MEASURING THE EFFICIENCY OF BUS TRANSPORT UNDERTAKINGS IN THE SLOVAK REPUBLIC: AN APPLICATION OF DEA AND TOBIT ANALYSIS

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Abstract

The paper focuses on efficiency evaluation of a sample of Bus Transport Undertakings (BTUs) in the Slovak Republic. The data were collected for 15 BTUs for the year 2014. Technical efficiency of BTUs was measured by Data Envelopment Analysis (DEA) with the use of two inputs and one output variable. Number of bus drivers and fleet size were considered as inputs and passenger kilometers as an output. The tobit model applied in the second stage was used in an effort to identify effects of various exogenous variables on technical efficiency of BTUs.

Key words: *efficiency, data envelopment analysis, tobit regression, public bus transport.*

1.

2. Introduction

The issue of the public transportation efficiency has continuously interested economists. Many academics and policy makers draw their attention to the comparative studies on the relative technical efficiency of transport companies. Technical efficiency reflects an ability of a firm to produce maximum outputs from a given set of inputs. There are a wide variety of approaches how efficiency can be measured. One of the most popular methods which has become increasingly used in applications where there are multiple inputs and outputs is Data Envelopment Analysis (DEA). Due to the public-private nature of transport system and a relatively specific set of inputs and outputs, as well, DEA has found its application for the technical efficiency assessment in the transport sector, as well (see e.g. Agarwal, 2009; Barnum et al., 2008; Sampaio et al., 2008; Kerstens, 1996).

Having measured the technical efficiency, it is also of significant interest to investigate the determinants of technical efficiency. In such cases, a two-stage procedure is usually used. In the first stage, technical efficiency is evaluated using selected DEA model whilst in the second stage, the DEA efficiency scores are explained by relevant exogenous influences not directly included in the DEA evaluation. Exogenous influences usually are called environmental influences or contextual influences (Barnum, 2008). The Tobit model (Tobin, 1958) is widely used as an appropriate multivariate statistical model in the second stage to consider the characteristics of the efficiency measure distribution. Many authors use this two-stage procedure for measuring technical efficiency in transportation (see e.g. Barnum et al., 2008; Fethi et al., 2000; Kerstens, 1996; Oum and Yue, 1994).

This paper focuses on the efficiency evaluation of a sample of the Bus Transport Undertakings (BTUs) in the Slovak republic. Section 2 discusses the two-step methodology to measure technical efficiency of the BTUs and incorporate the determinants of efficiency. The characteristics of the BTUs included in the analysis are briefly described in Section 4. The empirical results are reported in Section 5. Finally, Section 6 concludes.

3. Methodology

In our analysis, the two-stage method is used to identify exogenous influences beyond the control of the BTUs. With this procedure, a DEA is first employed using only traditional inputs and outputs. In the second stage, the DEA scores are adjusted by relevant exogenous variables of interest. The regression results are used to identify exogenous factors that influence the first-stage DEA scores to a statistically significant degree (Barnum et al., 2008).

2.1 First Stage: Technical Efficiency Measurement

The idea of measuring technical efficiency was initially proposed by Farrell (1957) who used the non-parametric frontier approach to measure efficiency as a relative distance from the Production Possibility Frontier (PPF). This non-parametric technique for technical efficiency measurement, known as DEA, was later extended by many researchers, especially Charnes et al. (1978). DEA determines technical efficiency without having to specify either the production function or the weights for the inputs used and outputs produced in the production process. DEA quantifies relative efficiency by estimating an empirical PPF, employing the actual input and output data. DEA determines the technical efficiency score of individual Decision Making Unit (DMU) based on its distance from the constructed PPF and for each inefficient DMU projects the exact amount of inputs that could be saved (input excesses), and the exact amount of additional outputs that could be achieved (output shortfalls) in order to achieve the PPF.

