EFFICIENCY ANALYSIS OF THE BULGARIAN FORESTRY AND FOREST-BASED INDUSTRY: A DEA APPROACH

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Abstract: The economic efficiency of forestry has long been a leading issue in the sector's economic research. The wide variety of policies, goals and models in forest management makes researching the factors of economic efficiency a constantly relevant issue. Since 1978 Data Envelopment Models have provided a comprehensive approach without following the particular assumptions for production function of forests. Data Envelopment Analysis (DEA) models are quite suitable to estimate the efficiency and determine the weaknesses of forests and forest-based industries with their current state and structural weaknesses. The current study estimates the relative efficiency of the Bulgarian forestry and forest-based industries comparing it to those in the EU. The methodology applied provides a specific approach for classifying the countries by the share of their sectoral GVA in comparison to the overall country GVA. The results confirm that the Bulgarian forestry and forest-based industries are efficient compared to most EU countries. The paper develops further the results that the efficiency varies based on the share of forestry and of forest-based industries in the country GVA. The results reveal that in countries where forestry is better involved than forest based industries, the efficiencies are higher. The study also suggests solutions for problems of small countries like Bulgaria in order to achieve better efficiency of their respective economic sectors.

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Introduction

Forests and forest-based industries construct value chains that generate incomes and help maintain employment and wealth generation in rural areas. The European Union has about 182 million hectares of forests covering 43% of its land area and these forest areas are one of Europe's most important renewable bio-based resources with carbon storage properties. They provide multiple benefits for society and the economy and represent a key resource for improving the quality of life and the creation of jobs. The sector gives jobs to more than five hundred thousand people but adds value to only about 0.2% of the Union's Gross Value Added (GVA). According to Eurostat the forest-based industries represent about 7% of the EU manufacturing GDP. In 2011, they had a combined production value of €460 billion, with a total added value of €135 billion on a turnover of €485 billion. The EU forest-based industries provide nearly 3.5 million jobs across over 400 thousand companies, most of which are small and medium-sized or micro enterprises. Raw material used by the forest-based industries provide incomes to around 16 million forest owners in the EU. The forests of Bulgaria cover the territory in about 3,870 million ha. The forest area represents about 30% of the country's territory. It predominantly includes forests with economic purposes. They account for over 68% of the total forest area and 64% of the tree stock. Forestry activities like plantation and logging are mostly situated in some of the poorer regions of the country. They give jobs to more than twelve thousand people. Forest-based industries in the country provide incomes to more than forty thousand people, most of them located in poor and vulnerable regions. All these features of the forestry and forest-based industries define the capability of adding value as crucial for economy improvement and providing livelihood to people in forest and rural regions. Here comes the analysis of efficiency and particularly the relative efficiency that gives the major highlights of reducing imperfections. One of the most recommendable approach for that is the Data Envelopment Analysis (DEA). It was introduced by Charnes, Cooper and Rhodes (1978) for the assessment of relative efficiency of similar economic units that use particular inputs to produce outputs. Relying on a technique based on Linear Programming (LP) and without having to introduce any subjective or economic parameters (weights, prices, etc.), DEA provides a measure of efficiency of each DMU allowing, in particular, to separate efficient from non-efficient DMU and to indicate for each non-efficient DMU its `efficient peers' (Bouyssou, 1999).

The main goal of the paper is to review the relevant literature and measure the relative efficiency of forestry and forest-based industries of the Republic of Bulgaria in comparison with the European Union countries by applying the DEA method in order to outline the influence of involvement of these economic sectors in the national economies at the efficiency level.

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Literature review

Efficiency can be defined as the demand that the desired goals are achieved with the minimum use of available resources (Martic et. al.,2009). Data Envelopment Analysis (DEA) was introduced by Charnes, Cooper and Rhodes (1978) for the assessment of relative efficiency of similar economic units that use particular inputs to produce outputs. DEA is a well-known, linear-programming-based, nonparametric approach (Charnes et al., 1978) that is widely used to analyze the efficiency of a set of organizational units like a set of forest districts (Diaz-Balteiro, 2008). Models comprehensively describe, use and provide possibilities to distinguish different types of efficiency. The analysis provides a great deal of opportunities for problems uncovering and establishing policy priorities, that make DEA more and more involved in the recent years. Liu et. al. (2013) estimated that until 2009 the cumulated share of DEA-based papers dedicated to Forestry is only 0.86%, and in industry 4.66%, but the growth of such papers is almost exponential. Narendra Chand et al. (2015) state that the efficiency of the forestry system will increase in result to intentional policies for human capital improvement. Hily et al. (2015) provide the cost-efficient policy for N2000 forest management considering economies of scale exploitation, which on their own can be successfully assessed by DEA.

