Relationship between Efficiency of Bus Transit System and Subsidy, Using a Stochastic Cost Frontier Model

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Abstract: Over the last decades, the regional government of Kyung-gi Providence of Korea has devoted a large amount of effort and subsidy to projects aimed at increases some of public transport cost efficiency. However, the overall results indicated that most of these efforts has revealed as very ineffective. This research is concerned with evaluating the cost efficiencies of the bus transport industry in the Korea using stochastic cost frontier model. These Bus companies are ranked based on their technical efficiency for the period 2010–2014. The key findings are that the average cost efficiency of Bus Transit system are 0.828 without time trends and 0.869 with time trend respectively. Also, the amounts of government subsidies to the bus companies negatively affect the cost efficiency.

Keywords: Bus, Subsidy, Technical Efficiency, Stochastic Frontier, Korea

1. INTRODUCTION

It is very important factors to improve reliable public transportation systems in major cities in Korea in order to compete to other major cities in worldwide. However, it is necessary to require huge financial subsidies are needed for maintain the systems. Most of private transport firms, especially for small and medium size bus enterprises, are unable to keep the balance of budgets all by themselves. In Korea, the central and local governments have been giving direct subsidy to local bus companies to cover the large budget deficits after major bus reform in 2003.

Generally, the bus operating system can be classified into pure public, private and semi-public systems depending on ownership and operation of the bus system in Korea. Private bus systems are market-based, where private bus operators supply fleets of buses and design bus routes and etc. Until the 1990s, the representative bus operating of Korea was the private operating system.

The major advantages of pure private bus operating systems are i) No financial support to the systems, ii) Cross-subsidy between profit and non-profit lines and iii) Great flexibilities based on passenger demand and efficient operating systems because of intense competition. Also, the disadvantages are i) Non-profit lines are very vulnerable to continuous operations and severe equity issues if there are no alternative public transportation systems ii) difficult to enforce integrated public transportation among other modes such as regional rail and subway because private operators are interested in the profitability of systems.

As continuous economic growth along with rapid increase in automobile ownership and urban population required huge investments on regional commuter rails and subway resulted continue declines of bus passengers which are serious financial problems to the private bus operators. As a result, private bus operators could not provide adequate bus services to passengers and demand. Consequently, the private bus operating systems deteriorated and the Korea bus operating systems require major changes.

The major bus transit system in the Korea has changed substantially over the last few decades. The local bus transit service provider is a mixed system where five largest major metropolitan areas including Seoul, and many small privately owned firms provide services in different areas under the strict supervision of a regulator

The public transport fare system was one-dimensional in nature, so it could not adequately respond to various changes in travel demand, thereby causing inequity in fare pricing among public transport users and lowering the efficiency of the overall transport system. To tackle this problem and subsequently improve the city's public transport competitiveness and cope actively with changes in travel demand, the Seoul Metropolitan Government has restructured the fare system.

The major bus operation reform project was aimed at fundamentally improving the traffic congestion problem by increasing bus and subway ridership and discouraging the use of private vehicles through revolutionary restructuring of the bus system. The Seoul municipal government pushed for the restructuring of the bus operation system, service, and the industrial structure. Specifically, it carried out the redesigning of bus routes, fare system reform, operation system renovation through the introduction of the semi-public operation scheme, the smart card and bus management system via the use of Information technology, construction of public transit centers, and the implementation of the exclusive bus lane (XBL) system.

The routes were restructured into trunk and feeder lines, which led to increases in the number of lines, total length of the routes, and the number of buses sanctioned for operation. However, the actual number of buses in operation and the total distance traveled by the buses went down, indicating that the bus companies cut down low-efficiency or overlapping lines. The number of bus users during the one-year period immediately after the reform rose 9% from1,919 million to 1,760 million for previous one-year span, according to the official statistics compiled by the Seoul city government. Subway users also increased 0.2% in number from 2,272 million to 2,277 million (Korea Transport Institute, November 2005).