2.1.1 First Step: Inputs and Outputs Selection

The basis for the application of DEA in the BTUs efficiency measurement is the assumption that each BTU is seen as a DMU, which transforms a set of inputs (e.g. number of busses, transport capacity of busses, number of connections, transport distance, number of employees, number of bus drivers, operating costs, etc.) into a set of desirable outputs (e.g. number of passengers transported, transport performance in kilometres driven, passenger kilometres, seat kilometres, etc.), as well as undesirable outputs (e.g. noise, emissions, dust, liquid waste, etc.).

In selecting an appropriate combination of inputs and outputs for DEA it is necessary to adhere at least the following four requirements): (1) suitability of variables with respect to the economic purport of technical efficiency, (2) availability of the data required, (3) meeting the initial condition regarding the number of inputs and outputs in relation to the number of DMUs, and (4) uniqueness of information contained in inputs and in outputs as well as high information value of the nexus between input and outputs.

In evaluation of technical efficiency of the BTUs in the Slovak republic, we considered two inputs, viz., Bus drivers and Fleet size and one output, Passenger kilometers. Bus drivers referring to the average number of bus drivers worked in a BTU is representative of the labor input. Fleet Size comprising the average number of buses on-road in a BTU is representative of the capital input. Passenger-kilometers represent the transport of one passenger by a bus transport over one kilometer.

2.1.2 Second Step: DEA Model Selection

In the DEA model selection it is required to choose the orientation of the model (input, output or base oriented models), the form of efficiency to identify (radial, non-radial and hybrid models) and the assumption on the character of returns to scale (constant returns to scale, CRS; variable returns to scale, VRS; non-increasing returns to scale, NIRS; or non-decreasing returns to scale, NDRS). The ultimate choice of DEA model should result especially from weighing the specifics of the problem that exhibit themselves in the goal of the analysis, in the nature of the inputs and outputs considered and in the nature of the DMUs evaluated (Roháčová, 2015).

The selection of the model orientation principally depends on the extent to which inputs or outputs are controllable. In the context of the bus transport it appears that input oriented models are definitely valid (Holvad, 2010). Input oriented model compares the actual input level for a given DMU to the best practice input level, holding the outputs constant, i.e. it quantifies the input reduction required for the production of the given level of output to become technical efficient. Due to the nature of inputs and outputs considered in this study, input-oriented model has been employed, i.e. how much inputs can be reduced without changing the outputs produced to make BTUs efficient. The reason for this choice is that the output is less likely to be under the control of the individual BTUs than their choice of inputs. In the Slovak republic, the performance of the BTUs is divided into two main areas. The performance in the public interest is realized by urban public transport (UPT) and regular bus transport (RBT), and the performance in the private interest is covered by long-distance transport (LDT), international transport (IT) and irregular bus transport (IBT). In this paper, the main attention is given to the activities of the BTUs in UPT and RBT. UPT and RBT are ordered and financed by municipalities and self-governing regions known as higher territorial units (HTUs). Municipalities and HTUs conclude with the BTUs a public service performance agreement (PSPA) covering the transport services, which would, especially for economic disadvantage, not be provided in the desired extent, quality and affordable price. From foregoing it follows that the current setting of transport network system supported by professional public transport timetables of UPT and RBT is, in the short term, beyond the control of BTUs. Passenger kilometres depends especially on vehicle kilometres driven which represent the result of the contractually agreed performance embodied in individual PSPAs, i.e. they have been fixed in a contract with the public authority. An input-oriented DEA model provides the recommendations for improving efficiency of BTUs in the form of the determination of the efficient number of busses and bus drivers in relation to the achieved transport performance.

In the next step it is required to decide whether radial or non-radial DEA model will be used. This decision depends particularly on the characterization of input or output items. While radial inputs (outputs) can be changed proportionally (radially), non-radial inputs (outputs) can be changed un-proportionally (non-radially). These differences should be reflected in the evaluation of efficiency. The radial approach is represented by Charnes-Cooper-Rhodes (CCR) model (Charnes et al., 1978) or Banker-Charnes-Cooper (BCC) model (Banker et al., 1984). Its shortcoming is that it neglects the non-radial input/output slacks. The non-radial approach, e.g. the additive model of Charnes et al. (1985) or the Slacks-Based Measure (SBM) model of Tone (2001), deals with slacks directly, but it neglects the radial characteristics of inputs and/or outputs. If the set of inputs (outputs) involves both radial and non-radial variables, the hybrid measure needs to be applied. Since we consider two inputs (Bus drivers and Fleet size), which are not strictly linked to each other, i.e. they are non-radial, a non-radial DEA model has been applied in our analysis.

