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Economic Efficiency of Forest Enterprises—Empirical Study Based on Data Envelopment Analysis

Nikolay Neykov [1], Stanislava Krišťáková [2,*], Iveta Hajdúchová [2], Mariana Sedliačiková [3], Petar Antov [4] and Blanka Giertliová [2]

[1] Faculty of Business Management, University of Forestry, 1797 Sofia, Bulgaria; nneykov@ltu.bg
[2] Faculty of Forestry, Technical University in Zvolen, 96001 Zvolen, Slovakia; hajduchova@tuzvo.sk (I.H.); giertliova@tuzvo.sk (B.G.)
[3] Faculty of Wood Sciences and Technology, Technical University in Zvolen, 96001 Zvolen, Slovakia; sedliacikova@tuzvo.sk
[4] Faculty of Forest Industry, University of Forestry, 1797 Sofia, Bulgaria; p.antov@ltu.bg
* Correspondence: xkristakova@is.tuzvo.sk

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Abstract: Countries are forced to develop bio-based economic strategies to promote efficient use of renewable natural resources. The transition towards a sustainable forest bio-based economy is associated with resource efficiency optimization, adoption of innovative bio-based approaches in terms of technological improvements and cost effectiveness, and an opportunity to reach multiple societal challenges. This paper is focused on a comparative analysis of the forestry sector in the Republic of Bulgaria and the Slovak Republic by estimating the economic efficiency of four Bulgarian state-owned forest enterprises and four Slovak forest enterprises. The evaluation of economic efficiency was carried out using selected indicators of the studied enterprises over a period of five years. A data envelopment analysis (DEA) approach was used as a non-parametric linear technique for measuring the relative efficiency of a set of production decision-making units (DMUs). The Malmquist productivity index (MPI) was used to assess the pure efficiency changes (PEC) and technological changes (TCs) of the studied forest enterprises. Data for 2014–2018 were processed. The results obtained for the economic efficiency study outlined the major factors affecting the differences in efficiency scores. The long-term sustainability and increased economic efficiency of forest enterprises in both countries can be achieved by improvements in forest management and investments in research and development activities.

Keywords: forest enterprises; data envelopment analysis; economic efficiency; forest bio-based economy; technical and organizational innovations

1. Introduction

The efficiency of forestry and forest enterprises has been a topical issue with consistent appeal for many years. Forest bio-based economies manage to meet sustainability challenges, innovate bio-based approaches and provide an opportunity to reach multiple societal challenges [1–3]. Kao and Yang [4] investigated the relative efficiency of forestry management to obtain a guideline for planning. Viitala and Hänninen [5] estimated the technical and scale efficiency of public forest enterprises in order to support the budget cut offs. Li et al. [6] provided analysis of the efficiency of whole forest territories in Chinese provinces in terms of resource effectiveness. In many cases, researchers focused mainly on operational efficiency of forests [7–9]. When it comes to forestry efficiency many authors involved ecological [10], socio-eco-efficiency [11,12], climate change [13–15], ecosystem services [16,17], bio-based economy [18,19], forest certification [20–23], and forest offices organizational structure [24]. The papers on the current topic appear to broadly cover the problem of forestry efficiency. Studies present efficiency scores in cross-country comparisons but do not factor the differences at an enterprise level; hence, future improvement of the analysis is needed. A common theme in many of the recent studies is the methodology used, which is comprised of the application of the data envelopment analysis (DEA). DEA was successfully implemented in the forestry efficiency calculation by Alzamora and Apiolaza [25] who estimated the efficiency of usage of pine logs for grade producing, and by Susaeta et al. [26] with a calculation of the efficiency of an entire pine forest. In the same manner, Boosari et al. [27] directly compared alternate plans for forestry management. Kovalčík [28] compared the Slovak forestry efficiency to other European countries, which was via direct comparisons throughout the forestry of European Union countries. In addition, Kovalčík [28], Gutiérrez and Lozano [29] made direct cross-country efficiency comparisons of the forest sector using the DEA approach. The research of Gutiérrez and Lozano covered 29 countries including Bulgaria and Slovakia. Kovalčík analyzed 22 countries and covered indicators for entire forest sectors in each studied country. Korkmaz [30], Sporcic et al. [31,32] used DEA to calculate efficiency of forestry units at the level of enterprises. A recent study by Lundmark et al. [33] focused on DEA, and explicitly addressed the efficiency issues; they proved that long-term sustainability and efficiency could be increased if a more efficient forest management approach was adopted. Li et al. [34] stated in their conclusions that efficiency resulted from the industrialization of advanced forestry and manufacturing technologies. Other studies [35–38] investigated the particular aspects of business foundations that generate efficiency. Furthermore, the current widespread outbreak of the COVID-19 pandemic posed new challenges to enterprises, recently investigated by Hitka et al. [39], which made resolving the trivial problems more topical in order to sort out the new ones.

