MEASURING THE EFFICIENCY OF GERMAN PUBLIC BUS TRANSPORT

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ABSTRACT

This paper quantifies the technical efficiency of German bus companies and elaborates on the main factors influencing their performance. Efficiency is measured with a stochastic production frontier. We test for the impact on efficiency of ownership structure and participation at tendering. Furthermore, we investigate the influence on efficiency when a bus company is a part of a multi-product enterprise. The results yield insights how public bus companies might improve their performance in order to cope with the changing market environment. The analysis shows that the German public bus market exhibits low technical efficiency. The mean technical efficiency of the investigated bus companies is around 87 percent. Bus companies with participation at tendering show a significantly higher mean efficiency than other companies. The ownership structure has no influence on technical efficiency.

Keywords: Stochastic Frontier Analysis, Production Function, Public Transport, Efficiency Analysis

I. INTRODUCTION

Germany's local public bus transport markets remain dominated by small, publicly-owned companies with monopoly power. In most municipalities, local authorities offer the services of a publicly-owned bus company, sometimes supported by private subcontractors. Traditionally, competition has been virtually non-existent. However, local bus companies have come under pressure to enhance their performance. As public deficits rise, the authorities are becoming increasingly reluctant to offset losses incurred by their own bus companies. Moreover, some municipalities have started to tender out at least some of their bus services. Furthermore, private international transport operators have recently been able to gain access to some local bus markets by acquiring private (sub-)contractors.

This paper evaluates the level of technical efficiency of German bus companies and some potential determinants with a Stochastic Frontier Analysis (SFA) approach, which is a parametric benchmarking method. In order to investigate some determinants of technical efficiency, we apply the production frontier methodology developed by Battese/Coelli (1995).[1]

Various international studies investigate the efficiency of urban public transport.[2] Hirschhausen/Cullmann (2008) use a Data Envelopment Analysis (DEA) to analyze German bus companies. Overall, they find very low efficiency scores. Other studies investigate the determinants of efficiency with a stochastic production function. Roy/Yvrande-Billon (2007), for example, show that private operators outperform public ones in terms of efficiency. Furthermore, their results imply that operators subject to cost-plus contracts exhibit a lower level of technical efficiency than those subject to fixed-price agreements. The most recent study of the German bus market is from Walter (2009), who analyzes cost efficiency and finds that a high degree of outsourcing increases cost efficiency.

II. METHODOLOGY

For our analysis, we follow Roy/Yvrande-Billon (2007) and use the stochastic frontier model proposed by Battese/Coelli (1995). The stochastic production frontier is defined by:[3]

$$y_{it} = exp(\beta x_{it} + v_{it} - u_{it}) \quad (1)$$

y_{it} denotes the production level for the i-th firm at the t-th observation. x_{it} is a vector of inputs and other explanatory variables (environmental variables). β is a vector of unknown parameters to be estimated. v_{it} are stochastic variables which represent uncontrolled random shocks in the production process. The v_{it} are assumed to be $iid\ N(0, \sigma_v^2)$ random errors, independently distributed of the u_{it}. u_{it} are non-negative random variables ($u_{it} \geq 0$), which accounts for the fact that the output of a company must lie either below or on the production frontier. They capture the technical inefficiency of the firm. It is assumed that the u_{it} are independently distributed as truncated normal $N(z_{it}\delta, \sigma_u^2)$.

The technical inefficiency effect is specified as:

$$u_{it} = z_{it}\delta + w_{it} \quad (2)$$

z_{it} is a vector of explanatory variables associated with the technical inefficiency of firms over time. δ is a vector of unknown parameters to be estimated. w_{it} is a random variable defined by truncating of the normal distribution with a zero mean and variance σ_w^2 at $-z_{it}\delta$.

β and δ are estimated simultaneously with the method of maximum likelihood. The likelihood function is expressed in terms of the variance parameters, $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u^2/\sigma^2$.

[1] See Battese/Coelli (1995) and Coelli (1996).
[2] See De Borger et al. (2002) for a brief overview.
[3] See Battese/Coelli (1995).

The technical efficiency of production for the i-th at the t-th observation is:

$$TE_{it} = \exp(-u_{it}) = \exp(-z_{it}\delta - w_{it}) \tag{3}$$

For the analysis, we choose a transcendental logarithmic function (translog function) as the analytical form for the production function.[4] The translog function is a flexible function that does not restrict a bus company's production technology. There are no restrictions on substitution elasticity and elasticity of scale. We use the following translog production function:

$$\begin{aligned} ln\, y_{it} = {} & \beta_0 + \beta_c\, ln\, c_{it} + \beta_l\, ln\, l_{it} + \frac{1}{2}\beta_{cc}\,(ln\, c_{it})^2 + \frac{1}{2}\beta_{ll}(ln\, l_{it})^2 \\ & + \beta_{cl}\, ln\, c_{it}\, ln\, l_{it} + \beta_{nl}\, nl_{it} + \beta_{ih}\, ih_{it} + v_{it} - u_{it} \end{aligned} \tag{4}$$

The output y_{it} is measured in vehicle-kilometres. The main inputs for bus companies are labour, capital and energy.[5] Because data about energy is not available, we follow Gathon (1989) and use labour and capital as inputs. c represents the capital emyployed and is measured as the number of vehicles. Labour (l) is measured as the number of full-time employees. We follow Roy/Yvrande-Billon (2007) and additionally use two control variables. The first is the network's length (nl), which is a proxy of the exogenous environmental characteristics of the network. We assume that the network's length has a positive influence on the output measured in vehicle kilometres. The number of inhabitants in the supplied area (ih) is the second control variable.[6] Furthermore, we assume that the number of inhabitants in the supplied area exerts a positive influence on the output.