Finally, the character of returns to scale needs to be selected. Overall technical inefficiency that a DMU might have could be caused by an inefficient operation of a DMU itself, i.e. pure technical inefficiency or by the disadvantageous conditions under which a DMU is operating, i.e. scale inefficiency. The DEA method can establish the direction of scale inefficiency, i.e. too high scale (Decreasing Returns to Scale, DRS) or too low scale (Increasing Returns to Scale, IRS). If a DMU operates according to CRS, it is declared scale efficient. While the pure technical efficiency measure reveals an ability of a DMU to achieve the PPF in the short term, the scale efficiency measure indicates an ability of a DMU to adjust the scale of its operations in the long term (to increase for IRS, or to decrease for DRS). From the foregoing, if only pure technical inefficiency needs to be evaluated, the VRS assumption should be selected, and if overall technical efficiency needs to be evaluated, the CRS assumption should be preferred. Since, the BTUs in the Slovak republic vary considerably in size and we want to take into account possible differences in the scale of operations of BTUs, the variable returns to scale hypothesis has been embodied in the analysis.

In order to meet all aforementioned requirements, the input oriented SBM model under the VRS assumption will be applied in our analysis. To describe DEA efficiency evaluation, assume that the performance of the homogeneous set of n DMUs, each using m inputs for producing s outputs. For each DMU$_o$, $o = 1,...,n$ input and output vectors are denoted by $\mathbf{x}_o \in R_+^m$ and $\mathbf{y}_o \in R_+^s$, respectively. The input matrix is defined as $\mathbf{X} = (\mathbf{x}_1, \ldots, \mathbf{x}_n) \in R_+^{m \times n}$ and the output matrix is defined as $\mathbf{Y} = (\mathbf{y}_1, \ldots, \mathbf{y}_n) \in R_+^{s \times n}$. The input oriented SBM model under VRS (SBM-I-V) can be presented as follows:

$$\min_{\mathbf{s}_o^-, \boldsymbol{\lambda}} \ \rho = 1 - \frac{1}{m} \sum_{i=1}^{i=m} \frac{s_{io}^-}{x_{io}} \qquad \text{subject} \qquad \begin{aligned} &\mathbf{s}_o^- = \mathbf{x}_o - \mathbf{X}\boldsymbol{\lambda} \geq \mathbf{0}, \\ &\mathbf{Y}\boldsymbol{\lambda} - \mathbf{y}_o \geq \mathbf{0}, \\ &\boldsymbol{\lambda} \geq \mathbf{0}, \\ &\mathbf{e}'\boldsymbol{\lambda} = 1. \end{aligned} \tag{1}$$

where $\boldsymbol{\lambda}$ is a vector of non-negative weights, $\mathbf{X} = (\mathbf{x}_1, \ldots, \mathbf{x}_n) \in R_+^{m \times n}$ is a matrix of inputs, $\mathbf{Y} = (\mathbf{y}_1, \ldots, \mathbf{y}_n) \in R_+^{s \times n}$ is a matrix of outputs, $\mathbf{e}' \in R^n$ is a row vector in which each element is equal to 1, $\mathbf{s}_{\mathrm{o}}^-$ is a vector of potential disproportional slacks of the inputs (i.e. input excesses) and ρ is a SBM-I-V efficiency score taking the values in the interval (0,1]. Let an optimal solution for program (1) be $(\rho^*, \mathbf{s}_o^{-*}, \boldsymbol{\lambda}^*)$. The DMU $(\mathbf{x}_o, \mathbf{y}_o)$ is SBM-I-V efficient if and only if $\rho^* = 1$, i.e. $\mathbf{s}_o^{-*} = \mathbf{0}$, and that the DMU that does not qualify this requirement may be termed as SBM-I-V inefficient.

