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The Measurement of Public Postal Operators' Profit Efficiency by Using Data Envelopment Analysis (DEA): a Case Study of the European Union Member States and Serbia

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Data envelopment analysis (DEA) is a linear programming methodology aiming to evaluate the relative technical efficiency for each decision making unit (DMU) with multiple inputs and multiple outputs. Each DEA model is formulated as a mathematical programming problem utilizing the values of inputs and outputs of all DMUs. The analytical process is developed on the basis of these inputs and outputs by identifying the best practices in the field. Additionally, DEA can be used as a method to evaluate economic efficiency. In this study, we propose the measurement of public postal operators' profit efficiency by DEA-based profit efficiency approach. In order to demonstrate the applicability of this approach we measured the profit efficiency of public postal operators (PPOs) in the European Union member states and Serbia as a candidate country. The implications are derived from the empirical study by using VRS model, CRS super-efficiency model and Slack-based model. First, we calculated profit efficiency and super-efficiency scores of all observed PPOs. After that, we repeated the analytical process without influential observations. Finally, we determined the target values of inputs and outputs for profit inefficient PPOs.

Keywords: *profit efficiency, DEA-based method, two-stage analytical hierarchy process, public postal operators.*

Introduction

Speaking about the achieved performance, one can describe a company as more or less efficient, or more or less productive. It is useful to emphasize that these are two related concepts that gives us the information about how successful is some business organized.

On the one hand, the productivity is a ratio of production output to what is required to produce it - inputs or resources used. This ratio could be easily calculated if a company uses single input to produce single output. In reality, it is usual that many inputs are used to produce a few outputs. The outputs should be expressed in some economically sensible form, as well as the inputs, so that productivity remains the ratio of two scalars. Productivity growth then becomes the difference between output growth and input growth. Changes in the productivity of a company can be observed in relation to other companies, or in relation to the ways it is organized in different periods of time. Generally, the changes in productivity in relation to other companies can be attributed to differences in production technology, the amount of work, operating efficiency and operating environment in which production occurs. Bureau of Labor Statistics of the US Department of Labor (BLS, 2005) and the OECD (2001) attribute variations in productivity of the organization in different periods of time to the same sources. A proper perceiving of the causes for different productivity is important to adopt a good business practice and to design a public policy aiming to improve productivity performance. The first three components are mostly under the control of companies; the fourth component is not; it mostly depends on public policy.

On the other hand, the efficiency of a company can be considered as a comparison between observed and optimal values of its output and input. Therefore, it is possible to compare observed output to maximum potential output obtainable by the input, or observed input to minimum potential input required to produce the output, or the combination of these two concepts. In the case of this type of comparison the optimum is defined in terms of organizational or production possibilities and the efficiency is technical. It is also possible to define the optimum in terms of financial targets. In this case the efficiency is measured by comparing observed and optimum costs, revenue and profit. The optimum is expressed in value terms and this type of efficiency is called an economic efficiency. For example, in the case of profit analysis we speak about a profit efficiency.

In this study we measured profit efficiency of public postal operators (PPOs) in the European Union member states and Serbia as the European Union candidate country. Profit efficiency is measured by a mathematical programming approach aiming to construct the frontiers of efficiency and to measure the efficiency relative to the constructed frontiers. This approach is known as data envelopment analysis (DEA) (Charnes *et al.*, 1978).

A mathematical programming approach, as well as an econometric, can be categorized according to the type of data available (cross-section or panel data), and according to the types of variables available (quantities only, or quantities and prices). With quantities only, technical efficiency can be estimated, while with quantities and prices economic efficiency can be analyzed and decomposed into its technical and allocative components. However, DEA was first developed in a public sector and most examples of DEA implementation considered technical efficiency. It means that the majority of DEA studies use only quantity data despite the fact that the procedures are easily adapted to the estimation of economic efficiency. To conduct this type of analyzes it is necessary that prices are available and reliable. The intention of the authors of this study was to contribute to the illustration of economic efficiency applicability. We proposed an approach for the measurement of public postal operators' profit efficiency by using DEA.

The intention of many researchers in the field of economy is to determine if some organization is efficient. There are several examples in the literature considering postal sector. Some authors conduct analyzes observing the reaction of employees about the way some business is organized (Dobrodolac *et al.,* 2012, Dobrodolac *et al.*, 2014b). (Filippini & Zola, 2005) introduced an econometric approach for calculating cost efficiency. They presented an example of Swiss Post.

