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RESEARCH PAPER

Public Road Transport Efficiency: A Stochastic Frontier Analysis

SAMI Jarboui *[1], PASCAL Forget[2], YOUNES Boujelbene[1]

1. Faculty of Economics and Management of Sfax, University of Sfax, Tunisia
2. School of Engineering, University of Quebec at Trois-Rivieres, Canada

Abstract: The objectives of this paper are to measure the technical efficiency of 64 public road transport operators in 18 countries and to investigate the degree to which various factors influence efficiency levels in these firms. Stochastic frontier analysis (SFA) methods are applied to the sample over a twelve year period from 2000 to 2011. The empirical results indicate that operating profit, investment and firm size have a significant influence on technical efficiency levels. Conclusions indicate that technical efficiency level of public road transport operators varies between 0.46 and 0.95. Observations can be made that large-size operators with more investment capacity tend to be more technically efficient than small-size operators. Finally, the results concluded that operators from developed countries are technically more efficient than those of developing countries.

Key Words: urban traffic; efficiency; public road transport; stochastic frontier analysis

1 Introduction

The transport sector plays a significant role in the overall development of a nation's economy. Road transport is the primary mode of transportation, linking remote areas with the rest of the country [1]. In the absence of a transport system, dependency upon personalized modes of transport increases, therefore leading to wasted energy [2]. Generally, public road transport operators of passenger vehicles offer a public service with a social aim. In most cases, they are controlled by the government. Efficiency evaluation in public transportation is therefore an issue of foremost importance.

Efficiency has long been a critical consideration in both policy and operational decisions of public transport operators, and public transport efficiency has recently become even more vital [3]. Passenger road transportation is a "service business" and evaluating the effectiveness of a service business is a complex matter. Transport efficiency is often more difficult to evaluate than manufacturing business efficiency, because it is challenging to determine the accurate amount of resources required to produce various service outputs. The manufacturing standard can be used to identify operating inefficiencies through classical cost analyses. However, in service organizations such as road passenger transportation systems are difficult to identify the resources required to provide a specific service output [1].

Several approaches have been adapted to measure transport operators' efficiency. Parametric and non-parametric frontiers are the two main approaches used to measure technical efficiency [4]. The parametric frontier approach [5] establishes a functional form for the cost, profit, or production relationship among inputs, outputs, and environmental factors, and allows for random error. Both inefficiencies and random errors are assumed to be orthogonal to the input, output, or environmental variables determined in the estimating equation[6]. The non-parametric approach, the data envelopment analysis (DEA) method, was developed by Farrell [7]. The DEA frontier is formed as the piecewise linear combinations that connect the set of best practice observations,

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*Corresponding author. E-mail: sami.rec.fseg@gmail.com

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yielding a convex production possibilities set. The DEA method does not require explicit form specification of the underlying production relationship. The non-parametric approaches, however, do not allow for random error. If random error exists, measured efficiency may be confounded with these random deviations from the true efficiency frontier. As well, statistical inference and hypothesis tests cannot be conducted for the estimated efficiency scores [6].

In empirical analysis of efficiency, debate still exists between the use of the parametric and nonparametric approach. There is a wide range of literature comparing the two approaches. Thus, Lovell [8] offers a detailed presentation. Ferrier and Lovell [9], for example, assessed the strengths and weaknesses of both approaches through an empirical analysis of cost efficiency in banking. Bjurek *et al*.[10] compared the two approaches as part of service production. Cullinane *et al.* [11] provided a technical efficiency analysis of container ports by comparing the parametric stochastic frontier analysis (SFA) and Data Envelopment Analysis (DEA) as a non-parametric approach, and highlighting the strengths and weaknesses of each approach.

According to the literature, the public transport efficiency works are always related to a specific study context, for example, Agarwal *et al.* [1] and Kumar [12] propose an Indian application and Von Hirschhausen and Cullmann [13] study German data. Moreover, the efficiency operators' evaluations in different countries are difficult to follow. There is omitted data of indicators and variables to measure different countries efficiency. So, the lack of comparative work of operators' efficiency in different countries has become an initiative for this research, but for this study, we select financial variables relating to operating activities operators'.

The aim of this paper is to assess the efficiency of 64 public transport operators in different countries between 2000 and 2011. The assessment is conducted using the stochastic frontier analysis (SFA) of the production function model specified by Battese and Coelli [14] for panel data. Again, this study will identify the determinants of inefficiency in public transport operators of passenger services. In the literature, most research has shown that the market organization, contract conception, regulatory system degree and nature, and network characteristics are the inefficiency determinants [15]. In this study, in addition to these determinants, this study also considers investment, operating profit and firm size as explanatory variables of public transport inefficiency.

2 Stochastic frontier Model

The parametric approach is used alongside the stochastic frontier production function for panel data proposed by Battese and Coelli [14]. The starting point of this parametric approach is to estimate a stochastic production frontier. According to Battese and Coelli [14], this frontier can be written as Eq.(1).

$$Y_{it} = \exp(x_{it}\beta + V_{it} - U_{it}) \tag{1}$$

where Y_{it} is the output of the *i*-th transport operator (i = 1, 2, $\cdots$, N) in the *t*-th period (t = 1, 2,$\cdots$, T); x_{it} is a $(1\times k)$ vector of input quantities of the *i*-th transport operator in *t*-th period; β is a $(k\times 1)$ vector of unknown parameters to be estimated; V_{it} is a random variable which is assumed to be independent and identically distributed N (0, σ_V^2) and independent of U_{it} ; the U_{it} is non-negative random variable, associated with technical inefficiency of production, which is assumed to be independently distributed as truncations at zero of the $N(u, \sigma_U^2)$ distribution; where $u = z_{it}\delta$ and variance σ_U^2 ; and z_{it} is a $(1\times p)$ vector of explanatory variables associated with technical inefficiency of public transport production industry over time; where δ is a $(p\times 1)$ vector of unknown parameters.

Eq. (1) specifies the stochastic frontier production function in terms of the original production values. However, the technical inefficiency effects, U_{it} is assumed to be a function of a set of explanatory variables, z_{it} and an unknown vector of coefficients δ .

According to Battese and Coelli [14], the technical inefficiency effect, U_{it} in the stochastic frontier model displayed in Eq. (1) is specified by Eq. (2),

$$U_{it} = z_{it}\delta + W_{it} \tag{2}$$

where the random variable W_{it} follows truncated normal distribution with mean zero and variance σ^2, such that the point of truncation is $-z_{it}\delta$, that is $W_{it} > -z_{it}\delta$. These assumptions are consistent with U_{it} being a non-negative truncation of the $N(z_{it}\delta, \sigma_U^2)$ distribution [14]. The mean $z_{it}\delta$ of the normal distribution, which is truncated at zero to obtain the distribution of U_{it} , is not required to be positive for each observation.

The likelihood function and its partial derivatives with respect to the parameters of the model are presented in Battese and Coelli [16]. The method of maximum likelihood is proposed for simultaneous estimation for parameters of the stochastic frontier in Eq. (1) and the model in Eq. (2) for the technical inefficiency effects. The likelihood function is expressed in terms of the variance parameters, $\sigma^2 = \sigma_V^2 + \sigma_U^2$ and $\gamma = \sigma_U^2 \big/ \left(\sigma_V^2 + \sigma_U^2\right)$.

After obtaining the estimates of U_{it} , the technical