deshpande and Weisskopf (2014). The passenger kilometers, average trip length, fixed asset, and electricity correspond to the output, its attribute, capital, and intermediate input from the previous section, respectively. As shown in Table 1, the passengers' route-use ratio ranges from 5% to 95%, and the non-rail-pass passenger ratio ranges from 23% to 93%. This suggests that there are large difference in Japanese regional small and medium-sized passenger railroad companies in terms of their transportation distance and main types of passengers.

As shown in Table 2, we use tangible fixed assets as the capital (fixed asset) variable. Several studies, such as Bogart and Chaudhary (2013), defined capital as the capital stock estimated using the perpetual inventory method. However, estimating capital stock requires equipment investment data, which are unavailable for Japanese railroad companies. Thus, we use fixed assets instead of capital stock.

4. Empirical Results

Table 3 presents the estimation results of the model composed of (4)–(8). First, we describe

Table 1 Descriptive Statistics for the Distance Function

Variable	Mean	Median	Minimum	Maximum	Standard deviation
Passenger kilometers (thousand people kilometers)	61,574.96	32,040.00	1,287.00	746,895.00	94,791.08
Average trip length (km/person)	8.58	6.72	3.31	56.51	7.13
Fixed asset (million yen)	5,838.65	2,110.57	12.49	84,789.57	12,868.16
Electricity (thousand kWh)	7,933.62	5,138.34	261.86	67,556.32	10,527.13
Labor (people)	132.94	91.00	13.00	948.00	138.02
Time trend (FY 1994=1)	10.55	11.00	1.00	20.00	5.76
Passengers' route-use ratio	0.38	0.39	0.05	0.95	0.18
Non-rail-pass passenger ratio	0.51	0.50	0.23	0.93	0.15

Note: The number of observations is 785.

Table 2 Definitions of Variables for the Distance Function

Variable	Definition
Passenger kilometers	Number of passengers multiplied by the running distance of train vehicles
Average trip length	Passenger kilometers divided by the number of passengers
Fixed asset	Sum of railroad exclusive and related tangible fixed assets
Electricity	Electricity consumption
Labor	Number of employees
Passengers' route-use ratio	Average trip length divided by operating kilometers
Non-rail-pass passenger ratio	Number of passengers who did not use a rail pass, divided by the total number of passengers

the estimation results for the parameters of the inefficiency function of Battese and Coelli (1995)'s model shown in the second column of Table 3. The coefficient of the log of the passengers' route-use ratio shows a negative sign and statistical significance at the 1% significance level. The coefficient of the log of the non-rail-pass passengers' ratio shows a positive sign and statistical significance at the 5% significance level. In contrast, the coefficient of the time trend of the inefficiency function does not show statistical significance at any conventional significance level.

Second, we check whether the estimated model satisfies the monotonic properties: non-decreasing in inputs and non-increasing in output. The coefficient of the log of passenger kilometers shows a negative sign and statistical significance at the 1% significance level for the Battese and Coelli (1995)'s model. Thus, this estimated input distance function is non-increasing in output. The coefficients of the logs of electricity and labor show positive signs and statistical significance at the 1% significance level. However, the coefficient of the log of capital, estimated by subtracting the coefficients of the logs of electricity and labor from one, shows negative signs for Battese and Coelli (1995)'s model (–0.038). Thus, the estimated model of Battese and Coelli (1995) does not satisfy the property of being non-decreasing in inputs.

Then, we tried controlling for railroad companies' time-invariant individual effects. Letting μ_i be the individual effect, adding it to (4), and suppressing the constant term, β_0, we obtain

$$-\ln k_{it} = \beta_Y \ln y_{it} + \beta_{OA} \ln OA_{it} + \beta_M \ln \tilde{m}_{it} + \beta_L \ln \tilde{l}_{it} + \beta_T t + \mu_i + v_{it} - u_{it}. \quad (9)$$

This is the true fixed effect (TFE) model proposed by Greene (2005a,b). This model separates companies' time-invariant individual effects from their time-variant inefficiency. Also, it allows the individual effects to be correlated with the independent variables of the function (Greene, 2005a). The method separating the individual effects from the inefficiency have been applied in some transportation literature such as Walter (2011) and Nieswand and Walter (2013). (2) For the TFE model, we simultaneously estimate the input distance frontier, including individual effects (9), and the inefficiency function (7) using the assumptions of the random variables' distributions, (5), (6), and (8). See Greene (2005a,b) and Kumbhakar et al. (2015) for details of the TFE model.