The forests of Bulgaria cover a territory of about 3893 million ha [33]. The forest area represents about 30% of the country's territory. Broadleaved forests account for 72% of the forest area, and coniferous forests account for 28% of the area. The growing stock of Bulgarian forests has almost tripled from the 1960s and now amounts to about 680 million m^3 [40].

Forests with economic purposes, i.e., forests with the primary function of wood production, are the most predominant type, accounting for over 68% of the total forest area and 64% of the tree stock. Three quarters of the forests are state-owned, while the remainder are owned by individuals, municipalities, and institutions. Bulgarian forests are managed in accordance with forest management plans, providing guidance on management and setting the quantity of wood from forests to be used over a period of 10 years ahead. Over half of the forests in Bulgaria are situated on slopes of over 20°, making harvesting and reforestation activities very difficult. Forestry activities like plantation and logging are predominantly implemented in some of the poorer rural regions of the country. They provide jobs to more than 12,000 people. Forest-based industries in the country provide incomes to more than 40,000 people, most of them located in poor and vulnerable regions.

In 2019, the total area of forests in the Slovak Republic was estimated to 1949 million ha. The country's territory covered by forests, calculated as the percentage of forest land out of the total area of the Slovak Republic, reached 41.3% in 2019. Broadleaved tree species account for 63.5% of the forest area, and coniferous tree species account for 36.5%, respectively. These percentages have been steadily decreasing due to harmful impacts on the forests. The majority of Slovak forests are natural forests. Growing stock volume continues to increase, reaching 483 million m^3 in 2019. The most common category of forests in Slovakia is production forests, accounting for 73% of all forests, and this area has increased by 6.3% since 2000. Terrain conditions in Slovakia are relatively challenging with more than 50% of the forests located on slopes over 20°. In 2019, forest enterprises supplied 8.96 million m^3 of timber and sectoral earnings and revenues reached €968.1 million. Forty percent of the forestry land is state-owned; the remaining area of forests is managed and owned by the private sector, municipal, church and community forests, and agricultural cooperatives. The aim of the forestry in rural areas is to contribute to the development and to maintain employment. Forestry directly employs approximately 9000 employees. In addition, there are nearly another 10,000 self-employed sole traders [41,42].

Bulgarian forest enterprises (BFE) have not yet been analyzed with the DEA approach. Yovkov and Kolev [43] estimated the Bulgarian forestry efficiency implementing the return on investment method, based on transaction costs. Kolev [44] also developed performance measurement, using an investments assessment of forestry units. Kovalčík [45] estimated the performance of Slovak forest contractors, using DEA for the assessment efficiency and profitability of Limited Liability Companies in the forestry service sector in Slovakia.

In both countries studied, the forestry sector plays an important role by providing employment to people from the poorest rural regions. According to Lu et al. [46] and Jiangdi et al. [47] poverty among farmers can be significantly reduced by improving the efficiency of the forestry sector. Existing studies on the forestry sector and forest enterprises in both countries were implemented mainly on a national basis. There are no investigations that reveal the sources of efficiency inside the forest enterprises on a comparative basis. In the present paper we tried to outline some of the main features of the specific business models for both countries and uncover the pros and cons for each of them. In addition, this provides opportunities for intercountry sharing experiences.

The aim of the current study was to estimate the efficiency scores of four Bulgarian state-owned enterprises with a direct comparison to four Slovak ones, and outline the major factors affecting the differences in efficiency scores by the DEA-Malmquist productivity index. The evaluation of profitability was obtained by using selected indicators of financial data for a period of five years. The results helped to identify the parameters affecting the efficiency and possibilities for further development of forest enterprises in both countries.

2. Materials and Methods

This research estimated the cost efficiency of forest enterprises in Bulgaria and Slovakia by an input-oriented DEA model. In this way the analysis clarifies the specifics of resource involvement in the business model for each country. To reveal the reasons for improvement during the period, the Malmquist index supplements the results with information about some of the main reasons for improvement in forest enterprises in both countries—the degree of costs transformed into revenues (technical efficiency) and the technological improvements hidden behind the efficiency changes.

The selected period for the research was 2014–2018 due to the availability of economic and financial data. It is based on the requirement for comparability of the business activities through the years and the last available published accounting reports. The analyzed forest enterprises follow a fundamental strategy prioritizing the development and protection of sustainable forest ecosystems. Some of the basic activities of the above-mentioned enterprises included timber harvesting, cultivation activities, afforestation and other specific services.

Supplementary analysis was conducted by using the slack-based model (SBM) in order to give recommendations to enterprise managers and specify a range of quantitative goals for enterprises' improvement.

