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Relationship between Efficiency of Bus Transit Operations and Accidents, using a Stochastic Cost Frontier Model

Kyungwoo Kang

Abstract

Over the last decades, the regional government of Gyeonggi Province of Korea has devoted a large amount of effort and subsidy to projects aimed at increases some of public transport safety and cost efficiency. However, the overall results indicated that most of these efforts have been revealed as very ineffective and the bus related accidents were continued increased compare to sharp decrease other major cities and Province of Korea. The key objectives of this research are to find the relationship between the cost efficiencies of bus operating firms and bus related accidents using stochastic cost frontier model. The main results can be summarized as follows. First, the cost efficiency scores reported in this study, with an average of 0.73 during the study periods, can be considered relatively low compare to other studies and raise questions about possible policy methods to increase the cost efficiency of bus operation system. Secondly, this study found that the cost efficiency positively related bus accident rate, which indicated that the higher cost efficiency firm has higher bus accident rates as other related variables are constants.

Keywords: Bus accidents, Stochastic Frontier, Technical Efficiency.

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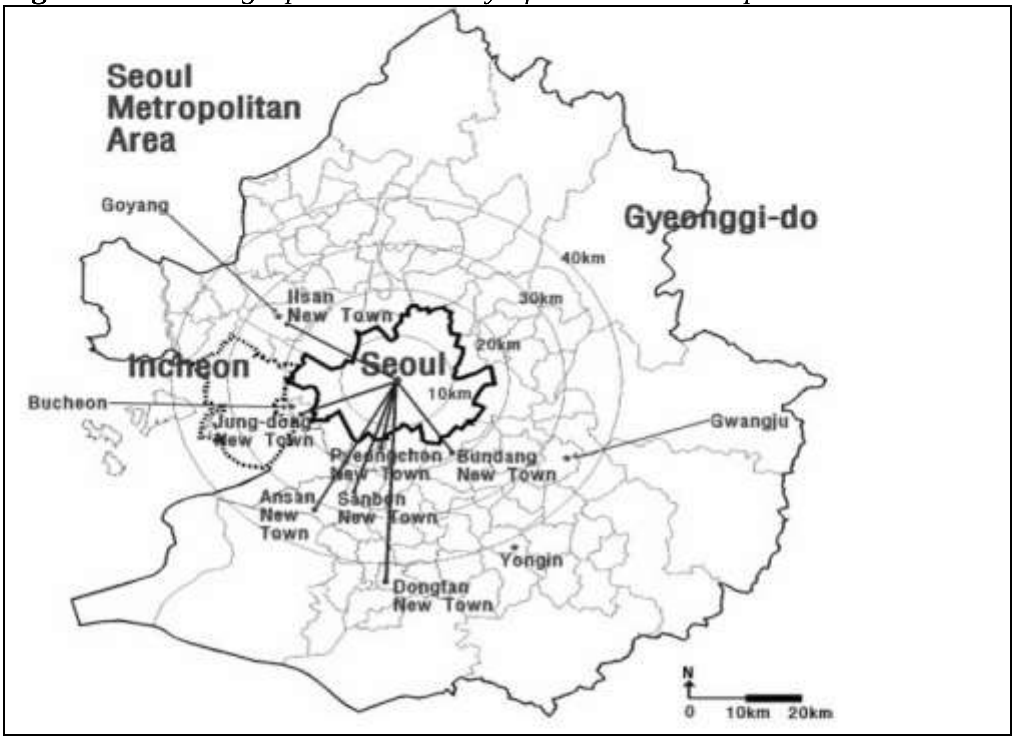
Introduction

Korea has been one of the fastest growing countries in the world. Indeed, the Seoul, the capital of Korea, metropolitan area including Gyeonggi Province and the city of Incheon quadrupled in population between 1965 and 2015. With more than 26.2 million residents, it is now one of the world's largest and fastest growing metropolitan area. Especially, the population of Province has increased from 11.7 million in 2009 to 12.9 million residents in 2015 resulted in 1.6 percent annually. However, the residents Seoul has peaked 10.5 million in 2010 and continue decreased -0.3 percent annually (Figure 1).

Gyeonggi Province is adjacent to Seoul and includes 31 cities so that 75% of buses in Gyeonggi are running across different administrative districts and have traffic characteristics of metropolitan areas. More people obviously generate more trips and more overall travel demand. For decades, bus services in most of cities of Korea were operated by a large number of small private firms, with virtually no government control of routes, schedules, or other aspects of service. Only the fares were determined by the local governments which also provided increasing operating subsidies to cover growing operating.

Figure 1. *The Geographical Boundary of the Seoul Metropolitan Area*



The safety statistics of local bus public transportation in province is continuing to increases compare to dramatic decreases in city of Seoul bus systems which is major bus reform since 2004.

Just like car accidents, there are many causes of bus accidents, only the crashes are usually more serious due to the sheer size and weight of buses.