Note that the TFE model does not always yield unreasonably small or statistically insignificant coefficients for the inefficiency determinants (logs of the passengers' route-use ratio and non-rail-pass passenger ratio, as well as the time trend), even though the within-individual variation of the inefficiency determinants is small. This is because the inefficiency function, (7), does not include individual effects on the right-hand side.

The estimations of the TFE model yield results that are consistent with economic theory and that are robust for the signs of the coefficients of the inefficiency determinants. The results of the TFE model are presented in the last column of Table 3. The coefficient of the log of capital in the TFE model has a positive sign (0.009), although it is still low. Thus, the estimated TFE model satisfies the properties of being non-decreasing in inputs and non-increasing in output. With regard to coefficients of the inefficiency function, the coefficient of the log of passengers' route-use ratio shows a negative sign and statistical significance at the 1% significance level. This is essentially the same result as that of the model without individual effects (Battese–Coelli's model). The coefficient of the log of non-rail-pass passengers' ratio shows a positive sign and statistical significance at the 1% significance level: the same sign as that in Battese–Coelli's model, and stronger statistical significance. Furthermore, the absolute values of both coefficients from the TFE model are larger than those from Battese–Coelli's model. Moreover, the Akaike and Bayesian information criteria of the TFE model are smaller than those of Battese and Coelli (1995)'s model. Hence, incorporating railroad companies' time-invariant individual effects and separating them from time-variant inefficiency has improved the results in terms of their consistency with the properties of the input distance function and the likelihood of the parameters.

Based on these results, we accept the TFE model shown in the last column of Table 3. This is because the model satisfies the monotonicity conditions, and its information criteria are smaller than those of Battese–Coelli's model. Thus, we focus on this model below.

5. Discussion

Here, we discuss the factors affecting the TE of railroad companies. With regard to the estimation results of the accepted TFE model, the passengers' route-use ratio is negatively and significantly correlated with inefficiency. This suggests that railroad companies that transport mainly passengers with long trip distance per operating distance are more technically efficient than are those that transport mainly passengers with short trip distance per operating distance. This may be because a longer distance per boarding means the value of passenger kilometers (the output) becomes higher. Thus, the first hypothesis described in Section 1 is supported.

Furthermore, the non-rail-pass passenger ratio is positively and significantly correlated with

Table 3　Estimation Results of the Distance Function

	Battese and Coelli (1995)'s model	True fixed effect model
Parameter of the input distance frontier:		
Log of passenger kilometers	−0.639***	−0.475***
	(0.011)	(0.017)
Log of average trip length	−0.017	0.105
	(0.025)	(0.077)
Log of electricity	0.582***	0.452***
	(0.030)	(0.020)
Log of labor	0.456***	0.539***
	(0.028)	(0.020)
Time trend	−0.006	−0.001**
	(0.005)	(0.001)
Constant term	−3.163***	—
	(0.316)	—
Company-level individual effects	No	Yes
Parameter of the inefficiency function:		
Log of passengers' route-use ratio	−0.366***	−1.263***
	(0.026)	(0.447)
Log of non-rail-pass passenger ratio	0.059**	3.296***
	(0.026)	(1.124)
Time trend	0.000	0.015
	(0.005)	(0.016)
Constant term	0.212**	−1.461
	(0.094)	(0.890)
Parameter of the inefficiency and disturbance terms:		
Standard deviation of the inefficiency term	0.199***	0.345***
	(0.010)	(0.075)
Standard deviation of the disturbance term	0.039	0.049***
	(0.052)	(0.003)
Ratio of standard deviation of the inefficiency term to that of the disturbance term	5.095***	7.001***
	(0.063)	(0.076)
Likelihood and information criteria:		
Log-likelihood	165.878	913.802
Akaike's information criterion	−307.756	−1715.605
Bayesian information criterion	−251.768	−1454.326