On the other hand, there are few illustrations of DEA implementation in the postal sector. For example, (Doble, 1995) measures the technical efficiency of UK post office counters using DEA. Maruyama and Nakajima (2002) estimate the technical efficiency and productivity of the Japanese postal service analyzing 47 regions and 1000 postal branches. (Borenstein *et al.,* 2004) measure the efficiency of Brazilian post office stores using data envelopment analysis. (Iturralde & Quiros, 2008) analyze efficiency of the European postal sector considering the changes in technical efficiency by using Malmquist index. (Horncastle *et al.,* 2006) illustrates the implementation of parametric and nonparametric approaches to measure cost efficiency of delivery offices using Royal Mail data. (Cazals *et al.,* 2008) analyze the cost efficiency of delivery post offices observing a sample provided by Royal Mail of 1108 delivery branches. (Knezevic *et al.*, 2011) used DEA method to define required number of employees in postal network delivery units in Serbian Post. Ralevic et al. (2014a) carried out the research measuring the cost efficiency of the complete delivery postal network of the Serbian Post, which includes 1194 post office branches. (Ralevic *et al.*, 2014b) analyzed the stability of the RTS classifications and scale efficient inputs and outputs targets of 27 public postal operators from Europe.

By reviewing the literature on Thomson Reuters Web of Science (2014), we could not find the examples of using DEA for profit efficiency measurement in the postal sector. This was an inspiration for authors and the aim of the research to propose DEA-based profit efficiency approach which could be implemented in the postal sector. Beside that we determined the best practice among observed PPOs and ranked them. Additionally, we specified the target values of inputs and outputs for profit inefficient PPOs. Finally, we compared profit efficiency of PPO in Serbia as a candidate country to PPOs in the European Union member states.

A Measurement of Profit Efficiency

Methodology

Cost efficiency and revenue efficiency are important performance indicators; however, each reflects just one dimension of a company's overall performance. A measurement of profit efficiency captures both dimensions (Fried *et al.*, 2008).

Suppose that the DMU uses the inputs $x=(x_1,x_2,x_3,\dots,x_m)\in(R^+)^m$ for producing the outputs $y=(y_1,y_2,y_3,\dots,y_s)\in(R^+)^s$, where R^+ is a set of positive real numbers. Further, let the DMU faces output prices $p=(p_1,p_2,p_3,\dots,p_m)\in(R^+)^m$ and input prices $w=(w_1,w_2,w_3,\dots,w_s)\in(R^+)^s$, and seek to maximize profit. The maximum profit function, or profit frontier, is defined as shown in Eq. (1), wherein p^{tr} the transposed vector-specie p and w^{tr} the transposed vector-specie w.

$$\pi(p,w)=\max_{y,x}\{(p^{tr}y-w^{tr}x):(y,x)\in T\} \quad (1)$$

If the production set T is closed and convex, and if outputs and inputs are freely disposable, the profit frontier is dual to T in the sense of Eq. (1) and than T is defined according to Eq. (2).

$$\begin{aligned}T=\{&(y,x):(p^{tr}y-w^{tr}x)\le\pi(p,w),\\ &p\in R^m>0,\ w\in R^s>0\}\end{aligned} \quad (2)$$

A measure of profit efficiency is provided by the ratio of maximum profit to actual profit as follows in Eq. (3).

$$PE(y,x,p,w)=\frac{\pi(p,w)}{p^{tr}y-w^{tr}x} \quad (3)$$

Based on Koopmans' definition of efficiency (Koopmans, 1951) A dominates in profitable sense in relation to all other producers for which holds $(y^A,x^A-\Delta x)\ge(y,x-\Delta x),\ \Delta x\ge 0,$ so we may say that A is the benchmark for the other units. On the other hand, A is profitable in a subordinate (inferior) position in relation to all units which hold $(y,x-\Delta x)\ge(y^A,x^A-\Delta x),$ so far we may say that all units are benchmarks for A. Dominance is an underutilized concept in the field of producer performance evaluation, where the emphasis is on efficiency. In the paper (Tulkens & Vanden Eeckaut, 1995) is demonstrated that dominance information offers a potentially useful complement to an efficiency evaluation. It is possible that dominators utilize superior business practices that are transferable to the benchmarking producer. However, it is also possible that dominance is due to a more favourable operating environment. Inefficient producers can have many dominators, and hence many potential role models from which to learn.

DEA-based method for profit efficiency measurement

The DEA method is a useful tool for evaluating the relative efficiency for a group of DMUs. DEA has been widely studied and applied in various areas since Charnes et al. (1978) first proposed the DEA method with the CCR model. Among them, the main forms of DEA models and their extensions include those of BCC model (Banker *et al.*, 1984), the additive model (Charnes *et al.*, 1985) and the imprecise DEA models (Cooper *et al.*, 1999; Zhu, 2003a). Modifications and extensions are the assurance region models (Thompson *et al.*, 1986; Zanakis *et al.*, 2007), super-efficiency models (Andersen & Petersen, 1993; Li *et al.*, 2007), cone ratio models (Charnes *et al.*, 1989, 1990). A taxonomy and general model frameworks for DEA can be found in (Gattoufi *et al.*, 2004; Kleine, 2004).