Comparison of the pre- and post-reform annual transport revenues in the bus sector showed a 2.6% expansion from 1,089.4 billion won to 1,118.3 billion won. The survey conducted by the Seoul Development Institute also indicated that the bus sector registered an increase in transport revenue by over 10%. (Seoul Development Institute, March 2005). Bus operation subsidies given by the Seoul Metropolitan Government went up, but those for subways dwindled. Compared to the pre-reform period, the number of traffic accidents increased slightly and of that accident-related deaths rose sharply. This phenomenon is considered to be related with the exclusive median bus lane system, which led the increase of bus travel speeds and jaywalking.

The semi-public operation system requires subsidy payment under the following two objectives. First, it aimed to reinforce the public utility nature of route operation by exercising the right to adjust the bus routes. Second, it aimed to enhance the efficiency of bus company operation through the route tendering system. As mentioned in the previous section, route adjustments are being made fairly quickly, without being affected by the conflicting interests of bus firms, while the municipal government is exercising the right to adjustments. So, the first objective is considered to have been achieved. To judge whether the second objective has been accomplished, it is necessary to conduct productivity-related evaluations.

Thus, the aim of this research is twofold: first, to analyze the technical efficiency of bus companies of Korea, and take into account the nature of the unobserved heterogeneity in the bus transportations; second, to account for observed heterogeneity in the cost frontier model and its relationship with the estimated technical efficiency scores.

In this paper, the stochastic cost frontier model is used as the instrument of estimation. The bus companies are ranked according to their total productivity for the period 2012–2016 according to their observed and non-observed heterogeneity and the bus companies are disentangled into segments by the cost frontier model. This segmentation of the cost frontier is a specific characteristic of the latent frontier model. The paper is organized as follows: the second section surveys the literature on the topic; the third section presents the methodological framework; the fourth section presents the data and results; and last section consists of the findings and conclusions.

2. PREVIOUS RESEARCH

In public transport literature, many studies on efficiency estimated stochastic production frontiers by assuming homogeneous technology for bus transit systems; for example, Sakano and Obeng (1995), Sakano et al. (1997), and Obeng et al. (1994, 2011) studied inefficiency in bus transit systems using cross-sectional data and examined how federal government subsidies contributed to allocative and technical inefficiencies. They found a large variation in technical inefficiency among bus transit systems based on various operating characteristics such as size of company, network length, age of fleet, and etc. Farsi et al. (2006) using transportation data estimated and compared various stochastic frontier models without accounting for the panel nature of their data and did not use the one-step approach. More recently, a number of transportation-related studies have applied the one-step estimation method. Jha and Singh (2001) used it to study a longitudinal panel of nine bus operators in India. Dalen and Gomez-Lobo (2003) applied it to a panel data of Norwegian bus systems, and Picacenza (2006) used it to study a longitudinal panel data of 44 companies.

Some transportation economics have done many studies on how to evaluate the connection between the subsidy policy and the cost efficiency quantitatively. Piesse and Thirtle (2000) studied the effect of subsidy policy on cost efficiency using stochastic cost frontier model and efficiency and amount of subsidy. Also, Sakano, Obeng and Azam (1997) analyzed subsidy policy by stochastic cost model, and they selected the ratio of subsidy to the cost as the dependent variable of the technical inefficiency effect. And Yuji (2004) studies the ratio of subsidy to the revenue as the dependent variable.

Recent study results by Obeng at al. (2016) indicated that the average technical efficiency of transit systems in the USA is about 0.68. While operating and capital subsidies increase output due to their large lump-sum effects and increase overall output efficiency, input regulations decrease output due to their large lump-sum effects.

The current bus subsidy policy of major providence of Korea is operator subsidies which is relatively easy to manager for administers and very politically attractive, however, the efficiency and effectiveness are very questionable for the society. Usually, the amount of subsidies was calculated the difference between fare revenue and operating cost. Bus operators can have preserve incentive not to minimize operating costs. Problems are very severe when labor contract are strong for some companies.