2.1. Data Envelopment Analysis (DEA)

DEA is a non-parametric technique that makes it possible to comparatively assess the efficiency scores of several basic production components [48]. The essence of DEA in measuring the relative efficiency of production decision-making units (DMUs) lays in maximizing its efficiency rate. The main advantage of using DEA is the assumption that the production function in forestry is unknown. In this way, the study removes subjective assumptions or additional analysis of its nature, for which reliable data can rarely be found. DEA will compare each DMU in the sample with the best-practice DMUs [48]. In the study, the DEA–Malmquist productivity index (MPI) [49–51] was implemented. DEA–MPI has proved to be a good tool for measuring the productivity change of DMUs that can measure the change in the technology frontier and in technical efficiency [52].

In research by conducted by Mlynarski and Kaliszewski [53], DEA was evaluated as the most important non-parametric approach used to measure the efficiency of forest management. The DEA approach provides various models. In the context of returns to scale according to Lei et al. [54], it is the appropriate model if the DMUs operate in optimal scale. The Charnes, Cooper and Rhodes (CCR) model, developed by Charnes et al. [55], proposed that the efficiency of a DMU can be obtained from the maximum of a ratio of weighted outputs to weighted inputs. The Banker, Charnes and Cooper (BCC) model, developed by Banker et al. [56], is applicable in variable returns to scale. As stated by Cook et al. [57], the main task before using the DEA is to predetermine the purpose of the estimation. A classical input-oriented CCR model was applied in the present study as well as a BCC model [58–60] and also a SBM [61,62]. Thus the optimal combination and scale of inputs in forestry enterprises can be determined. Additional possibilities for total efficiency improvements have been revealed by the implementation of a SBM.

In this study, forestry enterprises (FE) in both countries were regarded as DMUs. The first task after the decision of the analysis orientation was to determine the number and the essence of the DMUs and the inputs and outputs. According to Martic et al. [61], in order to preserve the discriminating power of the method, the number of the units to be evaluated should be much greater than the number of inputs and outputs. According to Cooper et al. [62], the number of DMUs should be max {m × s; 3 × (m + s)}. This is the rule of thumb for DEA data preparation. In the current research the rule is partially observed. DMUs chosen were eight forest enterprises, four from Bulgaria and four from Slovakia, respectively. Inputs were selected as an output. Analysis was carried out with the implementation of a combination of two cost type and single input—single output efficiencies. All of these combinations were chosen to follow the rule of thumb to a sufficient degree.

Mathematical forms of the implemented DEA models are as follows:

CCR model for the period t:

$$\min\theta_0^t\left(x_o^t;\ y_o^t\right)\sum_{j=1}^{m}\lambda_j x_{ij} \le \theta x_{i0}\sum_{j=1}^{s}\lambda_j y_{rj} \ge y_{ro}\sum_{j=1}^{n}\lambda_j = 1 \text{ for the variable returns to scale (BCC) model} \quad (1)$$

where λ_j are individual scalars of each j-th DMU, x_{ij} are amounts of inputs of type i in DMU j, x_{i0} is the amount of i-th input of DMU being estimated, indexed with 0. If the additional constraint $\sum_{j=1}^{n}\lambda_j = 1$ is added, the model becomes the BCC with variable returns to scale.

2.2. Malmquist Productivity Index

Malmquist [63] presented the comparison of factor productivity, which means that the input in one period could be decreased to the next level and that the enterprise could produce the same output in the next period with a lower input (Malmquist input index). Caves et al. [64] improved the Malmquist input index to elaborate the so-called Malmquist productivity index. Fare et al. [65] and Oruc [66] measured the productivity change of a particular DMU by DEA. The models are as follows:

$$MI = PEC \times TC \quad (2)$$

where PEC is pure efficiency changes, TC—technological changes.

$$\mathrm{PEC} = \frac{\theta_0^{t+1}\left(x_o^{t+1};\ y_o^{t+1}\right)}{\theta_0^t\left(x_o^t;\ y_o^t\right)} \quad (3)$$

$$\mathrm{TC} = \left(\frac{\theta_0^t\left(x_o^t;\ y_o^t\right)\ \theta_0^t\left(x_o^{t+1};\ y_o^{t+1}\right)}{\theta_0^{t+1}\left(x_o^t;\ y_o^t\right)\ \theta_0^{t+1}\left(x_o^{t+1};\ y_o^{t+1}\right)}\right)^{1/2} \quad (4)$$

where $\theta_0^{t+1}\left(x_o^{t+1};\ y_o^{t+1}\right)$ are the minimum DEA scores from the CCR model with inputs of year $t + 1$ and output of t-th year, $\theta_0^{t+1}\left(x_o^t;\ y_o^t\right)$ are the minimum DEA scores with inputs of year t and output of year $t + 1$, $\theta_0^t(x_o^t;\ y_o^t)$ and are $\theta_0^{t+1}(x_o^{t+1};\ y_o^{t+1})$ the minimum DEA scores for year t and $t + 1$ inputs and outputs.