DEA makes it possible to measure efficiency using actual inputs and outputs. It does not require knowledge of the specific functional forms of the inputs and outputs, as opposed to other traditional statistical approaches. The advantage of DEA is its ability to address multiple inputs and multiple outputs that are diverse in nature (financial, technical, social, etc.), and which express themselves in different measurement units. In DEA terminology, business units, their activities or processes, are seen as Decision Making Units – DMUs. A DMU is the unit that actually makes business decisions, and whose performance is characterized by a set of inputs and outputs, and their interdependence. Decision units are compared with the weights that are assessed using the same inputs and outputs, and the larger the set of units, the more objective is the analytical process. Suppose there are a set of *n* DMU observations. Each observation, DMU$_j$ ($j = 1,2,3,\ldots,n$) uses m inputs x_{ij} ($i = 1,2,3,\ldots,m$) to produce s outputs y_{rj} ($r = 1,2,3,\ldots,s$). The efficiency limit of operations is determined by these n observations. The DEA model generalizes the usual input/output ratio measure of efficiency for a given unit in terms of a fractional linear program formulation. The DEA method states that a DMU is considered inefficient if some other DMUs or some combinations of other DMUs produce at least the same amount of output with less of the same resources input and not more of any other resources. Conversely, a DMU is considered Pareto efficient if the above is not possible.

In selecting the DMUs, we need to consider each other comparable DMUs. In the paper (Cooper *et al.*, 2006) is suggested some practical advices in selecting the DMUs:

- the values of inputs and outputs of all DMUs should be available; they should have a positive value,
- all data of interest to analyst should be entered into analyzes,
- it should be generally required to reduce the inputs and increase the outputs; therefore in defining inputs and outputs we should maintain this principle,
- measurement units of inputs and outputs can be of various types.

The inputs and outputs are defined on the basis of experience, theory and practice in the given field, and depend on the specific considered business. Also, it is important that the values of the defined inputs and outputs are obtained from reliable sources and references, and remain uniform for all units that are compared. A number of DMU under consideration should be higher than the total number of inputs and outputs. In the paper (Cooper *et al.*, 2006) is recommended that the number of observed DMU should satisfy $m + s < \frac{n}{2}$. In the papers (Golany & Roll, 1989; Jerkins & Anderson, 2003) it is shown how the number of observations can be increased.

In the DEA literature, there are various models used to calculate profit efficiency. In the paper of (Zhu, 2003b, Chapter 12) there are four profit efficiency models presented (VRS, CRS, NDRS and NIRS). The VRS model (see the M1 model) is used in this study to measure profit efficiency of PPOs.

M1 model

$$PE^* = \max \frac{\sum_{r=1}^{s} p_r^0 \tilde{y}_{r0}}{\sum_{r=1}^{s} p_r^0 y_{r0}} - \frac{\sum_{i=1}^{m} w_i^0 \tilde{x}_{i0}}{\sum_{i=1}^{m} w_i^0 x_{i0}},$$

$$\text{Subject to } \sum_{j=1}^{n} \lambda_j x_{ij} \le \tilde{x}_{i0}, \quad i = 1,2,3,\ldots,m;$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \ge \tilde{y}_{r0}, \quad r = 1,2,3,\ldots,s;$$

$$\tilde{x}_{i0} \le x_{i0}, \tilde{y}_{r0} \ge y_{r0};$$

$$\sum_{i=1}^{n} \lambda_j = 1;$$

$$\tilde{x}_{i0}, \tilde{y}_{r0} \ge 0, \quad j = 1,2,3,\ldots n.$$

In the M1 model PE^* is profit efficiency score, x_{ij} are inputs, y_{rj} are outputs and λ_j are dual variables, representing benchmark. The DMU$_0$ is one of the DMU's which are being tested, and x_{i0} and y_{r0} are the *i*-th input and the *r*-th output of DMU$_0$. The DMU$_0$ is considered efficient if and only if the rating of efficiency $PE^* = 1$ and the benchmarks $\lambda_j = 0$ for every *j*, except DMU$_0$, for which $\lambda = 1$

In order to detect influential observations and identify the extreme efficient PPOs Super-efficiency CRS Model (see the M2 model) is used. This model is the modified model of the original CCR DEA model for a measurement of super-efficiency. (Banker & Chang, 2006) proved that this model and other models for a measurement of super-efficiency can be used in detecting influential observations (non-standard DMUs). Non-standard DMUs affect the objectivity of the analysis by introducing "noise". Therefore it is very important to detect them. Beside that, the M2 model is used as an addition to the M1 model for ranking of public postal operators' profit efficiency. A review of analytical approaches for ranking of efficient DMUs is shown in (Adler *et al.*, 2002; Jablonsky, 2012). (Anderesen & Petersen, 1993) suggested the use of Super-efficiency CRS models for ranking of efficient DMUs. This models assign to efficient DMUs super-efficiency scores (SE^*) greater than 1 (an input orientation is chosen) or less than 1 (an output orientation is chosen). It enables that efficient DMUs are ranked according to super-efficiency scores. The M2 model is input orientation. It means the best efficiency achieve efficient DMU*0* with the highest super-efficiency score.