2.2 Second Stage: Investigation into the Determinants of Efficiency

Another important issue for the analysis is the need take into account the fact that efficiency of BTUs can be highly dependent on the conditions in which transport takes place. It is necessary to identify environmental influences in order to explain variations in efficiency caused by factors external to the BTUs. It is important for correctly evaluation of the endogenous efficiency of individual BTUs. Endogenous efficiency often is called managerial efficiency or true efficiency, because it represents the efficiency under the agency's control (Barnum et al., 2008).

In the second stage, the DEA efficiency scores are used as dependent variables which are explained by relevant variables not directly included in the DEA analysis in the first stage. To investigate the determinants of efficiency, the Tobit model (also known as censored regression model) is employed in this study to accommodate the censored DEA efficiency scores. Following Fethi et al. (2000), there would be a concentration of variables at unity. For this purpose, censoring at zero was suggested. Therefore using the formula in (2), the DEA efficiency scores $\rho_i^*,\ i=1,...,n$ computed by the SBM-I-V model (1) are transformed and thus censoring point is concentrated at zero as follows:

$$\rho_i^{\#} = \left(1/\rho_i^*\right) - 1 . \tag{2}$$

The best practising BTUs with an efficiency score of 100% is transformed to zero. Under this transformation, BTUs having efficiency scores less than 100% will take any positive value. Thus, transformation bounds the DEA efficiency score in one direction and censors the distribution at zero value.

The standard Tobit model is defined as follows:

$$\rho^{\#}{}_i = \begin{cases} \beta^T X_i + \varepsilon_i, & \beta^T X_i + \varepsilon_i > 0 \\ 0, & \beta^T X_i + \varepsilon_i \le 0 \end{cases}, \tag{3}$$

where $\varepsilon_i \sim N\ (0, \sigma^2)$ is an disturbance term, X_i is a vector of explanatory variables and β is a vector of unknown parameters to be estimated.

When the DEA efficiency scores were transformed, the coefficient of the Tobit model indicates the expected proportionate change of dependent variable with respect to one unit change in independent variable $X_{i,}$ holding other factors constant.

4. Empirical Results and Discussion

4.1. Data and the Specification of Variables

The attention is given to the technical efficiency assessment of 15 BTUs (see Table 1) in the Slovak republic in the year 2014. Since BTUs are public utility service with a social objective, it is essential to regularly monitor their performance (Agarwal, 2010). The main aim of this paper is in the first stage to evaluate technical efficiency of the BTUs in the Slovak republic using the DEA method and in the second stage to investigate the determinants of efficiency by using censored regression techniques.

Table 1 BTUs considered in the analysis

No.	BTU	No.	BTU
1	Slovak Lines Inc.	9	ARRIVA Liorbus Inc.
2	SBT Trenčín Inc.	10	SBT Prešov Inc.
3	SBT Žilina Inc.	11	SBT Humenné Inc.
4	SBT Prievidza Inc.	12	ARRIVA Michalovce Inc.
5	ARRIVA Nové Zámky Inc.	13	Eurobus Inc.
6	SBT Dunajská Streda Inc.	14	CTC Považská Bystrica Inc.
7	SBT Lučenec Inc.	15	CTC Žilina Inc.
8	SBT Poprad Inc.		
CTC – City Transport Company; SBT – Slovak Bus Transport			

Source: the authors

To evaluate the technical efficiency of the BTUs, two inputs, viz., Bus drivers (x_1) and Fleet size (x_2) and one output, namely, Passenger kilometers (y) are considered. The dataset summarized in Table 2 was obtained from the annual reports of the BTUs.