Output measurement can be based on supply (vehicle- or seat-kilometres) or on demand (passenger-kilometres).[7] Data on supply can easily be collected and correlates highly with the inputs. However, such output measures do not reflect the actual use of the services offered, which, of course, is accounted for by demand-oriented output measures. However, the efficiency scores obtained from models with output based on demand, can be misleading, as demand can only be influenced to some degree by the bus company.[8] Taking into account the focus of this paper, we therefore use vehicle-kilometres as the output-measure.

The technical inefficiency effects are defined by equation (5):

$$u_{it} = \delta_0 + \delta_{wb}\, wb_{it} + \delta_p\, priv_{it} + \delta_{qv}\, qv_{it} \tag{5}$$

[4] See Christensen et al. (1973) and Gathon (1989).
[5] See De Borger et al. (2002), p. 18.
[6] See Roy/Yvrande-Billon (2007), pp. 271f.
[7] See Berechman/Giuliano (1985), p. 318
[8] See De Borger et al. (2002), pp. 19f.

wb, $private$ and qv are variables that do not impact on the production technology per se. They explain why some bus companies are more or less efficient than other bus companies. The variables are defined as follows:

- wb is a dummy variable that assumes the value 1, if the bus company participates at tendering and 0 otherwise.
- $priv$ is a dummy variable that assumes the value 1, if the bus company is a private company and 0 otherwise. A private bus company is defined as one with a minimum private shareholding of 50%.
- qv is a dummy variable that assumes the value 1 if the bus company is a part of a multi-product enterprise operating in multiple-utility sectors such as transport, water, energy and 0 otherwise.

III. DATA

The statistics from the Association of German Transport Companies (Verband Deutscher Verkehrsunternehmen (VDV)) provide data on bus companies.[9] The dataset is an unbalanced panel for the years 2004 to 2008. Companies offering services in both local bus and rail services are deleted from the data set. Information about participation at tendering was obtained through interviews and online resources. Information about ownership structure and multi-utility involvement was obtained from the annual reports of the companies themselves and from the Handbook of Transport Companies in the VDV.[10] The unbalanced panel consists of 692 observations. 154 bus companies are included with a mean of 4.5 observations per company. The number of observations per year ranges from 133 (in 2005) to 145 in 2008.[11]

The number of full-time employees (l) obtained from the VDV does not include the number of full-time employees who work in the subcontract bus companies. The vehicle-kilometres of each company (y), however, are stated inclusive of the supply of subcontractors. We address this problem by estimating the number of the firms' own and outsourced full-time employees (l_{EF}). We use a very conservative approach and assume that subcontractors need as many full-time employees per bus as the contracting bus company:

$$l_{EF_{it}} = \frac{l_{it}}{own\ buses_{it}} * total\ number\ of\ buses_{it}\ . \qquad (6)$$

We then estimate Equation (3) with l_{EF}.

Descriptive statistics of the variables are provided in Table 1. In our sample, 9 % of the bus companies participate at tendering and nearly 13% of the bus companies are private. 34%

[9] See Verband Deutscher Verkehrsunternehmen (various years *a*).
[10] See Verband Deutscher Verkehrsunternehmen (various years *b*).
[11] The exact data structure is as follows: 2004: 137, 2005: 133, 2006: 143, 2007: 134 and 2008: 145 observations.

are a part of a multi-product enterprise operating in multiple-utility sectors, such as transport, water and energy.

Table I – Descriptive statistics

	Min.	Max.	Mean	Median	Std. Dev.
Vehicle-kilometres in thousands (y)	185	45,409	5,734	3,341	7,266
Vehicles (c)	3	1,352	131	73	191
Estimated full-time employees $(\mathrm{l_{EF}})$	8	2,543	281	146	398
Network length (nl)	13	17,953	1,361	500	2,457
Inhabitants (ih)	13,552	5,412,865	390,103	124,178	814,789
wb			0.09		
$priv$			0.127		
qv			0.344		

IV. RESULTS

The maximum-likelihood estimates are reported in Table 2. The model was estimated using the FRONTIER 4.1 software.[12] The local point of approximation is the sample mean, that is, the independent variables are evaluated at their sample mean values. The first-order coefficients (β_c and $\beta_{l_{EF}}$) can be interpreted as elasticities with respect to the factors c and l_{EF} for the mean bus company.[13] The first-order coefficients yield the expected signs and are statistically significant at the 1% significance level. The sum of these coefficients represents the scale elasticity. If the inputs are increased by 1%, the output increases by 0.743%. Therefore, the mean-bus company operates with decreasing returns to scale. The elasticity of scale for the bus companies in our sample ranges from 0.627 to 1.137 with an average value of 0.854.