M2 model

$$SE^* = \min \theta^{SE}$$

Subject to
$$\sum_{\substack{j=1 \\ j\neq 0}}^{n} \lambda_j x_{ij} \leq \theta^{SE} x_{i0}, \; i = 1,2,3,\ldots,m;$$
$$\sum_{\substack{j=1 \\ j\neq 0}}^{n} \lambda_j y_{rj} \geq y_{r0}, \; r = 1,2,3,\ldots,s;$$
$$\lambda_j \geq 0, \; j = 1,2,3,\ldots n; \; j \neq 0.$$

The target values of inputs and outputs for profit inefficient PPOs are estimated by using Slack-based Model (see the M3 model). This model is the additive model of DEA. (Charnes *et al.,* 1985) developed an additive DEA model which considers possible input decreases as well as output increases simultaneously. The M3 model is based upon input and output slacks.

M3 model

$$\max \sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+$$

Subject to
$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = x_{i0}, \; i = 1,2,3,\ldots,m;$$
$$\sum_{j=1}^{n} \lambda_j y_{rj} + s_r^+ = y_{r0}, \; r = 1,2,3,\ldots,s;$$
$$\lambda_j, \, s_i^-, \, s_r^+ \geq 0, \;\; j = 1,2,3,\ldots,n.$$

The DMU*0* under evaluation will be termed efficient if and only if the optimal value to the M3 model is equal to zero. Otherwise, the non-zero optimal s_i^- identifies an excess utilization of the *i*-th input, and the non-zero optimal s_i^+ identifies a deficit in the *i*-th output. Thus, the solution of the M3 model makes the information on possible adjustments to individual outputs and inputs of inefficient DMU.

Empirical example

The measurement of profit efficiency is performed on the sample of 27 PPOs. The observed DMUs are PPOs in the countries of the European Union (Austria, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Great Britain, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden) and the PPO in Serbia. A PPO is considered as one DMU with two inputs and according input prices for each selected input, and one output and according output price for selected output, as shown in Figure 1.

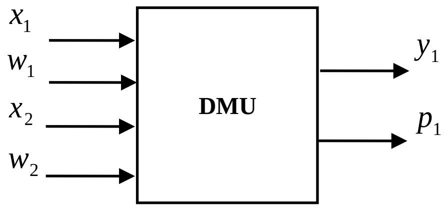


Figure 1. The public postal operator as DMU

The first input is the total number of staff (x_1), the second input is the total number of permanent post offices (x_2), w_1 and w_2 are the costs for staff and other expenditure necessary for the operation of permanent post offices, respectively. The output is the number of letter-post items, domestic services (y_1), p_1 is the operating revenue of letter-post items. Considering the operating revenue of the public postal operators, it certainly depends on the amount of provided services and set prices. However, it is interesting to mention that the most common situation in this field is that prices are defined by the state authorities, not by the companies (see, for example, Svadlenka & Chlan, 2009). This phenomenon will not be further discussed in this study since the method of forming the price do not affect the results of the proposed model.

The values for the inputs and outputs of all 27 PPOs are shown in the first Appendix. Data are official, obtained from Universal Postal Union for the year of 2011 (Universal Postal Union, 2012). Considering the 27 European Union member states, there is only one PPO that is not included in the research. It is PPO in Belgium for which there are no official data on the website of the UPU.

Results and Discussion

Profit efficiency and super-efficiency scores of PPOs

The application of the M1 and M2 model are performed in two stages. In the first stage we observed all PPOs. In the second stage we excluded PPO introducing "noise" in the analysis, i.e. DMUs which are non-standard. By using the M1 and M2 model, for each observed PPO, its profit efficiency scores PE^* and its super-efficiency scores SE^* are obtained, respectively. The analytical results in the first stage are shown in Table 1.

The distributions of profit efficiency and super-efficiency scores in the first stage are shown in the second Appendix.

Based on super-efficiency scores, we have concluded that PPO in Austria is non-standard DMU. It means that this PPO enters "noise" in the analysis, so profit efficiency scores are not objective. That's why we performed the second stage where we observed PPOs without PPO in Austria. The analytical results in the second stage are shown in Table 2.