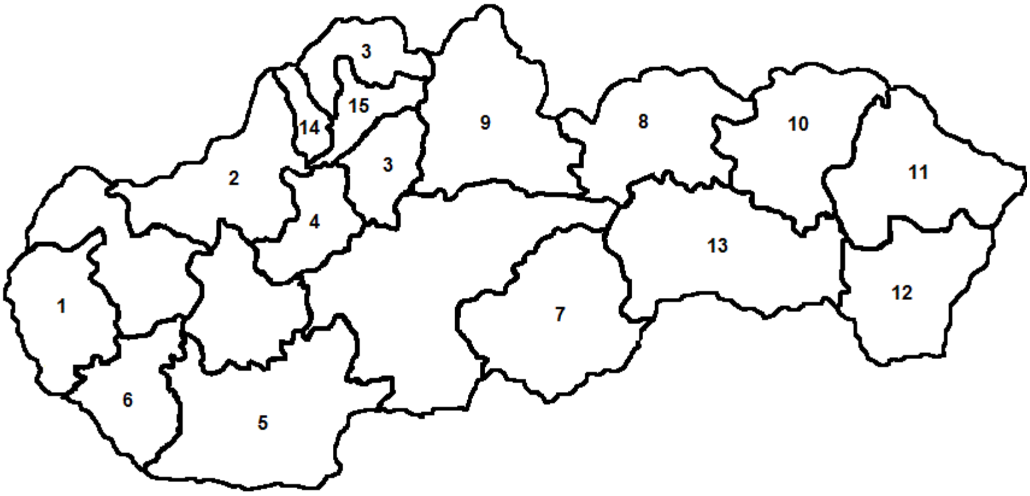
Table 2: Summary statistics of considered input and output data for BTUs

	Units	Max	Min	Mean	S.D.
Inputs					
x_1 Bus drivers	Number	503	43	271.2	125.8
x_2 Fleet size	Number of buses	335	25	208.6	89.4
Outputs					
y Passenger kilometers	10^{12} Pkm	423.29	3.81	157.08	127.38

Source: the authors

The BTUs carry out UPT and RBT operations in the different areas of the Slovak republic. The regional distribution of the BTUs´ operations in the Slovak republic is graphically illustrated by Figure 1.

Figure 1: Regional distribution of the BTUs operations in the Slovak Republic



Source: the authors

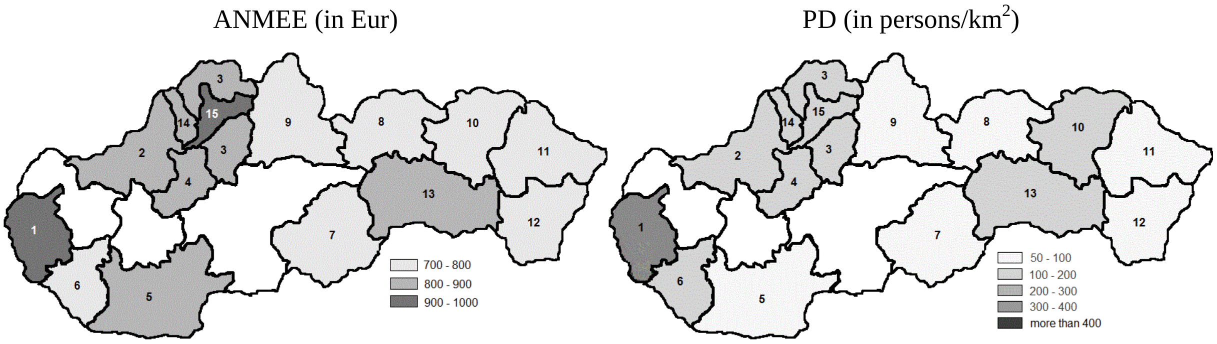
To further investigate the effects of exogenous variables on the efficiency of these BTUs, we follow with a Tobit regression. Using the DEA efficiency scores ρ_i^* obtained from SBM-I-V evaluations and transformed according to formula (2) as the dependent variable, we estimate the following regression model

$$\rho_i^{\#} = \beta_0 + \beta_1 ANMEE_i + \beta_2 PD_i + \varepsilon_i \qquad (4)$$

where variables *ANMEE* and *PD* represent aspects of the BTU's environments that may influence efficiency, but which are out of management control. We consider the effects of average nominal monthly earning of employee in Eur (*ANMEE*) and population density in persons/km^2 (*PD*) in the regions where the BTUs operate. Both variables may have a considerable influence on efficiency when comparing BTUs in different regions, and there is little management can do to affect this difference.