The coefficients of network length (β_{nl}) and for the inhabitants in the supplied area (β_{ih}) are statistically significant and positive. Network length and the number of inhabitants in the supplied area have a positive influence on the output measured in vehicle kilometres.

[12] See Coelli (1996).
[13] See McCarthy (2001), pp. 168f.

Table 2– Regression results

Parameter	Estimate	Standard-Error	p-value
β_0	2.024	0.017	0.0000
β_c	0.474	0.042	0.0000
$\beta_{l_{EF}}$	0.264	0.033	0.0000
β_{cc}	-0.195	0.041	0.0000
$\beta_{l_{EF}l_{EF}}$	-0.052	0.049	0.2886
$\beta_{cl_{EF}}$	0.086	0.038	0.0244
β_{nl}	0.069	0.011	0.0000
β_{ih}	0.109	0.016	0.0000
δ_0	-0.942	0.319	0.0032
δ_{wb}	-2.460	0.941	0.0092
δ_p	-0.090	0.093	0.3329
δ_{qv}	0.459	0.117	0.0001
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.204	0.038	0.0000
$\gamma = \sigma_u^2/\sigma^2$	0.885	0.028	0.0000
log likelihood function	106.328		

The parameter γ is statistically different from zero and close to one, which indicates that the inefficiency effects (productive inefficiency) are important relative to the random noise term.[14] The null hypothesis that these are no inefficiency effects (H_0: $\gamma = \delta_0 = \delta_{wb} = \delta_p = \delta_{qv} = 0$) is rejected at a p-value of 0% (the likelihood-ratio test statistic is 86.001). The estimated coefficient for "part of a multi-product enterprise" (δ_{qv}) is positive and significantly different from zero at the 1% level. Bus companies that are part of a multi-utility-owned enterprise are less efficient than others. One explanation of this inefficiency may be that losses incurred by the transport division of these enterprises can be compensated for by monopoly or oligopoly

[14] See Roy/Yvrande-Billon (2007), p. 269 and Battese/Coelli (1995), p. 330.

profits from other utility services. The coefficient δ_{wb} is negative and significantly different from zero at the 1% level. Bus companies which participate at tendering are more efficient than other bus companies. Participation at tendering seems to increase efficiency, or it may be that more efficient bus companies participate at tenders. The estimated coefficient δ_p is negative, but not statistically different from zero. Ownership structure seems to have no influence on the estimated inefficiency of a bus company. At first glance, that might be surprising, as privately owned companies are generally perceived as more efficient than publicly owned ones. Looking at empirical studies on the issue, ambiguous results can be found. Based on a comprehensive review of the relevant literature, Shirley/Walsh (2001) come to the conclusion that ownership is important in competitive markets and that private companies generally outperform public companies within this market structure. However, in monopoly markets, there is no clear evidence that private companies are more efficient than public ones. Taking these results into account, the lack of significance of the coefficient δ_p in our study might be attributed to the fact that most companies in our sample operate in monopoly markets without tendering, in which even privately owned companies have weak incentives to be efficient.

The estimated efficiencies are limited to 0 and 1. A value of 1 means full technical efficiency. The difference between 1 and the estimated efficiency can be interpreted as technical inefficiency. The mean efficiency of the German public bus transport industry is 0.865. Other analyses using Data Envelopment Analysis (DEA) have yielded even lower values.[15] The mean efficiencies for bus companies, with participation at tendering and without participation at tendering, are given in Table 3. The first group yields a higher mean efficiency (0.952 compared 0.857). Bus companies which are part of multi-product enterprises yield a higher mean efficiency (0.885 compared 0.827). The result suggests that private bus companies are more efficient than public bus companies, but the coefficient of the variable δ_p is not significantly different from zero.

Table 3– Mean Efficiency

Bus companies…	Mean
with participation at tendering	0.952
without participation at tendering	0.857
which are part of multi-product enterprises	0.827
which are not part of multi-product enterprises	0.885
which are private operators	0.886
which are public operators	0.862

[15] See, for example, Hirschhausen/Cullmann (2008) or Hartwig/Scheffler (2009).

V. DISCUSSION AND CONCLUSION

This paper applies a stochastic production frontier to examine the technical efficiency of German Public Bus Transport. It is clear that further research needs to be conducted with our data set and that it is necessary to deal with the issues of outsourcing and unobserved heterogeneity. However, the analysis demonstrates that German Public Bus Transport exhibits a low level of technical efficiency. Participation at tendering influences technical efficiency positively, and bus companies that are part of a multi-utility-owned enterprise are less efficient than other bus companies. Tendering improves technical efficiency. The ownership structure of companies in our sample seems to have no influence on efficiency. This might be attributed to the fact that most companies in our sample, whether private or public, have been granted monopoly rights in their markets. In monopoly markets, however, there are weak incentives for both private and public companies to be efficient. This result is consistent with those of other studies, which show that the ownership issue is more important in competitive environments than in monopoly markets

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