Table 1

Analytical results derived from M1 and M2 model in the first stage

PPO	Profit efficiency scores (PE^*)	Super-efficiency scores (SE^*)
Austria	1,0000000	1,8900627
Bulgaria	0,0052993	0,0052137
Cyprus	0,1558300	0,1142591
Czech Republic	0,3411094	0,2413003
Denmark	0,3168579	0,3043964
Estonia	0,0373382	0,0314401
Finland	0,2659481	0,2588829
France	0,8083836	0,2642876
Germany	1,0000000	0,4603493
Great Britain	1,0000000	0,4626302
Greece	0,1724122	0,1669200
Hungary	0,1182218	0,0944117
Ireland	0,2286688	0,2218202
Italy	0,2889266	0,1160530
Latvia	0,0239765	0,0218429
Lithuania	0,0200155	0,0189489
Luxembourg	0,5144281	0,2889339
Malta	1,0000000	0,1946628
Netherlands	0,5324515	0,4394307
Poland	0,0650326	0,0303038
Portugal	0,2521698	0,2474903
Romania	0,0398358	0,0292853
Slovakia	0,0992229	0,0981897
Slovenia	0,5917597	0,5511414
Spain	0,6573432	0,4868794
Sweden	0,3559401	0,3507609
Serbia	0,0558466	0,0552927

Table 2

Analytical results derived from M1 and M2 model in the second stage

PPO	Profit efficiency scores (PE^*)	Super-efficiency scores (SE^*)
Bulgaria	0,0112875	0,0098543
Cyprus	0,2630238	0,2159568
Czech Republic	0,5834110	0,4560726
Denmark	0,5767942	0,5523019
Estonia	0,0651140	0,0594237
Finland	0,5002064	0,4697213
France	0,8083836	0,4795277
Germany	1,0000000	0,8352652
Great Britain	1,0000000	0,8394038
Greece	0,3412885	0,3154893
Hungary	0,2064501	0,1713021
Ireland	0,4567499	0,4192541
Italy	0,2940358	0,2193475
Latvia	0,0425328	0,0412844
Lithuania	0,0358933	0,0358146
Luxembourg	0,7899997	0,5242464
Malta	1,0000000	0,3679249
Netherlands	0,8969252	0,7973101
Poland	0,0745777	0,0561157
Portugal	0,5320854	0,4677722
Romania	0,0705074	0,0553510
Slovakia	0,2179556	0,1855846
Slovenia	1,0000000	1,3420839
Spain	1,0000000	0,8834019
Sweden	0,7967254	0,6470653
Serbia	0,1229699	0,1045067

The distributions of profit efficiency scores and super-efficiency scores in the second stage are shown in the third Appendix.

The best practice and ranking of PPOs

The best practice is characterized by dual variables λ_j, representing benchmark. The values of dual variables are determined by using the M1 model. The obtained values of dual variables are shown in Table 3.

Table 3

The values of dual variables

PPO	Benchmarks			
Bulgaria	0,04	G. Britain	**0,96**	**Slovenia**
Cyprus	**0,81**	**Malta**	0,19	Slovenia
Cz. Republic	0,20	G. Britain	**0,80**	**Slovenia**
Denmark	**0,91**	**Slovenia**	0,09	Spain
Estonia	**0,63**	**Malta**	0,37	Slovenia
Finland	**0,84**	**Slovenia**	0,16	Spain
France	0,21	Germany	**0,79**	**G. Britain**
Germany	1,00	Germany		
Great Britain	1,00	G. Britain		
Greece	0,02	G. Britain	**0,98**	**Slovenia**
Hungary	0,18	G. Britain	**0,82**	**Slovenia**
Ireland	0,02	G. Britain	**0,98**	**Slovenia**
Italy	**0,92**	**G. Britain**	0,08	Slovenia
Latvia	0,34	Malta	**0,66**	**Slovenia**
Lithuania	0,01	G. Britain	**0,99**	**Slovenia**
Luxembourg	**0,89**	**Malta**	0,11	Slovenia
Malta	1,00	Malta		
Netherlands	0,22	Slovenia	**0,78**	**Spain**
Poland	**0,59**	**G. Britain**	0,41	Slovenia
Portugal	0,04	G. Britain	**0,96**	**Slovenia**
Romania	0,18	G. Britain	**0,82**	**Slovenia**
Slovakia	0,06	G. Britain	**0,94**	**Slovenia**
Slovenia	1,00	Slovenia		
Spain	1.00	Spain		
Sweden	0.10	G. Britain	**0.90**	**Slovenia**
Serbia	0,06	G. Britain	**0,94**	**Slovenia**

The results from Table 2 and Table 3 show that PPOs in Germany, Great Britain, Malta, Slovenia and Spain meet the necessary and sufficient condition for profit efficiency because their profit efficiency scores and self benchmark are equal to one, while all other benchmarks, $\lambda_j = 0$ for all j = 1,2,3,…,26. The remaining 21 PPOs are profit inefficient. Based on the value of benchmarks, for each of public postal operators' profit inefficient is determined appropriate benchmark (bold letters) as shown in Table 3.