3. MODEL

We apply the stochastic cost frontier model to examine the effects of the economic inefficiencies of bus companies. Although this model estimates production and cost functions, the stochastic frontier model allows for individual companies to produce less than they might due to inefficiencies. Usually, the cost share equations derived from Shephard's lemma are estimated by seemingly unrelated regression (SUR) methods to obtain more efficient parameter estimates because there are many unknown parameters to be estimated. However, the share equations approach has analytical problem. It cannot examine the causal effect of factors on inefficiencies by using the basic cost frontier model. When designing effective systems and policy reforms, it is vital to examine these causalities.

In production economics, the production process is usually analyzed by using a dual approach (i.e. cost functions or profit functions). The assumption underlying cost functions is that the units have cost behavior. A cost function represents the minimum cost required to achieve a certain output level given the input prices. Thus, a cost function is specified as:

$$C = C^*(w, y, t) \tag{1}$$

where C is cost, w is input prices, y is output and t represents the state of the technology usually time trends. Based on the cost function definition, the stochastic frontier analysis (Aigner et al., 1977; Meeusen and van den Broeck, 1977) offers an analytical framework to estimate cost function such as:

$$\mathrm{C} = C^*(w, y, t)\exp(\varepsilon)\,;\ \varepsilon = \vartheta + \mu;\ \mu \geq 0 \tag{2}$$

where ε is the random error term, which is composed of two components. The symmetric component, ϑ, captures statistical noise and is assumed to follow a distribution centered at zero, while μ is a non-negative term that reflects inefficiency and is assumed to follow a one-sided distribution (i.e. truncated normal, half-normal, exponential). Since the estimation procedure of equation (2) yields the residual ε_{it}, rather than the inefficiency term μ_{it}, the latter must be calculated indirectly, using the Jondrow et. al. (1982) formula.

$$\ln C_{it} = \alpha_o + \alpha_y lny_{it} + \sum_{j=1}^{J} \alpha_j lnw_{it} + \vartheta_{it} + \mu_{it} \tag{3}$$

where C_{it} is the cost of the economic entity i in year t; y_{it} is the output; w_{it} is the factor price; ϑ_{it} is an error term, uncorrelated with the regressors, and distributed as iid N(0, σ_ϑ^2); and μ_{it} is a non-negative inefficiency term, distributed as iid $N^+(\mu_{it}, \sigma_\vartheta^2)$ and defined as;

$$\mu_{it} = \sum_{k=1}^{K} \beta_k z_{itk} \tag{4}$$

where z_{it} is the vector of the covariates that affect the inefficiency such as subsidy of bus transit.

In this study, we estimate the cost frontier model based on Equations (3) and (4) to examine the causal effects of several factors on cost inefficiency.

4. DATA AND ESTIMATION RESULTS

This paper uses a data sample of bus transit systems from the Data Analysis, Retrieval and Transfer System, Financial Services Commission, Korea, which consists of 97 observations for an unbalanced panel of 35 bus transit systems for the period 2011 to 2015. Table 1 presents summary statistics for the bus transit systems used in this study.

The data includes total revenues, total operating costs, annual operating vehicle km of service used as the output measures, total annual work hours by labor, liters of fuel used as a proxy for all non-labor and non-capital inputs, total operating subsidies and total annual revenues. Labor price is total labor compensation including benefits divided by hours worked. Fuel and maintenance price is the total expenditure on fuel and maintenance cost divided by bus operating fleet. Capital price is the total annual capital cost dividend by bus fleet. The total cost is the dependent variable and includes labor, fuel and maintenance, capital cost and other indirect costs. The output variable is the total annual revenues as a supply-related measure. Usually, vehicles-km and seat-km would be another good measure, but we do not have data for private companies. Even demand-related indicators as number of passengers or passenger-km could be more relevant and as they do not ignore fully empty buses, we choose supply related as total annual revenues because they vary with inputs. The three inputs and output are expected to have a positive sign.