In the recent years DEA has been successfully implemented in Forestry and forest-based industries by many researchers. Alzamora and Apiolaza (2013) estimated the efficiency of very particular and narrow subjects like the usage of pine logs for grade producing, until Susaeta et al. (2016) successfully calculated the efficiency of an entire pine forest. Korkmaz (2011), Sporcic et al. (2009 and 2014) used DEA to calculate the efficiency of forestry units at the enterprise level. In the same manner Boosari (2015) directly compared alternate plans for forestry management. Kovalcik (2018) compared the Slovak forestry efficiency to other European countries, which is the only direct comparative study using the DEA approach throughout forestry of European Union countries. In forest-based industries, such as the wood-processing and furniture industry, the existing studies are related mainly to the enterprise level. Ma (2016) and Sari et al. (2018) estimated the efficiency of furniture enterprises, mainly SMEs. Vahid and Sowlati (2007) conducted a study on DEA efficiency analysis throughout the wood supply chain. N. Salehirad and T. Sowlati (2005) directly implemented the DEA efficiency model to Canadian primary wood producers which proved the applicability of the models to the forest subsectors. Trigkas et al. (2012) estimated the overall efficiency of the furniture sector.

The Bulgarian Forestry and forest-based industries have never been analyzed by DEA, but only by parametric approaches. Yovkov and Kolev (2007) estimated the Bulgarian Forestry efficiency implementing the Return on Investment method, based on transaction costs. Kolev (2017) also developed performance measurement, using investments assessment of forestry units. Many other authors analyzed not the efficiency itself, but the respective influencing factors. R. Popova (2013 a,b, 2014, 2017, 2018) and Chobanova et al. (2017) described the innovations in furniture producing enterprises as one of the main determinants for economic efficiency improvement and an option for performance measurement. Petkov et al. (2009), Petkov & Neykov (2012) and Neykov (2008) examined the efficiency estimation of woodworking enterprises in Bulgaria by parametric approaches as relative indicators for allocation efficiency and profitability. However, all studies, related to the economic efficiency of Bulgarian forestry and forest-based industries, are narrowly specialized in parametric estimations.

Materials and methods

The classical input oriented CCR model proposed by Charnes et. al (1978) was applied in the present study. Despite the BCC model, used by Korkmaz (2011) and preferred due to the more accurate pure technical forestry efficiency estimation, it was aimed at assessing the common scale and pure factor efficiency (Martic et al., 2009). Distinguishing the pure factor efficiency is needed to outline the problems in some of the resources involved, so we compared CCR to BCC in the manner of Kovalcik (2018). Sporcic et al (2009) also solved the trivial DEA task of assessing the efficiency or forestry organizational units, providing the comparison of CCR and BCC. The two-step procedure, comprehensively described by Cooper et al. (2007) was used in order to fill all the sufficient conditions for efficiency. The existence of constant returns to scale (CRS) of Forestry throughout European countries has not been proven in any previous research, despite the similar assumptions being made. Making the assumption on that could bias the results, so a constant return to scale (VRS) model seems

to be more appropriate for the purpose of the current study, in order to take into account effect of scaling. The model is used in the following envelopment form (dual model):