Notes: *** and ** indicate statistical significance at the 1% and 5% levels, respectively. Standard errors based on the outer product of the gradient vectors are shown in parentheses. The true fixed effect model includes each company's dummy variables as independent variables of the input distance function (the constant term is suppressed). The number of observations is 785.

inefficiency. This indicates that railroad companies that transport commuters are more efficient than those that transport other types of passengers. This may be because railroad companies with a high ratio of rail-pass passengers transport a stable number of passengers every year. This result is in line with those of Yamashita (2003) and Nakanishi (2008).(3) Hence, the second hypothesis is also supported.

As a related point, railroad companies that transport mainly non-commuters, such as tourists, may be less efficient because they may transport a variable number of passengers every year. However, there may be another reason why these railroad companies operate inefficiently. That is, they may use too much of their fixed or variable inputs to supply their transport services.

One possible solutions to improve less efficient transportation is to attempt to increase tourists by operating special trains for tourists. As mentioned in Section 1, more and more Japanese regional small and medium-sized passenger railroad companies have advanced in operating the special tourist trains. Most of these are trains with retro design interior, selling goods, and meal services. For example, Fuji Kyuko Company Limited has operated the special limited express train, named Fujisan View Express, since FY 2016.

However, this study adopted data from FY 1994 to FY 2013, the period that few railroad companies operated such the special tourist trains. According to the data used in this study, the non-rail-pass passenger ratio did not change significantly for almost all railroad companies during the 20-year period. Thus, we could not find the effect of operating the special tourist trains on technical efficiency. This is also one of the reasons for obtaining the results that railroad companies that transport mainly non-commuters may be less efficient. In the future, we may obtain different results if the data including railroad companies that operates the special tourist trains and period that many railroad companies operates such special trains becomes available and we analyze by using that data.

6. Conclusion

This study econometrically tested two hypotheses using panel data of Japanese regional small and medium-sized passenger railroad companies. The first hypothesis is that railroad companies that transport mainly passengers with long trip distance per operating distance are more technically efficient than are those that transport mainly passengers with short trip distance per operating distance. The second hypothesis is that railroad companies that transport mainly commuters are more technically efficient than are those that transport mainly non-commuters, such as tourists.

To conduct these empirical analysis, we estimated the input distance function and inefficiency function using panel data.

The empirical results support both hypotheses. We obtained these results because the value of passenger kilometers (output) increases with the distance traveled using the transport service per boarding. In addition, railroad companies with high ratio of rail-pass passengers transport a stable number of passengers every year.

The empirical analysis in this study has several limitations. First, we estimated a Cobb–Douglas type function that imposes a strong assumption (i.e., constant substitution elasticity). When we tried to estimate a translog input distance function to relax this assumption, the estimated function did not satisfy concavity. Thus, future work should identify why the translog function yields poor estimates. Obtaining estimates that are consistent with economic theory by estimating a more flexible form of function (with weaker assumptions) would contribute to a more precise analysis. Second, we omitted certain companies, such as those that use diesel vehicles, among others, from the sample. Therefore, the results may not be generalizable for Japanese regional small and medium-sized passenger railroad companies. Finally, the coefficients of capital in the input distance functions were calculated as being quite small (negative for the estimation without individual effects and 0.009 for the estimation with individual effects). One reason for this issue might be that we use fixed assets instead of capital stock as the capital variable. However, as mentioned in Section 3, constructing a capital stock variable is difficult owing to lack of data. Because of these limitations, we need to carefully interpret our findings. Nevertheless, this study contributes to identifying the factors that represent passengers' types and affect the TE of Japanese regional small and medium-sized railroad companies.

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Notes

(1) For definitions in Table 2, the passengers' route-use ratio is affected by the number of routes the company owns: the values of this variable are necessarily small for companies that have many short-distance routes. One way to handle this is to multiply the passengers' route-use ratio by the company's number of routes. However, when we estimated the models using this definition, some parameters did not converge.