The ranking of PPOs is not possible only by using M1 model because the results derived from M1 model indicate that PPOs in Germany, Great Britain, Malta, Slovenia and Spain work equally well. However, this claim is not completely correct in practice. In fact, there is a difference in their performance. The problem of public postal operators' profit efficiency ranking was solved by using the M2 model. The results derived from M2 model indicate that PPO in Slovenia has $SE^* = 1.342$, PPO in Spain has $SE^* = 0.883$, PPO in Great Britain has $SE^* = 0.839$, PPO in Germany has $SE^* = 0.835$ and PPO in Malta has $SE^* = 0.368$. It practically means that PPO in Slovenia has achieved the best performance, then follow PPO in Spain, PPO in Great Britain, PPO in Germany and PPO in Malta. Finally, by using the M1 and M2 model, we have obtained ranking of PPOs as shown in Table 4.

Table 4

Ranking of PPOs

PPO	Profit efficiency scores (PE^*)	Ranking
Bulgaria	0,0112875	26
Cyprus	0,2630238	17
Czech Republic	0,5834110	10
Denmark	0,5767942	11
Estonia	0,0651140	23
Finland	0,5002064	13
France	0,8083836	7
Germany	1,0000000	4
Great Britain	1,0000000	3
Greece	0,3412885	15
Hungary	0,2064501	19
Ireland	0,4567499	14
Italy	0,2940358	16
Latvia	0,0425328	24
Lithuania	0,0358933	25
Luxembourg	0,7899997	9
Malta	1,0000000	5
Netherlands	0,8969252	6
Poland	0,0745777	21
Portugal	0,5320854	12
Romania	0,0705074	22
Slovakia	0,2179556	18
Slovenia	1,0000000	1
Spain	1,0000000	2
Sweden	0,7967254	8
Serbia	0,1229699	20

The target values of input and output of inefficient PPOs

By using M3 model, for each inefficient PPO, the efficient input targets for Total number of staff and Total number of permanent post offices and output target for Number of letter-post items, domestic services are estimated. The analytical results are shown in Table 5. It should be noticed that these results indicate the values that should be achieved by the inefficient operators. The other problem is the method of reaching this target. For this purpose, further research should be carried out. The improvements could be considered in the field of business operations and technology (see, for example, Dobrodolac *et al.*, 2014a), service portfolio (Dobrodolac *et al.*, 2009) or marketing activities (Madlenak & Svadlenka, 2009).

Table 5

Analytical results derived from M3 model

PPO	Efficient input target		Efficient output target
	x_1	x_2	y_1
Bulgaria	12485	1067	1944296004
Cyprus	1748	149	272217014
Czech Republic	36252	3099	5645544151
Denmark	9301	795	1448483241
Estonia	2792	239	434799715
Finland	11442	978	1781907685
France	199526	17054	31072243011
Greece	9088	777	1415279302
Hungary	32127	2746	5003188654
Ireland	9409	804	1465268810
Italy	144451	12347	22495434681
Latvia	4493	384	699697392
Lithuania	6562	561	1021903915
Luxembourg	1357	116	211351014
Netherlands	30419	2600	4737177895
Poland	94082	8041	14651442258
Portugal	11923	1019	1856775431
Romania	33949	2902	5286896678
Slovakia	14731	1259	2294066835
Sweden	22140	1892	3447874531
Serbia	14939	1277	2326458790

Conclusion

This study develops a DEA-based profit efficiency approach for the postal sector. The proposed approach considers the profit efficiency of PPOs in the European Union member states and Serbia as a candidate country. The development of this analytical process is performed in two stages based on public data obtained from the same source. In the first stage we applied a DEA-based method to all observed PPOs. In the second stage we performed the analytical process without influential observations.

The focus of this study is a measurement of public postal operators' profit efficiency. It has been done by using the VRS model, CRS super-efficiency model and Slack-based model. The analytical results derived from these models are profit efficiency and super-efficiency scores, the best practice, ranking and the target values of inputs and outputs for profit inefficient PPOs.

We believe that further research is needed to unleash the full potential of this DEA-based profit efficiency approach. It would be useful to focus upon the causes of inefficiency. This would lead to the improvement of business operations and technology of inefficient public postal operators.

The First Appendix

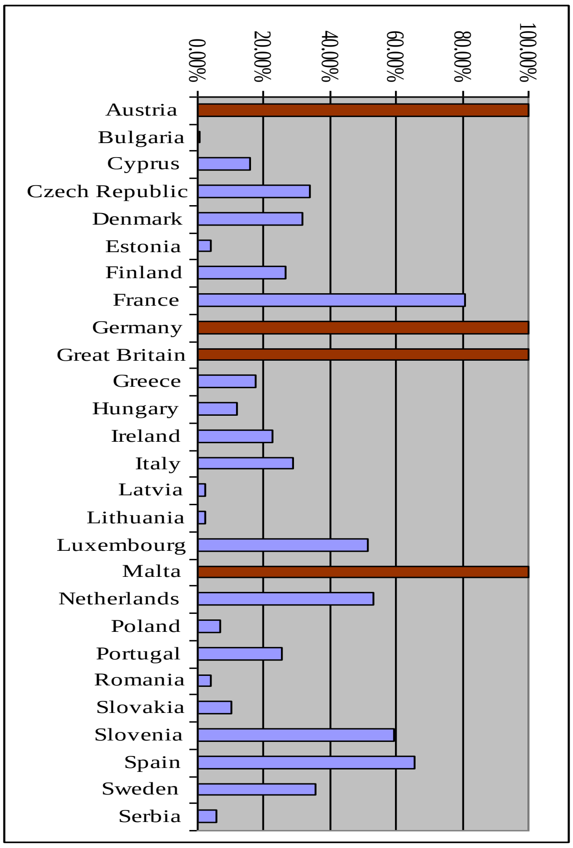
Selected input and output parameters of public postal operators