Step 1 – estimation of efficiency

$$\min \theta \,, \tag{1}$$

Subject to: $\sum_{i=1}^{n} \lambda_j x_{ij} - \theta x_0 \leq 0$ (2)

$$\sum_{i=1}^{n} \lambda_i y_{ij} - y_0 \geq 0 \tag{3}$$

Step – 2 estimation of slacks:

$$\max \sum_{i=1}^{n} s^- + \sum_{r=1}^{s} s^+ \,, \tag{4}$$

Subject to:

$$\sum_{i=1}^{n} \lambda_i x_{ij} - \theta^* x_0 = -s^- \tag{5}$$

$$\sum_{i=1}^{n} \lambda_i y_{ij} - y_0 = s^+ \tag{6}$$

Where λj are individual countries coefficients in dual form of j-th Decision Making Unit (DMU). Θ is the so called efficiency scores and Θ* is the optimal efficiency, delivered by the first step. Notations s+ and s- are slacks that measure shortage of GVA (notated as y0 for the particular DMU being estimated) or surplus of resources (xij i-th type of resource of j-th country). Many studies dedicated to DEA of Forestry include additional models for revealing some of the reasons to be efficient at the estimated value. Some additional DEA estimations in order to answer the questions about influence of different factors like main value adding determinants – labour and capital; intermediate consumption, consumption of fixed capital, have been conducted in the present study.

The implementation of different inputs and outputs into DEA models is the key factor for reliable estimation. In the study for forestry we used GVA as the output, Compensation of employees, Consumption of fixed capital and Intermediate consumption. In the forest-based industries the outputs were GVA, and the inputs - Gross investments in tangible goods, Energy products, Wages and Salaries, Purchases of goods and services.

The approach, proposed in analytical form by Cooper et al. (2007) and successfully implemented in many papers like Zadmirzaei et al. (2016), has also been used in the present paper. It is called scale efficiency (SE) and is expressed by the following equation:

$$SE = \frac{\theta^*_{CCR}}{\theta^*_{BCC}} \tag{7}$$

Where Θ* are the optimal efficiency scores by the CCR and BCC models. SE is always less or equal to 1. In the second case the DMU is optimal. The fraction directly presents the effect of the scale to DMU performance.

The data source was information from the Structural Business Statistics (SBS/Annual detailed enterprise statistics for industry) and Economic aggregates of forestry (EAF). Data included these in years from 2013 to 2016. All the inputs and outputs in the models are in Euro. The forest-based industries included in the current study follow the supply chain of wood and wooden materials in the context of the European Commission definition of what these sectors include. According to NACE Rev. 2, B-E, they include the following activities: C16: Manufacture of wood and of products of wood and cork, except furniture; Manufacture of articles of straw and plaiting materials; C31: Manufacture of furniture; C17: Manufacture of paper and paper products.

The Printing industry is not included in the study to highlight the efficiency of the processes that confer the qualities of wood through its mechanical or chemical processing.

A grouping procedure for the EU countries was performed, similar to the research of Rametseiner et al. (2006) and Kovalcik (2011). The EU countries were grouped according to their involvement of the forest sector in a manner of contribution to the overall added value of the respective country. This is a major criterion and derives common indicators for each group. In this way a profile that facilitates the country analysis was elaborated. Throughout this approach all the strengths and weaknesses are visible, and policy measures are easier to be proposed. Each obtained group is compared to another by nonparametric tests, utilizing all the advantages (Singh et al. 2013) of such testing. The applied test is the Friedman Test, suitable for three or more samples that have equal population means. Grouping was created by the

criterion – involvement of the sectors analyzed into national economies. This criterion was the share of "Gross Value Added (GVA)" of forestry and forest-based industries of the particular country in its overall GVA. Countries were divided in following categories:

- share of Forestry above the average and share of industries below the average (FAIB);
- share of Forestry below the average and share of industries above the average (FBIA);
- share of Forestry below the average and share of industries below the average (FBIB);
- share of Forestry above the average and share of industries above the average (FAIA);

The model of inputs and outputs close to the basic one proposed by Kovalcik (2018) was also applied in this paper, but focused on the capabilities for adding value, similar to the research of Korkmaz (2011). In order to compare different sectors, some of the specific outputs or inputs were omitted, due to the availability in the SBS and EAF. The analysis was decomposed into two branches: basic models between groups and particular models – within groups. Basic models revealed the trivial results for DEA efficiency in the overall EU by the degree of involvement of forestry and forestry based industries. The particular ones revealed the performance of countries in each group. Including Bulgaria in each group revealed the relative position of the country to those of others.