Determining the cause of a bus accident is important, as that defines who is responsible for your damages.

Stochastic cost frontier analysis measuring transport cost efficiency (or inefficiency) has impractically assumed that accidents are freely disposable. This research attempts to rectify this impractical assumption by proposing stochastic cost frontier models into which different types of casualties are factored.

One of the top causes of serious bus accidents in Korea and throughout the country is bus company negligence. The bus transit industry is carrying most passengers, representing almost 35 percent of commuters in province which accounts for almost 3.88 million passengers in 2016. However, the record keeping and bus inspection protocols are not nearly as stringent compare to other public such as subway and regional commuter rails. This means bus companies often ignore the central and regional regulations, training drivers or keeping their fleets maintained. In addition, buses require a great deal of upkeep and maintenance to keep them safely operating. A bus accident could occur due to poor bus maintenance policy or a defective part that the company in order to save budget has failed to take action in fixing.

While there are many laws in place that attempt to regulate bus drivers, they are often disregarded, especially by local private bus systems companies such as province compare to semi-private bus systems in most major cities in Korea. For instance, there are “hours of service” laws that address how long a bus driver can be on the road and must be on break before starting another shift. Other laws regulate bus speed, turning and passing.

Table 1 shows that bus related traffic accidents statistics from 2005 to 2015. The numbers of buses and passenger carried are relatively stable in this period, the bus related traffic accidents are dramatically different. The number of bus related traffic accidents of local bus in Seoul has continued decreased from 1503 in 2005 to 1412 in 2014. However, these numbers of province have dramatically increased from 1261 in 2005 to 2447 in 2015.

Table 1. *The Local Bus Traffic Accidents in Seoul, Korea*

Region	*Gyeonggi Providence*	*Seoul*
2005	1,261	1,503
2006	1,204	1,404
2007	1,236	1,354
2008	1,308	1,356
2009	1,599	1,536
2010	1,724	1,543
2011	1,939	1,451
2012	2,165	1,413
2013	2,163	1,507
2014	2,272	1,451
2015	2,447	1,412

Source: Korea Transportation Safety Authority. Annual Statistics (2005-2016).

The stochastic cost frontier model is proved to be a simple and successful tool for modeling some transportation problems including accidents. In this regard, this paper suggests a methodology for modeling between cost efficiency measure and bus traffic accidents using stochastic cost frontier approach. The maximum likelihood estimation of the stochastic cost frontier model is applied to a bus related traffic accidents in province of Korea to illustrate the proposed method.

The statistical analysis will show that the results indicate a satisfactory methodology. Following introduction section, this paper is structured as follows. The next section provides a review of the relevant research. The “Data” section presents the data used in this paper. The brief stochastic cost frontier model is being presented in the “Model” section. “Estimation Results” section discusses the main results and policy implications. Finally, the last section outlines the main conclusions of this research.

Previous Research

The local bus accidents study done by Yoon, Kim and Kho (2017) for South Korea; they investigated factors that influence the severity of injuries that occur in local bus crashes and found that the factors such as vehicle speed, vehicle age, road alignment, surface status, road class, and traffic light installation are important as previous studies found. At the same time, the other factors such as conditions for pavement, emergent medical environment, traffic rate of compliance, and ratio of elderly in the community were quite important. However, they neglected the internal conditions for bus companies such as pressures for bus drivers to maintain tight schedules, especially for rush hours and penalties for minor traffic violations, which are quite important factors for bus drivers.

Recent bus accident study done by Diez et al. (2014) in Buenos Aires, the largest urban area of Argentina, are a partially sleep-deprived, over-weighted population, showing a high daytime somnolence, poor work-rest conditions and high levels of anxiety and fatigue. This association can be very harmful in view of the demanding working conditions considered.

As far as ownership of bus system in Korea, traffic accidents decreased generally because of semi-public bus system is implemented compare to private bus operation systems. The major factors, which influence the decrease of traffic offenses before-and-after semi-public management system of intra-city bus, are the decrease of violations, safe driving, and job security, which influenced by managers of bus companies.

The study done by Lim and Choi (2011) for relationship between fatal accidents of bus and roadway geometry design; they found that 43.7% of the accidents occurred on the curved roads, 60.7% on the vertical curve section, 57.2% on the roadways with radius of curvature of 0 to 24m, 83.9% on the roads with super elevation of 0.1 to 2.0% and 49.1% on the one-way 2lane roads. The vehicle types involved are passenger vehicles (33.0%), trucks (20.5%) and buses (14.3%) in order of frequency.

Recent study done by Sun et al. (2017) show that bus drivers do not display apparent negative emotions (tension, depression, angry and confusion) except fatigue under different temperatures, but these mood states increase with temperature. The factors of age (5560 years old), driving experience (>5 years), continuous work time, confusion, the number of reaction error, the number of judgment error, and temperature (>35°C) are significantly correlated to at-fault accident.