(2) Walter (2011) applied the true *random* effect (TRE) model to German local public buses and railroads, and Nieswand and Walter (2013) applied it to German local public buses. The TRE model assumes that the time-invariant individual effects are random and uncorrelated with any independent variables of the function, and it was also proposed by Greene (2005a,b).

(3) Yamashita (2003) and Nakanishi (2008) investigated the efficiency of public buses in Japan.

References

Atkinson, Scott E., Rolf Fare, and Daniel Primont (2003) 'Stochastic estimation of firm inefficiency using distance functions.' *Southern Economic Journal* 69(3), 596–611

Battese, George E., and Timothy J. Coelli (1995) 'A model for technical inefficiency effects in a stochastic frontier production function for panel data.' *Empirical Economics* 20(2), 325–332

Bogart, Dan, and Latika Chaudhary (2013) 'Engines of growth: The productivity advance of Indian railways, 1874-1912.' *The Journal of Economic History* 73(2), 339–370

Bougna, Emmanuel, and Yves Crozet (2016) 'Towards a liberalised European rail transport: Analysing and modelling the impact of competition on productive efficiency.' *Research in Transportation Economics* 59, 358–367

Coelli, Timothy J., D. S. Prasada Rao, Christopher J. O'Donnell, and George E. Battese (2005) *An Introduction to Efficiency and Productivity Analysis*, second ed. (New York, NY, USA: Springer)

Deshpande, Ashwini, and Thomas E. Weisskopf (2014) 'Does affirmative action reduce productivity? A case study of the Indian Railways.' *World Development* 64, 169–180

Greene, William (2005a) 'Fixed and random effects in stochastic frontier models.' *Journal of Productivity Analysis* 23(1), 7–32

__(2005b) 'Reconsidering heterogeneity in panel data estimators of the stochastic frontier model.' *Journal of Econometrics* 126(2), 269–303

Kitamura, Tomohiro (2017) 'Empirical studies on efficiency, economies of density, and productivity of railroad companies in Japan.' Ph.D. thesis, Graduate School of Economics, Kobe University, Kobe, Japan. (Publication is postponed.)

Kumbhakar, Subal C., Hung-Jen Wang, and Alan P. Horncastle (2015) *A Practitioner's Guide to Stochastic Frontier Analysis Using Stata* (New York, NY, USA: Cambridge University Press)

Lan, Lawrence W., and Erwin T. J. Lin (2006) 'Performance measurement for railway transport: Stochastic distance functions with inefficiency and ineffectiveness effects.' *Journal of Transport Economics and Policy* 40(3), 383–408

Mizutani, Fumitoshi, and Shuji Uranishi (2007) 'The effects of privatization on productivity and capital adjustment.' *International Journal of Transport Economics* 34(2), 197–224

Mizutani, Fumitoshi, Hideo Kozumi, and Noriaki Matsushima (2009) 'Does yardstick regulation really work? Empirical evidence from Japan's rail industry.' *Journal of Regulatory Economics* 36(3), 308–323

Nakanishi, Makoto (2008) 'Evaluation of efficiency in a local public transport service with multiproducts: Data Envelopment Analysis and Corrected Ordinary Least Squares (Fukusu seisanbutsu wo fukumu chiho koei kotsu jigyo no hyoka: DEA to COLS ni yoru koritsusei no sokutei).' *Saga University Economic Review (Saga Daigaku Keizai Ronshu)* 41(2), 13–59. (in Japanese)

Nieswand, Maria, and Matthias Walter (2013) 'Cost efficiency and subsidization in German local public bus transit.' Discussion Paper 9346, Centre for Economic Policy Research, London, UK

Walter, Matthias (2011) 'Some determinants of cost efficiency in German public transport.' *Journal of Transport Economics and Policy* 45(1), 1–20

Yamashita, Koji (2003) 'Inefficiency of local public services and compensation money for their revenue source: Looking at soft budget constraints of local public firms (Chiho kokyo service no hikoritsusei to zaigen hoten: Chiho koei kigyo ni taisuru soft na yosan seiyaku mondai no kensho).' *JCER Economic Journal (Nihon Keizai Kenkyu)* 47, 118–133. (in Japanese)