Results and Discussion

Analyzes were made between the specified groups and within them with Bulgaria included in order to clarify the position of the country. The estimated average involvement in national economies of forestry in the EU is 0.55% and of forest-based industries 1.24%. The groups included the following countries:

- (FAIB): Slovakia; Bulgaria.
- (FBIA): Austria.
- (FBIB): Belgium; Croatia; Cyprus; Denmark; France; Germany; Greece; Hungary; Ireland; Italy; Netherlands; Romania; Spain; United Kingdom.
- (FAIA): Czech Republic; Estonia; Finland; Latvia; Poland; Portugal; Slovenia; Sweden.

The groups were compared to each other by the place of each indicator (the outputs and inputs included in the DEA model) from 1 to 4. The 4-th place is taken by (FAIB) that reveals the small scale of Forestry and subsequent industries group and the first by the (FBIB) group, which reveals the large scale of Forestry and forest-based industries. These results prove that the relative amount of the GVA or inputs like Compensation of employees etc. do not automatically generate efficiency, which was proven by the DEA models. In order to prove the structural difference between groups a Friedman's test was provided. The relevant data is presented in Table 1.

The test presented that the groups are statistically significantly different, which means that a comparison through DEA is possible for discovering `efficient peers'. Furthermore, the differences made the assessment of the contribution of analyzed economic sectors involvement to the efficiency level feasible.

All the efficiency estimations of between groups comparison, proved that all Θ^* for industries are equal to 1, but for forestry $\Theta^*_{FAIA} = 0.78$. The results claim that the different levels of involvement do not influence the level of industry efficiency, but do so to that of forestry. The model recommended `efficient peers' to be FAIB, i.e. Slovakia and Bulgaria, and FBIB.

The situation is not the same when comparing countries within each group. All the average Θ^* efficiency characteristic inside the groups in Forestry are shown in Table 2.

In the table are quite visible that the group (FBIB) composed of the most powerful countries has the lowest $\Theta^*=0.71$. Greater amounts of GVA do not exactly mean higher efficiency. This is one of the main advantages of DEA. It reveals the quality of transformation not only the amount of the output derived of any inputs. The inclusion of FAIB countries into FAIA moves efficiency backward to the levels of $\Theta^*_{CRS}=0.71$ and $\Theta^*_{VRS}=0.93$. This is result of lowering the Θ^* of countries participating in FAIA comparing them to the efficient ones from FAIB. The fully efficient countries are in group FAIB, i.e. Slovakia and Bulgaria. Pure technical efficiency and global performance in both countries are effective when compared to each other. Forestry of all groups face decreasing economies of scale except FAIA and lower scale efficiency. Most of the EU forestry in meaning of implemented here inputs and outputs are working on decreasing returns to scale (Table 2). Standard deviations show that FAIA countries are quite similar in meaning of Θ^* i.e. transformation of the described inputs to GVA.

The results for efficiency characteristics inside the groups for industries are shown in Table 3.

Table 1: Freidman statistics for differences testing between groups

Indicators	**Forest-based industries**	**Forestry**
N	7	4
Chi-Square	17.914	9.3
df	3	3
Asymp. Sig.	0.00014	0.026
Exact Sig.	0.0006	0.012
Point Probability	0.0004	0.005

Source: Authors

Table 2: Average Θ* efficiency characteristic within the groups, for forestry

Group	Efficiency		Standard Deviation		Scale efficiency
	CRS	VRS	CRS	VRS	
FAIB	1	1	0	0	1.00
FAIA	0.89	0.97	0.17	0.07	0.91
FBIB	0.71	0.77	0.26	0.27	0.92
FAIA with SK, BG, A	0.86	0.93	0.17	0.11	0.93
FBIB with SK, BG, A	0.75	0.80	0.25	0.26	0.93

Source: Neykov et.al.

Table 3: Average Θ* efficiency characteristic within the groups, for industries

Group	Efficiency		Standard Deviation		Scale efficiency
	CRS	VRS	CRS	VRS	
FAIB	1.00	1.00	0.00	0.00	1.00
FAIA	0.99	1.00	0.00	0.00	0.99
FBIB	0.99	0.99	0.03	0.03	0.99
FAIA with SK, BG, A	0.99	1.00	0.03	0.00	0.99
FBIB with SK, BG, A	0.99	0.99	0.03	0.03	1.00