2.3. Slack-Based Model (SBM)

If the goals are not oriented particularly to inputs or outputs, the slack-based model (SBM) is recommended [67]. This method simultaneously resolves the problem of undesired output as well as the non-zero relaxation between inputs and outputs in the production processes. SBM is not suitable for individual input DEA, because the model suggests all the slacks should be regarded as outputs, which is the reason to implement SBM here for two input calculations. Ning et al. [68] assessed state-owned forestry enterprises' overall eco-efficiency by analyzing various undesirable outputs using the SBM-DEA model. A slack-based model is in the form of equal weights of inputs and outputs, as follows:

$$\max \sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+ \sum_{j=1}^{n} \lambda_j x_{ij} + s^- = x_{i0} \sum_{j=1}^{n} \lambda_j y_{rj} - s^+ = y_{ro} \tag{5}$$

where the s^- and s^+ are slacks to the best performance of input usage or output production.

The SBM can directly address recommendations to a particular input or output to be improved.

3. Results

3.1. Results of DEA

The calculation results performed by Formula (1) are presented in Table 1. All forest enterprises were assessed by the DEA in CCR and BCC models, which allowed direct comparison of efficiency scores.

The table shows that all enterprises were more efficient in terms of resource usage (pure efficiency changes), at the expense of the optimality of scale (scale efficiency). The most efficient enterprise according to most of the inputs is the South Central forest enterprise in Bulgaria. It is the leader in all types of inputs involved, excluding the other costs. Changes throughout the years of the analyzed time period are relatively small. An interesting result was that enterprises were stable in their efficiency. This shows that they had not made any significant changes, both in the management and nature of the production resources used. Although there is a prominent leader in the Bulgarian forest enterprises, this is not so obvious for the Slovak ones. In terms of a combination of inputs, the overall leader is Forest farm Ulič, s.e.; by labour costs efficiency it is Town FORESTS Košice, JSC; by the materials costs utilization, and by the other costs—again Town FORESTS Košice, JSC. These results are supported by the values presented in Table 2.

Scores in Table 2 demonstrated that the scores (static efficiency) of the Bulgarian enterprises are higher for the entire studied period. Furthermore, the t-statistic proved that the differences were significant; they were more efficient in the utilization of labor and materials with a better scale of efficiency. The big problem here appears in the other costs section. While the Slovak forest enterprises had slightly lower efficiency of labor and materials being purchased, the Bulgarian ones did not manage costs efficiently for external services, interests, etc. The reasons for this can be found in the way the Bulgarian enterprises execute their current activities, especially harvesting. The biggest part of their operations related to timber harvesting and transportation to temporary sites for selling were purchasing, which is mainly performed by external companies. In this respect, the harder part of ensuring the efficiency falls to these costs, but not to labor or materials being purchased.

Table 1. Efficiency scores of the forest enterprises analyzed by the input-oriented models. (s.e. means State enterprise, JSC stands for Joint Stock Company).