The level of *ANMEE* in the region can have an impact on the frequency of the use of public transport. The effect, however, may be ambiguous. On the one hand, higher wages may cause a preference for relatively more expensive, but more comfortable, individual transport, but on the other hand, higher wages are typical for those advanced regions in which regular transfers to work and schools is, due to the congested road traffic, preferable to carry out by public transport. While in the first case, the high wages counteract the public transport activities (adverse effect on the BTUs´ efficiency), in the second case, the high wages support the public transport activities (favorable impact on the BTUs´ efficiency). In terms of the *PD* variable, it is assumed that higher population density acts in favor of the BTUs´ activities. The higher population density, the better conditions for realization of public bus transport. As shown in Figure 2, there are relative differences between BTUs in terms of monitored exogenous variables.

Figure 2: Exogenous variables according to regional distribution of the BTUs



ANMEE (in Eur)

PD (in persons/km^2)

Source: the authors

4.2. Efficiency Estimation

Following the methodology described in Section 2, we evaluate the efficiency of all 15 BTUs by running the SBM-I-V DEA model. Table 4 summarizes the efficiency scores.

Table 3: The results of SBM-I-V model

No. of BTU	DEA efficiency score (ρ^*)	Rank	Excesses (in %)	
			Bus drivers (x_1)	Fleet size (x_2)
1	0.6626	6	19.53	47.95
2	0.8335	3	16.29	17.01
3	1.0000	1	0.00	0.00
4	0.4607	13	50.82	57.03
5	0.6406	8	31.36	40.51
6	0.3859	15	59.86	62.96
7	0.5307	9	40.90	52.95
8	0.4453	14	47.74	63.20
9	0.6561	7	24.63	44.15
10	0.5185	10	42.17	54.14
11	0.4782	12	46.08	58.28
12	0.5093	11	47.08	51.05
13	0.6932	5	22.31	39.05
14	1.0000	1	0.00	0.00
15	0.7065	4	23.46	35.24

Source: the authors

The results in Table 4 show that Slovak public bus transport industry displays significant variations in efficiency levels. The overall efficiency has a mean score of 63.5% for all BTUs in 2014 and only two BTUs (No. 3 and 14) achieve SBM-I-V efficiency. The remaining 13 BTUs exhibit varying degrees of inefficiencies, which implies that some resources are still not being fully utilized. These BTUs need to rearrange inputs (the number of bus drivers and number of busses) to improve their efficiency. Full SBM-I-V efficiency is attainable by a reduction in the number of redundant bus drivers by 16.29 – 50.82 % and by a reduction in the number of unused or deprecated busses by 17.01 – 63.20 %.

4.3. Explaining the Determinants of Efficiency

To incorporate the differences among the BTUs, we estimate the Tobit regression described in equation (4) by data of 2014. The results of the Tobit regression are summarized in Table 4. Tobit model was estimated in R with function `censReg`, which is available in the **`censReg`** package (Henningsen, 2011).

Table 4: The results of Tobit model

Total	Left-censored	Uncensored	Right-censored
15	2	13	0
Variables	Coefficient	t-statistic	p-value
Intercept	6.004203	3.765	0.000166
ANMEE	-0.007368	-3.178	0.001485
PD	-0.005219	-1.810	0.07092
logSigma	-1.007751	-4.934	8.06e-07
Log-likelihood	-7.764966 on 4 Df		

Source: the authors

It is important to note, that the dependent variable in the model is the inefficiency, which were obtained by transformation of the DEA efficiency scores. Thus the sign of the coefficients is reversed and it implies that a positive coefficient means an association with inefficiency increase (or efficiency decrease) and negative coefficient means an association with inefficiency decrease (or efficiency increase). For easy interpretation (for easy use) we will use the sign of estimated coefficient in accordance with the original forms, i.e. efficiency scores.