Source: Authors

Table 4: Country Θ* efficiency characteristic within the FAIA, for industries

Country	Model Θ*		Input Slacks, euro				Output Slacks, euro		
	CRS	VRS	Gross investments in tangible goods	Energy products	Wages and Salaries	Purchases	GVA C16	GVA C31	GVA C17
Czech Rep.	1.00	1.00	0	0	0	0	0	0	0
Estonia	1.00	1.00	0	0	0	0	0	0	0
Finland	1.00	1.00	0	0	0	0	0	0	0
Latvia	1.00	1.00	0	0	0	0	0	0	0
Poland	1.00	1.00	0	0	0	0	0	0	0
Portugal	1.00	1.00	0	0	0	0	0	0	0
Slovenia	0.89	1.00	9072723	32710096	0	0	0	0	2556352
Sweden	1.00	1.00	0	0	0	0	0	0	0
Bulgaria	0.99	1.00	55345849	50870703	0	0	8871691	0	0
Slovakia	0.99	1.00	71547983	59961965	0	0	0	0	0
Austria	1.00	1.00	0	0	0	0	0	0	0

Source: Authors

Countries succeed in achieving much higher efficiency in creating added value for the industry, i.e. transforming inputs better than those in forestry. Efficiency remains high even after Bulgaria's, Austria's and Slovakia's inclusion into the FAIA and FBIB. The efficiency between groups is also equal to 1. Moreover, the effectiveness of the groups are also much more sustainable than those of the forestry – standard deviations are maximum 3%. Resources are being transformed better here. It should be noted that the inclusion of the three countries in the other groups does not lead to a decrease in efficiency (Table 3) as in the previous analysis (Table 2). That reveals that forest-based industries are much more

capable for adding value than forestry. They seem to be technologically closer than forestry in different countries. It can be concluded that the observed countries face constant returns to scale. Differences of 1% in scale efficiency are within the statistical error of 1% to 5%.

The results from the DEA within groups proved that in general Bulgaria has efficient forestry and forest-based industries. Additional analyses revealed that little reduction of efficiency (Θ^*) appeared in comparing Bulgaria to countries in FAIA (Table 4).

Comparative efficiency of Bulgaria falls from 1.00 to $0.998 \approx 0.99$ in the CRS model. This 1% appeared to be the result (as the model suggested, but is not included in the table) from the comparison of the Bulgarian returns to scale with "efficient peers" Finland, Poland and Sweden. The calculated slacks (s^+ and s^-) determine the recommended economies of resources and improvement of output. The requirement for reduction of "Gross investments in tangible goods" reveals the problem of tangible goods type. The calculated amount is 55345849 euro or 34% economy. Energy efficiency is also an issue. The model suggests 75% economy. Furthermore, GVA in sector C16 (Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials) needs to be improved with 8871691 euro per year or about 7.8%. This sector in Bulgaria faces usual problems with investment activity and the results are visible in the model output.

Conclusion

It can be stated that the EU forestry is less efficient than forest-based industries in terms of value added. Countries with involvement in national economy below the average for the EU suffer more serious problems due to their inhomogeneity. It is interesting that big countries with large amount of value added like Germany or Italy are among the inefficient ones. Many European countries have problems related to the proper exploitation of bio-based resources, i.e. pure technical efficiency. The countries from the FBIB have to increase the efficiency from 71% to 100% (Table 2) or about 29% in order to achieve the proper scales. Forest-based industries are much more effective, as the result of the group comparison. Inclusion of so-called efficient countries from FAIB and FBIA into groups improve the efficiency of forestry in about 3% - 4% for the FBIB group but reduces it about 3% - 4% for the FAIA group that reveals the existence of the greatly efficient countries there. The DEA reliably indicates the problems of some the countries that appeared to be preliminary efficient like in group FAIB. In this way the methodology described in the present study provides an early alert for problems. The problems were clearly outlined by the within group comparison. Inefficiencies appeared in Bulgaria and the DEA proposed possible solutions. In the Bulgarian production of wooden materials there have been problems related to investments for many years but for the first time the particular problems are outlined as the result of the current study. The continuing investments in terms of innovations, new technologies and machinery, dedicated to the energy saving and value adding, can result in new products which are in line with new business models and supplier-consumer relationships. Moreover, research and investments in advanced manufacturing technologies can result in the creation of knowledge intensive jobs, which would give the sector the attractiveness it needs towards the new generations and keep it highly competitive on the world stage.

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