Inputs: Labor Costs and Material Costs										
			CCR					**BCC**		
DMU Name	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
North Western	0.95	0.81	0.99	0.90	0.92	1.00	1.00	1.00	1.00	1.00
North Central	0.93	0.83	0.86	0.83	0.94	0.96	0.96	1.00	0.93	0.98
South Western	0.92	0.90	1.00	0.85	0.83	0.93	0.98	1.00	0.88	0.87
South Central	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FORESTS Slovakia, s.e.	0.68	0.63	0.65	0.69	0.67	1.00	1.00	1.00	1.00	1.00
Military FORESTS, s.e.	0.55	0.46	0.48	0.51	0.50	0.57	0.54	0.54	0.55	0.53
Forest farm Ulič, s.e.	0.68	0.62	0.69	0.69	0.76	1.00	1.00	1.00	1.00	1.00
Town FORESTS Košice, JSC	0.62	0.56	0.59	0.64	0.65	1.00	1.00	1.00	1.00	1.00
Inputs: Labor Costs										
DMU Name			**CCR**					**BCC**		
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
North Western	0.77	0.76	0.99	0.90	0.75	1.00	1.00	1.00	1.00	1.00
North Central	0.52	0.59	0.66	0.66	0.70	0.62	0.72	0.67	0.70	0.83
South Western	0.84	0.90	1.00	0.72	0.83	0.91	0.98	1.00	0.74	0.87
South Central	1.00	1.00	0.88	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FORESTS Slovakia, s.e.	0.22	0.22	0.27	0.24	0.23	1.00	1.00	1.00	1.00	1.00
Military FORESTS, s.e.	0.30	0.26	0.30	0.24	0.22	0.35	0.32	0.30	0.26	0.27
Forest farm Ulič, s.e.	0.14	0.14	0.16	0.16	0.14	0.43	0.44	0.38	0.38	0.43
Town FORESTS Košice, JSC	0.27	0.28	0.31	0.31	0.28	0.85	0.99	0.80	0.80	0.93
Inputs: Material Costs										
DMU Name			**CCR**					**BCC**		
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
North Western	0.95	0.81	0.75	0.76	0.92	1.00	0.97	0.87	0.89	1.00
North Central	0.93	0.83	0.86	0.83	0.94	0.96	0.94	0.95	0.91	0.98
South Western	0.92	0.78	0.81	0.85	0.77	0.93	0.82	0.84	0.87	0.78
South Central	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FORESTS Slovakia, s.e.	0.68	0.63	0.65	0.69	0.67	1.00	1.00	1.00	1.00	1.00
Military FORESTS, s.e.	0.55	0.46	0.48	0.51	0.50	0.57	0.53	0.53	0.55	0.53
Forest farm Ulič, s.e.	0.68	0.62	0.69	0.69	0.76	1.00	1.00	1.00	1.00	1.00
Town FORESTS Košice, JSC	0.62	0.56	0.59	0.64	0.65	0.94	0.99	0.92	0.98	0.91
Inputs: Other Costs										
DMU Name			**CCR**					**BCC**		
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
North Western	0.01	0.01	0.02	0.02	0.01	0.03	0.04	0.03	0.03	0.05
North Central	0.01	0.01	0.02	0.02	0.02	0.03	0.04	0.04	0.03	0.10
South Western	0.02	0.01	0.02	0.02	0.02	0.04	0.05	0.04	0.03	0.09
South Central	0.01	0.01	0.01	0.01	0.01	0.05	0.04	0.04	0.03	0.07
FORESTS Slovakia, s.e.	0.30	0.22	0.35	0.51	0.18	1.00	1.00	1.00	1.00	1.00
Military FORESTS, s.e.	0.34	0.09	0.29	0.26	0.24	0.92	0.32	0.66	0.43	1.00
Forest farm Ulič, s.e.	1.00	0.73	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00
Town FORESTS Košice, JSC	0.20	1.00	0.56	0.35	0.54	0.21	1.00	0.60	0.37	0.58

Table 2. Average scores for the entire period by enterprise and country with statistical significance in scores, α = 0.05.

Average Scores for the Entire Period by Country								
	LC/MC		LC		MC		OC	
	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC
North Western	0.91	1.00	0.83	1.00	0.84	0.95	0.02	0.04
North Central	0.88	0.97	0.63	0.71	0.88	0.95	0.02	0.05
South Western	0.90	0.93	0.86	0.90	0.83	0.85	0.02	0.05
South Central	1.00	1.00	0.98	1.00	1.00	1.00	0.01	0.05
FORESTS Slovakia, s.e.	0.66	1.00	0.24	1.00	0.66	1.00	0.31	1.00
Military FORESTS, s.e.	0.50	0.55	0.27	0.30	0.50	0.54	0.24	0.67
Forest farm Ulič, s.e.	0.69	1.00	0.15	0.41	0.69	1.00	0.95	1.00
Town FORESTS Košice, JSC	0.61	1.00	0.29	0.87	0.61	0.95	0.53	0.55
	0.77	0.93	0.53	0.77	0.75	0.90	0.26	0.43
Average Scores for the Entire Period by Country								
	LC/MC		LC		MC		OC	
	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC
Bulgarian enterprises	0.92	0.97	0.82	0.90	0.89	0.94	0.02	0.05
Slovakian enterprises	0.62	0.89	0.23	0.65	0.62	0.87	0.51	0.80
	Shapiro–Wilk W test for normal data							
	p-value							
	LC and MC		LC		MC		OC	
BG	0.55		0.73		0.17		0.99	
SK	0.18		0.39		0.55		0.41	
	t-test for differences							
t-test *p*-value	0.0008		0.0003		0.0031		0.0221	

3.2. Results of the Malmquist Productivity Index

For the MPI we used an approach similar to that used by Pacagnella et al. [67] for the efficiency scores. The difference between every two years, calculated by the MPI, was valuable for the countries if there was any statistically significant difference between years in efficiency scores. The results of the Shapiro–Wilk test for normality are given in Table 3.

Table 3. Empirical probabilities of Shapiro–Wilk W test, α = 0.05.