Table1. Descriptive statistics of the data

Variable	Description	Mean	Standard deviation	Minimum	Maximum
Ln(Cost)	Total Cost	21.8857	.6835103	20.23998	23.69534
Ln(W)	Price of workers	15.21339	.5129575	14.05594	16.8297
Ln(C)	Price of capital	6.449087	1.175864	2.22874	8.120576
Ln(F)	Price of fuel	13.14225	1.324085	9.104438	14.9386
Ln(O)	Price of others	9.171383	.6784641	7.872057	10.46578

Ln(S)	Total subsidy	19.71941	3.832993	0	22.86319
Ln(R)	Revenues	24.50214	.744979	22.9445	26.27428

Source: Data Analysis, Retrieval and Transfer System, Financial Services Commission, Korea

Estimation results for the stochastic cost frontier model are presented in Table 2. Using the total annual revenues as the output variable, most of the output and input variables are statistically significant except for the capital variable which is unexpected negative, however, statistically insignificant

Table2. Stochastic Cost Frontier Model Results

Variable	Coefficient	Std. Dev.
Constant	-3.83139***	1.00123
Ln(W)	.21115***	.03781
Ln(F)	.05993***	.01739
Ln(C)	-.03525*	.01913
Ln(R)	.88750***	.03164
$\lambda=(\sigma_u/\sigma_v)$	1.70493***	.41593
σ	.28823***	.00247
LL(β)	15.20690	

Note: ***, **, * ==> Significance at 1%, 5%, 10% level.

The estimation results of the average efficiency levels for each year are shown in Table 3. This result indicates that there is room for improvement. Approximately 82.8% of cost efficiency is found during the study periods. The highest efficiency is 84.4% in 2012 and the lowest year is 80.5 in 2011. These results indicate that the bus transit system in Kyunggi Providence of Korea can be improved about 17.2%.

Table3. Cost Efficiency Level for Each Year

Subsample	Mean	Std. Dev.
2010	.810484	.090262
2011	.804853	.092359
2012	.843984	.072441
2013	.841386	.067730
2014	.841116	.082094
Full Sample	.827909	.081828

This study indicates that there is a significant negative correlation between cost inefficiency and amount of total subsidy to bus transit firms (Table 4, t-ratio = -2.40). This means that the increased subsidy to bus operating firms increases cost inefficiency. Therefore, bus operating firms have intentionally increased cost inefficiency in order to receive more operating subsidies. The results of our study support the suggestion of Hiroki Sakai and Kenichi Shoji (2010), who found that the governmental subsidies to this sector negatively affect the cost structure of Japan.

Table4. Determinant of the cost inefficiency, OLS estimator[1].

Variable	Coefficient	Std. Dev.	t-ratio
Constant	.92840***	.04272	21.73
Ln(Subsidy)	-.00510**	.00213	-2.40

Note: 1. Dependent variables; SFA efficiency, ***, **==> Significance at 1%, 5% level.

5. CONCLUSIONS

In order to analyze the cost efficiency of bus companies of Korea, while taking into account the nature of the unobserved heterogeneity in the bus transit industry, we estimated a stochastic cost frontier model to shed light on the efficiency related variables of the local bus transit system.

The main results can be summarized as follows. First, the cost efficiency scores reported in this study, with an average of 0.83 during the study periods, which considered relatively low compare to other studies and raise questions about possible policy methods to increase the cost efficiency of bus transit. Overall the cost efficiency scores were relatively similar stable across the study periods from 0.84 in year of 2012 and 0.80 in year of 2011. These results indicated that the bus transit system in Kyunggi Providence of Korea can be improved by 17.2%. However, we cannot confirm if the poor cost efficiency performance of bus transit system in Kyunggi Providence affects ownership of bus transit system.

Secondly, this study found that there is a significant negative correlation between cost inefficiency and amount of total subsidies to bus transit firms. This means that the increased subsidy to bus operating firms increases cost inefficiency. Therefore, bus operating firms intentionally increased cost inefficiency in order to receive more operating subsidies.

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