PPO	Total number of staff	The costs for staff (SDR)	Total number of permanent post offices	Expenditure necessary for the operation of permanent post offices (SDR)	Number of letter-post items, domestic services	Operating revenue of letter-post items (SDR)
Austria	21,115	1,228,976,411	1,880	661,756,529	6,215,000,000	2,041,449,031
Bulgaria	12,485	41,035,063	2,981	22,095,803	19,159,655	60,315,294
Cyprus	1,748	15,990,376	1,082	8,610,203	58,787,116	27,540,871
Czech Republic	36,252	433,402,241	3,408	233,370,437	2,574,778,260	678,783,654
Denmark	19,000	654,347,580	795	352,341,004	800,000,000	1,096,927,786
Estonia	2,792	25,518,113	343	13,740,522	25,837,400	40,101,095
Finland	27,585	1,057,742,207	978	569,553,496	837,000,000	1,622,325,190
France	230,287	11,319,418,703	17,054	6,095,071,609	14,900,000,000	17,978,938,500
Germany	512,147	28,717,733,782	13,000	15,463,395,114	19,784,000,000	46,233,361,415
Great Britain	155,764	4,443,957,704	11,818	2,392,900,302	18,074,291,171	7,295,065,458
Greece	9,088	258,136,325	1,546	138,996,482	446,505,500	402,954,527
Hungary	33,960	341,093,648	2,746	183,665,811	857,056,665	532,216,604
Ireland	9,409	440,542,292	1,156	237,215,080	614,320,000	679,612,468
Italy	144,451	4,564,516,122	13,923	2,457,816,373	4,934,317,901	8,116,337,382
Latvia	4,493	28,908,377	571	15,566,049	28,886,614	45,700,689
Lithuania	6,562	29,718,725	715	16,002,391	36,599,075	45,936,524
Luxembourg	1,497	84,574,562	116	45,540,149	110,800,000	137,172,905
Malta	613	10,219,794	63	5,502,966	35,123,154	18,290,353
Netherlands	59,731	2,153,706,824	2,600	1,159,688,290	3,777,000,000	3,620,050,548
Poland	94,082	736,600,887	8,207	396,631,247	822,176,000	1,152,241,727
Portugal	11,923	313,164,743	2,556	168,627,169	868,548,000	526,838,248
Romania	33,949	187,061,432	5,827	100,725,386	292,635,204	250,786,343
Slovakia	14,731	166,501,306	1,589	89,654,549	425,743,495	251,086,773
Slovenia	6,505	119,166,193	556	64,166,412	1,013,027,273	200,808,383
Spain	65,924	1,262,655,826	3,183	679,891,599	5,123,200,000	2,015,989,160
Sweden	22,140	1,689,852,468	1,924	909,920,560	2,231,000,000	2,724,323,813
Serbia	14,939	102,344,532	1,507	55,108,594	243,130,583	169,793,977

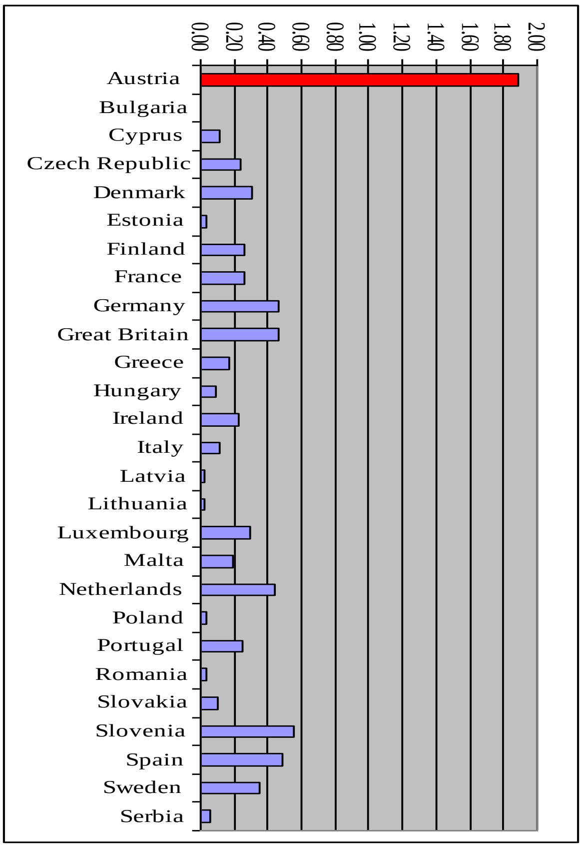
Source: Universal Postal Union (2012) http://pls.upu.int/pls/ap/ssp_report.main?p_language=AN&p_choice=BROWSE