Shapiro–Wilk W Test for Normal Data Prob > z					
Bulgaria					
	2014	2015	2016	2017	2018
LC and MC	0.405	0.511	0.100	0.458	0.846
LC	0.870	0.895	0.219	0.618	0.594
MC	0.405	0.132	0.726	0.567	0.474
OC	0.669	0.427	0.438	0.336	0.530
Slovakia					
	2014	2015	2016	2017	2018
LC and MC	0.60839	0.33865	0.71338	0.11206	0.71158
LC	0.72788	0.3823	0.1767	0.68541	0.71511
MC	0.25978	0.29892	0.77779	0.13543	0.69655
OC	0.05981	0.53082	0.35508	0.33041	0.42505

The results in the table show that the efficiency scores are normally distributed in all years studied. This result justified the application of the t-test for comparison by years. A paired data t-test was used in the study. This was due to the assumption that each enterprise was compared in the year before any possible changes and the following year(s). Comparisons were made by the type of inputs, i.e., type of DEA models; the significance of the year-to-year differences is presented in Table 4.

Table 4. *p*-values of *t*-test for the year-to-year differences in CCR scores, $\alpha = 0.05$.

		Bulgarian Enterprises				Slovak Enterprises			
Year	**to Year**	**LC/MC**	**LC**	**MC**	**OC**	**LC and MC**	**LC**	**MC**	**OC**
2014	2015	0.144	0.230	0.063	0.056	0.005 *	0.540	0.005 *	0.850
	2016	0.722	0.270	0.100	0.250	0.160	0.089	0.160	0.400
	2017	0.079	0.580	0.100	0.087	1.000	0.830	1.000	0.370
	2018	0.309	0.480	0.330	0.260	0.680	0.540	0.068	0.790
2015	2016	0.149	0.400	1.000	0.005 *	0.060	0.012 *	0.065	0.820
	2017	0.754	0.920	0.850	0.005 *	0.002 *	0.340	0.002 *	0.930
	2018	0.459	0.850	0.210	0.055	0.047 *	0.540	0.048 *	0.900
2016	2017	0.135	0.510	0.750	0.007 *	0.070	0.210	0.069	0.800
	2018	0.506	0.510	0.340	0.370	0.048 *	0.048 *	0.048 *	0.210
2017	2018	0.409	1.000	0.440	0.860	0.579	0.016 *	0.570	0.730

* statistically significant changes.

The results of the table can be used to make hypotheses about the actions of companies in the particular country. The results given in Table 4 reveal the path of development over the years. The existence of a statistically significant difference between two years means that the enterprises have undergone some changes during these two years. The absence of significant differences between any two years does not mean that the companies have returned to the previous technological level.

Results undoubtedly show that the Bulgarian enterprises have changed only the least efficient input—other costs. The Slovak enterprises have periodically improved some of the main inputs—labor and materials, and in 2018 they changed the efficiency of labor costs. The MPI reveals the nature of the significant changes in Table 5; Table 6.

The Bulgarian forest enterprises demonstrated an improvement in other costs management. Three of them, with the exception of the south western forestry enterprise, improved the efficiency on average in both periods. They managed to do this throughout the pure efficiency changes (PEC). It can be attributed to the improvement of the current year's management, including better prices for external services or the correct scheduling. The south central forestry enterprise recorded the greatest improvement in 2015. This was due to a 28% increment of the PEC. The north western forestry enterprise was the best performer in Malmquist. It gained a 30% improvement in PEC on average, but was down by −26% in technological changes. The problem of the Bulgarian enterprises' OC efficiency was the lack of technological improvement. This means that at present the enterprises optimize only the other costs efficiency, but do not change the types of processes that cause these costs.

Table 5. Malmquist Productivity Index of the investigated enterprises only for the statistically significant periods of changes.

Malmquist Index—Total Factor Productivity									
Inputs	LC/MC			MC		LC		OC	
Period	2014–2015	2015–2017	2016–2018	2014–2015	2015–2017	2015–2016	2017–2018	2015–2016	2016–2017
North Western								1.05	1.07
North Central								1.02	1.00
South Western								0.94	0.96
South Central								0.91	1.14
FORESTS Slovakia, s.e.	0.95	1.08	1.02	0.95	1.08	1.02	0.92		
Military FORESTS, s.e.	0.83	1.16	0.98	0.83	1.16	1.09	0.88		
Forest farm Ulič, s.e.	0.94	1.03	1.08	0.94	1.03	0.96	0.96		
Town FORESTS Košice, JSC	0.88	1.08	1.09	0.88	1.08	0.99	0.95		
Technological changes									
North Western								0.65	0.82
North Central								0.69	0.86
South Western								0.82	0.91
South Central								0.86	0.80
FORESTS Slovakia, s.e.	1.03	0.99	0.98	1.03	0.99	0.86	0.97		
Military FORESTS, s.e.	0.98	1.06	0.94	0.98	1.06	0.94	0.98		
Forest farm Ulič, s.e.	1.03	0.94	0.98	1.03	0.94	0.82	1.08		
Town FORESTS Košice, JSC	0.98	0.95	0.99	0.98	0.95	0.88	1.05		
Pure efficiency changes									
North Western								1.46	1.14
North Central								1.42	1.16
South Western								1.30	1.15
South Central								1.28	1.09
FORESTS Slovakia, s.e.	0.92	1.10	1.04	0.92	1.10	1.19	0.95		
Military FORESTS, s.e.	0.84	1.09	1.04	0.84	1.09	1.16	0.90		
Forest farm Ulič, s.e.	0.91	1.10	1.10	0.91	1.10	1.17	0.89		
Town FORESTS Košice, JSC	0.89	1.14	1.11	0.89	1.14	1.12	0.91		