It is noted that average nominal monthly earning of employee in Eur (*ANMEE*) has a statistically significant positive coefficient. It means that this environmental variable has positive influence on technical efficiency levels. This result is in accordance with the second mentioned possible effect of wages on the BTUs´ efficiency, i.e. higher wages tend to attain a higher efficiency. The environmental variable population density (*PD*) has a positive sign but it is statistically significant only at 10% level and higher. This low statistically significance may be, in this case, caused by a relatively low number of observations in the sample. Population density suggest that the bigger the town, given certain resources, the greater the efficiency expected in the performance services.

The statistical significance of the environmental variables beyond managerial control implies that these variables can affect the DEA efficiency score. We computed the new efficiency indicators using the Tobit regression model presented in Table 4 (Tobit efficiency scores $\hat{\rho}^{\#}$) and compared them with the DEA efficiency scores. The results are presented in Table 5.

Table 5: The comparison of efficiency scores

No.	BTUs	DEA efficiency score (ρ^*)	Rank	Tobit efficiency score ($\hat{\rho}^\#$)	Rank	Shift in rank
1	Slovak Lines Inc.	0.6626	6	0.6178	8	-2
2	SBT Trenčín Inc.	0.8335	3	0.7263	2	1
3	SBT Žilina Inc.	1.0000	1	0.6705	5	-4
4	SBT Prievidza Inc.	0.4607	13	0.5575	10	3
5	ARRIVA Nové Zámky Inc.	0.6406	8	0.6835	4	4
6	SBT Dunajská Streda Inc.	0.3859	15	0.5008	12	3
7	SBT Lučenec Inc.	0.5307	9	0.4767	13	-4
8	SBT Poprad Inc.	0.4453	14	0.5242	11	3
9	ARRIVA Liorbus Inc.	0.6561	7	0.6666	6	1
10	SBT Prešov Inc.	0.5185	10	0.4524	14	-4
11	SBT Humenné Inc.	0.4782	12	0.4521	15	-3
12	ARRIVA Michalovce Inc.	0.5093	11	0.5850	9	2
13	Eurobus Inc.	0.6932	5	0.7030	3	2
14	CTC Považská Bystrica Inc.	1.0000	1	0.6544	7	-6
15	CTC Žilina Inc.	0.7065	4	1.0000	1	3

Source: the authors

We believe that the DEA efficiency score does not reflect true managerial and operational efficiency. The results will be closer to the real of efficiency only after the effects of environmental variables are taken into consideration in the efficiency evaluation. Table 5 shows that in some BTUs a significant change in the rank is observed. For example BTUs No. 3 and 14 were most efficient within the first stage of DEA efficiency evaluation, but in the second stage after including environmental variables into analysis, these BTUs were classified as "mid-range" performers. A total of 6 BTUs had worsened their rank. On the other hand, 9 BTUs had improved their ranking. After including environmental variables, BTU No. 15 is only one efficient performer.

5. Conclusion

This paper attempts to identify the effect of environmental variables on technical efficiency. We focused on the efficiency assessment of 15 BTUs in the Slovak republic in the year 2014. We followed the two stage procedure conventionally used in the cases when external factors are considered in the efficiency analysis. In the first stage, we measured technical efficiency of transport companies using the SBM-I-V DEA model with using two input (number of bus drivers and fleet size) and one output (number of passenger kilometers) variables. To take into consideration the effect of determinants that are beyond the managerial control, we followed with the second stage, where Tobit regression model was employed. In the Tobit model, two explanatory variables were incorporated, namely average nominal monthly earning of employee and population density.

The empirical results show that a BTU which operates in a region with higher wages and higher population density tends to achieve higher efficiency. It should be noted, that we are aware of the fact, that other important external factors that may affect the BTUs activities are left out in our analysis, such as ownership (private vs. public), subsidy policies, type of the prevailing transport (UPT vs. RBT), etc. These factors were missed out in our analysis due to lack of data. The omission of these variables in our analysis makes it difficult to interpret Tobit efficiency score as an indicator for true managerial and operational efficiency.

Based on our empirical results it can be concluded when efficiency of companies is evaluated than it is necessary to take into consideration the impact of different environment in which the companies operate.

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