[1]1 SDR = 1.2938 EUR for 30.12.2011

The second appendix

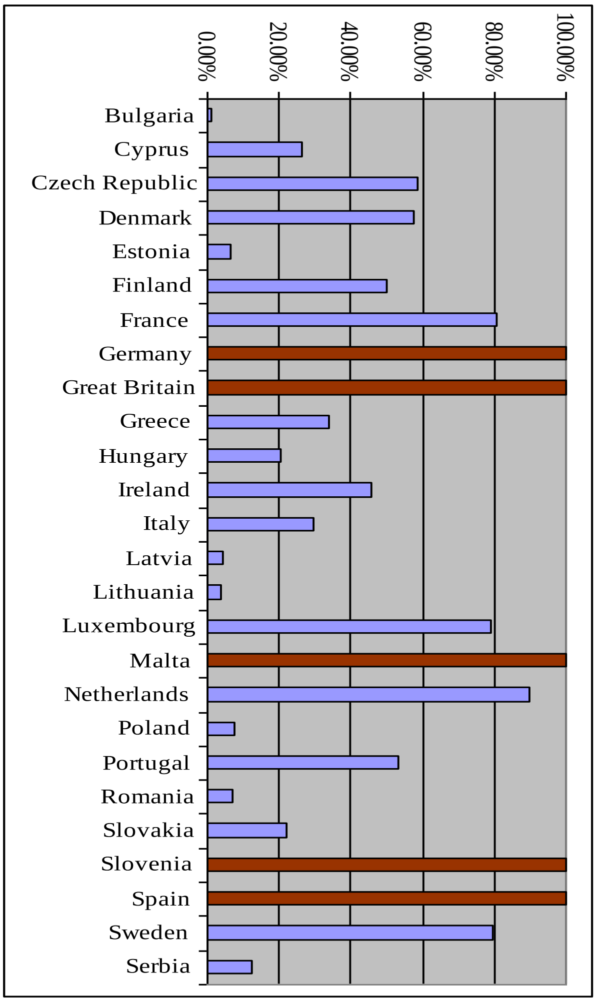


The distribution of profit efficiency scores in the first stage

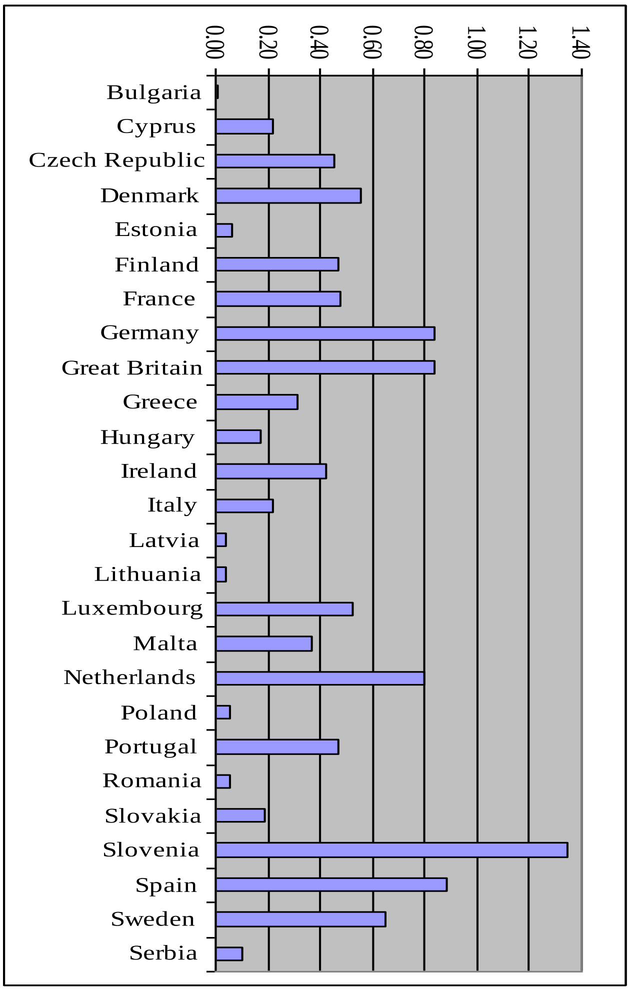


The distribution of super-efficiency scores in the first stage

The third appendix



The distribution of profit efficiency scores in the second stage



The distribution of super-efficiency scores in the second stage

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