Table 6. Descriptive statistics of the Malmquist Indexes.

Malmquist Index—Total Factor Productivity								
Inputs	LC/MC		MC		LC		OC	
	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
North Western							1.06	0.01
North Central							1.01	0.01
South Western							0.95	0.01
South Central							1.03	0.12
FORESTS Slovakia, s.e.	1.02	0.06	1.01	0.07	0.97	0.05		
Military FORESTS, s.e.	0.99	0.14	1.00	0.17	0.99	0.10		
Forest farm Ulič, s.e.	1.02	0.06	0.99	0.05	0.96	0.00		
Town FORESTS Košice, JSC	1.02	0.10	0.98	0.10	0.97	0.02		
Technological changes								
North Western							0.74	0.08
North Central							0.78	0.09
South Western							0.86	0.05
South Central							0.83	0.03
FORESTS Slovakia, s.e.	1.00	0.02	1.01	0.02	0.91	0.06		
Military FORESTS, s.e.	1.00	0.05	1.02	0.04	0.96	0.02		
Forest farm Ulič, s.e.	0.98	0.04	0.98	0.05	0.95	0.13		
Town FORESTS Košice, JSC	0.97	0.02	0.96	0.02	0.97	0.09		
Pure efficiency changes								
North Western							1.30	0.16
North Central							1.29	0.13
South Western							1.23	0.08
South Central							1.18	0.09
FORESTS Slovakia, s.e.	1.02	0.07	1.01	0.09	1.07	0.12		
Military FORESTS, s.e.	0.99	0.11	0.97	0.13	1.03	0.13		
Forest farm Ulič, s.e.	1.04	0.09	1.01	0.10	1.03	0.14		
Town FORESTS Košice, JSC	1.05	0.11	1.02	0.13	1.02	0.11		

The Slovak enterprises, unlike the Bulgarian ones, actively managed their labor and material costs, trying to improve the efficiency of their main resources. The Slovak enterprises improved mainly their PEC and to some extent the technology of economic activities. This proves that the type of management in the Slovak enterprises relied on internal services. In 2018, all of the enterprises faced a decrease in technical efficiency. On average, the best improvement was demonstrated by the FORESTS Slovakia, s.e. It underwent technological improvements for two of the investigated periods. The lowest performance in the Malmquist Index was Forest farm Ulič, s.e. Problems appeared here in a technological manner. Table 6 shows that the Slovak enterprises had better pure efficiency changes (PEC) than technological changes (TC). The reason for improvements with dynamic efficiency through time were the optimal combinations of inputs (costs) of labor and materials with outputs (revenues). These optimal combinations pushed the Slovak enterprises towards improvement. Forest farm Ulič, s.e. improved its PEC of LC and MC by 4% on average, and Town FORESTS Košice, JSC by 5%. FORESTS Slovakia, s.e. improved their utilization of labor costs by 7%—the highest increment in the indexes. Unlike the Bulgarian forest enterprises, there was an improvement in the method of materials utilization. The labor costs did not improve their total factor productivity—Malmquist index for the whole period.

3.3. Results of the Slack-Based Model

The slack-based model was implemented for the last year of the period studied. It directly suggests economies in inputs and improvements in outputs. The results for the slack-based model (2) are presented in Table 7.

Table 7. The slack-based model results for 2018—input and output slacks.

	Labor Costs	Material Costs	Revenues
North Western	18%		9%
North Central	25%		7%
South Western	0%	7%	21%
South Central	0%		0%
FORESTS Slovakia, s.e.	66%		49%
Military FORESTS, s.e.	56%		101%
Forest farm Ulič, s.e.	82%		31%
Town FORESTS Košice, JSC	57%		53%

Results clearly show the target for the economies in costs and the increment in revenues. It is interesting that the typical DEA algorithm compares everything with the most efficient enterprise—the south central forest enterprise in Bulgaria. The Slovak enterprises could drastically decrease their labor costs. The only problem with the material costs appeared in the Bulgarian south western forest enterprise. Military FORESTS, s.e. could almost double their revenue. All other enterprises had to improve their revenue except the south central enterprise in Bulgaria.