There is very limited research on relationship between public transportation subsidy policy and accident rates, however, many studies on effects on indirect productivity and public transit subsidies (Karlaftis and McCarthy, 1977; De Borger and Kerstens, 2000; De Borger et al., 2002; Obeng, 1994, 2011; Obeng, and Sakano, 2008).

As far as the major difference of bus accidents between Seoul which is operated by semi-public management since 2004 and province which is privately operated, one reasonable hypothesis of these trends namely continues decreasing for Seoul, however, sharply increasing trends of province is resulted from the tight cost saving management policy of province. These tight bus management policy outcomes of a jobs with high occupational strain is high labor turnover in province compare to quite stable in Seoul. Recent study done by Gyeonggi Research Institute found that about 24% lower wages and 27% higher working hours of bus drivers in province compare to Seoul.

Data

The data used in this research was from the annual reports of the Data Analysis, Retrieval and Transfer (DART) System, Financial Services Commission, Korea. The companies operating in inter-province are excluded from the data. These bus companies operate both inter-cities of metropolitan area, whose operating conditions are different from local bus transport. Our data set includes information on all the 57 local companies operating in province during the study period. However, the data is not available for all years. In several cases lack of information is due to closure or merging with other companies.

We decided to exclude the companies that have fewer than five years of operating from 2010 to 2014. That is, all the companies in the final sample have five years of non-missing data. Also, companies that were closed or taken over by other companies after a short period of operation are excluded. Obviously, such companies are not comparable with other companies because their closure may have been related to their excessive costs or other peculiar reasons. Moreover, since the panel models used in this study require the estimation of firm-specific effects, four observations per firm appears to be a reasonable minimum.

The final data set is an unbalanced panel with 135 observations including 27 operators over a five-year period from 2010 to 2014. The available information includes total revenues including subsidy and incentives and operating costs, total number of drivers and other staff, total network length, total numbers of buses (diesel and CNG buses) and types of accidents, passenger satisfaction index.

In addition, occupational stress has an aversive effect on individuals and organizations. Stress leads to physical and mental ill health. Bus driving is a classic example of high-strain occupation. In a mega-metropolitan region such as city of

Seoul and province, which accounts almost over 50% of population live in this region, bus drivers have responsibility to overcome traffic congestion and to get passengers safely and comfortably in scheduled time to the desired destination. However, the number of bus traffic accidents is drastically decreasing since June 2004, when the major bus reform started from private to semi-public operation for bus operation for Seoul, Korea. At the same time, the number of bus accidents increased almost double for province which is operate by private bus companies with small subsidy for deficit compare to semi-public system in Seoul.

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 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:

$$C = C^*(w, y, t) \quad (1)$$

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 and Chu, 1968; Aigner et al., 1977; Meeusen and van den Broeck, 1977) offers an analytical framework to estimate cost function such as:

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

where ε is the random error term, which is composed of two parts. 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.

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

where C_{it} is the cost of the economic entity i in year t; is y_{it} the output; w_{it} is the factor price; ϑ_{it} is an error term, uncorrelated with the regressors, and distributed as independent and identically distributed (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;

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

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 (Farsi et al., 2006).

Estimation Results

Table 2 presents summary statistics for the bus transit systems used in this study. 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.

Table 2. *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 presented in Table 3. 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 sign, however, statistically insignificant.

Table 3. *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( )	15.20690	

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

The estimation results of the average efficiency levels for each year are shown in Table 4. This result indicates that there is room for improvement. Approximately 82.8% of cost efficiency are 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 province of Korea can be improved about 17.2%.

Table 4. *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

Table 5 shows the relationship between bus accident rate which is defined as weight by accident types per annual operating number of buses and exogenous bus operation factors, particularly the cost efficiency, operating km and driver wage, and the inefficiency component. The cost efficiency positively related bus accident rate, which indicated that the higher cost efficiency firm has higher bus accident rates as other related variables are constant. Other exogenous variables such as annual operating km, number of buses and driver wages are negatively related bus accident rates.

Table 5. *Determinant of the Bus Accident Rate and Exogenous Variables, OLS Estimator*

Variable	Coefficient	Std. Dev.	t-ratio
Constant	-.0044589	.0103403	-0.43
Cost Efficiency	.0167398	.0101809	1.64
Annual Operating Km	-.0098007	.0036352	-2.70
Number of Buses	-9.22e-06	4.82e-06	-1.91
Driver Wage	-4.50e-11	2.21e-11	-2.03

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 0.73 during the study periods, can be considered relatively low compare to other studies and raise questions about possible policy methods to increase the cost efficiency of bus operation system. 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 province of Korea could be improved by 17.2%. However, we cannot confirm if the poor cost efficiency performance of bus transit system in province affects ownership of bus transit system.

Secondly, this study found that the cost efficiency positively related bus accident rate, which indicated that the higher cost efficiency firm has higher bus accident rates as other related variables are constant. Other exogenous variables such as annual operating km, number of buses and driver wages are negatively related bus accident rates

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