This is why the efficiency of forest enterprises is vital even for inter-sectoral income multiplication and here SBM proves its applicability. According to the results for SBM, slacks can be considered as practical recommendations for enterprises' management, i.e., the revenue slacks should be considered a high priority.

4. Discussion

Some of the main problems of the Slovak and Bulgarian forest enterprises are connected with technical inefficiency and lack of investments. As Diaz-Balteiro et al. [69] pointed out, the investments in research and development should be regarded as a means to improve the competitiveness of the companies. Comparing it with the Malmquist index results show that there is a lot to be desired from the Bulgarian enterprises. The lower technological changes component for these enterprises reveals that they have to invest in new technologies.

The results demonstrated that the low economic efficiency of state forest enterprises was due to low PEC. As a way to improve, some proposals were designed such as employing modern enterprise systems and accelerating the development of tertiary industries such as forestry tourism and forestry ecological services. It is an inevitable transition process to a bio-based economy to implement innovation in emerging technologies in the forestry sector [70–77].

Forest enterprises in both countries are significant employers providing employment in rural regions. Services like afforestation are regarded as an extremely important source of income for poor households and a viable tool to reverse deforestation and meet global environmental goals [64].

Šterbová et al. [73] referred to a competitive advantage of forest companies being brought about by the implementation of modern technologies. Whereas such implementations of modern technology play an important role in terms of positive impact on the environment, in many cases forestry companies have limited access to external sources of financing. Banks and lenders may regard forest enterprises as high-risk ventures because they operate seasonally, lack adequate business and financial management skills or have an inability to provide a credit history or collateral [53,75]. The Slovak forest enterprises use their own equity for financing their activities. This is one of the reasons for the lower efficiency and it is a potential opportunity for development and economic growth.

Results of our research showed that the DEA approach could also be used for generating directions for making future improvements.

5. Conclusions

In this article, the applicability of DEA for analyzing the forestry sector enterprises was demonstrated. The models showed that the Bulgarian enterprises had higher static labor and materials efficiency compared to the Slovak ones. This can be attributed to outsourcing activities out of the enterprises and relying on external services (sub-contractors). Markedly, DEA revealed the big difference of the business models between the examined enterprises. The Bulgarian forest enterprises rely on external services, with low material and labor costs. This model has worked for many years, but there are no guarantees that it will work in the future, mainly due to lack of improvement, proved by the Malmquist index, and the market fluctuations of external services. This business model could be considered as the reason for the lack of any improvement, neither organizational, nor technological, in the operational management of the Bulgarian forest enterprises. The current study can be used as guidelines for the management of Bulgarian forest enterprises. They have to include the labor costs more in their current activities. This research revealed that internal resources were not involved in improvements, despite being used efficiently. Investments in technology should be the main purpose of the enterprise management. In order to achieve this, the SBM recommendations should be addressed. All of the deficit that can appear from the transition of the Bulgarian forest enterprises business model to the Slovak one could be covered by central budget subsidiaries.

The Slovak forest enterprises rely on their own resources, which is the reason for the lower efficiency of labor and material costs. Financing mainly by owner equity has been used for a long time and is a potential opportunity for development and economic growth. This model puts the inefficiency over internal activities and requires constant technological improvements and current management in order to meet the goals of a bio-based economy. Despite technological changes, the lower efficiency of the labor and material costs should be improved following SBM. This means that not only the technology, but also the scale is very important for future development. The supply system and personnel education would be vital in order to meet SBM recommendations.

The Bulgarian business model makes enterprises more efficient, but does not lead to technological improvements, which hampers the sustainable development of the forest sector. New technologies improve harvesting and planting leading to costs efficiency. Moving all of these activities to within the enterprise would give improved control over them, which is the case in Slovakia, but not in Bulgaria. Thereby, the Slovak business model can be considered as more sustainable. The problem there appears from insufficient technological improvement to cover labor and material costs efficiency requirements. Slovak enterprises could consider the movement of some internal activities to external services, i.e., sources for financial funds accumulation.

The MPI revealed that these enterprises do what is required by the current management but it is not sufficient in a technological manner. The hypothesis that this business model leads to human resources and materials management improvement can be misplaced. The adoption of adequate measures, related to the improvement of forest management efficiency, will have a strong positive impact on the economics of the entire forestry sector in both countries.

The main limitations of the current research are as follows: there were two types of the main costs for current business activities used that revealed the specifics of the business models in the Bulgarian and Slovak enterprises in the current operational manner; the number of inputs and outputs followed the "rule of thumb"; the results outlined the available utilization of labor, materials and other costs like external services, interests, etc. These specific limitations should be the subject of additional research.

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