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THE APPLICATION OF THE NON-PARAMETRIC METHODOLOGY DEA: THE CASE OF THE REPUBLIC OF NORTH MACEDONIA

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Abstract: *The application of the analytical methods and techniques of the Operational Research discipline can help in making better decisions, which thus allow decrease of costs, increase of revenue and profit, as well as market share, efficiency, etc. The non-parametric methodology Data Envelopment Analysis (DEA) is considered to be the leading methodology for measuring the relative efficiency of the Decision Making Units (DMUs). The DMUs should be homogeneous, i.e. they should use the same inputs to produce the same outputs. Ever since its beginnings up to today, the application of this methodology has noted a significant growth. It has been used in education, health care, banking, agriculture, the defence sector, energetics, tourism, sports, supply chain, transportation, public policy, etc. The aim of this paper is to provide a literature review of the application of DEA in the Republic of North Macedonia. On the basis of the reviewed papers published in journals and conference proceedings, books, Master's theses and Doctoral dissertations, it has been confirmed that this methodology is most commonly used in the finance sector.*

Keywords: *Relative Efficiency, DEA, Literature Review, Republic of North Macedonia.*

1. INTRODUCTION

Amazon, American Airlines, BMW, British Airways, British Telecommunications, Citibank, Dell, DHL, Eastman Kodak, EDS, Federal Express, General Motors, Hewlett-Packard, IBM, Motorola, NASA, Peugeot, Procter & Gamble, Samsung Electronics, etc. These organizations belong to various industries, they are with different size, with headquarters in different countries, but something is common for all of them. What is it? They all use the discipline Operational Research (O.R.) to make better decisions. The usual phases of an O.R. study are the following six (Hillier and Lieberman 2010, p. 8): (1) Define the problem of interest and gather relevant data; (2) Formulate a mathematical model to represent the problem; (3) Develop a computer-based procedure for deriving solutions to the problem from the model; (4) Test the model and refine it as needed; (5) Prepare for the ongoing application of the model as prescribed by management; and (6) Implement. These phases are described in detail in Hillier and Lieberman (2010, pp. 8-19). Some of the decision areas where this discipline is applied are (Anderson *et al.* 2009): assignment, data mining, financial decision-making, forecasting, logistics, marketing, networks, optimization, project planning and management, queuing, simulation, transportation. By using O.R. numerous organizations have increased revenue, profit, efficiency, market share, as well as having decreased costs, improved production, etc.

According to the management guru, Peter F. Drucker: "What gets measured gets improved." Efficiency is an indicator of success and consists of achieving greater results (outputs) by using a minimum of resources (inputs). If an organization (profit or non-profit) achieved a higher output for a given input level, or the same output using less input, it means that the organization has increased efficiency. To measure the efficiency of entities, there exist two approaches in the relevant literature: the parametric (econometric) approach and the non-parametric (mathematical programming) approach. In this paper the focus is on the non-parametric approach, i.e. on Data Envelopment Analysis (DEA). In the literature of the discipline Operational Research, DEA was introduced by Charnes *et al.* (1978). DEA can be applied to measure the efficiency of decision-making units (DMUs) that use the same resources (inputs) to produce the same results (outputs). On the basis of the data for the specified inputs and outputs, an efficiency frontier is constructed, details can be found in Cooper *et al*. (2007). The bibliography of DEA published in 2018 (Emrouznejad and Yang 2018) includes 10300 DEA related articles published in journals since its introduction up to 2016. The focus of this paper is the application of DEA in the Republic of Macedonia. In the literature review there have been considered 14 articles (published in journals, conference proceedings, book, master thesis and PhD dissertation).

This paper is organized as follows: after the Introduction, the non-parametric methodology DEA is explained; then the application of DEA in the Republic of North Macedonia is presented, and the Conclusion is given in the end.

2. APPLICATIONS OF DEA IN THE REPUBLIC OF NORTH MACEDONIA

Table 1 shows a literature review of the applications of data envelopment analysis in the Republic of North Macedonia. In this review there have been included papers found through Google Scholar and personal contacts with researchers, as well as the author(s)/year, application, period, sample, variables, and the model of the covered papers. 14 papers are considered, 7 of which have been published in journals, 3 in conference proceedings, 2 are master's thesis, 1 is a doctoral dissertation, and 1 is a book. The analyzed paper are published in the period 2006-2017. Most of the applications are in the financial sector (7 papers), followed by the defense sector (2), education sector (2), tourism (2), and agriculture (1) (Table1). In terms of the period covered, the shortest is one year, and the longest is nine years. The smallest sample for analysis comprises 8 DMUs, and the largest consists of 47 DMUs. The average number of inputs and outputs is two. The most commonly used are CCR, BCC and window analysis models. Besides these papers, Cvetkoska (2013) uses DEA to measure the performance of the branches of one of the leading banks in the Republic of North Macedonia - Komercijalna Banka AD Skopje, but this paper (doctoral dissertation) is not given in the review because parts of it have been processed and published in Cvetkoska (2017).

Table 1: DEA applications in the Republic of North Macedonia: Literature review

Author(s)/ year	Application	Period	Sample	Variables	Model
Atanasova-Pacemska and Timovski (2014)	Higher education	Generation of students 2007/2008	24 courses of the study program of Informatics at the Faculty of Computer Sciences, "Goce Delchev" University in Stip	Three inputs: expenses for professors and assistants, number of classes held, and expenses for equipment and inventory; Two outputs: index of the level of contribution of each course in skills, competences and knowledge delivery, prescribed with the accreditation elaborate of the study program, index of the quality of skills, competences and knowledge delivered through the study program	Dual DEA CCR model
Cvetkoska (2010)	Banking sector	2005-2008	16 banks	Operating approach: Three inputs: interest expenses, commission and fees expenses, and other expenses; Three outputs: interest income, commission and fees income, and other income; Intermediation approach: Three inputs: tangible and intangible investments, number of employees, and total amount of received deposits; Two outputs: total amount of granted loans, and short-term securities	CCR model (input and output oriented), DEA model for measuring the super-efficiency, and combination of DEA and AHP for weight restrictions
Cvetkoska (2015)	Banking sector	2009-2011	8 bank-branches of Komercijalna Banka AD Skopje	Two inputs: deposits structure and operational costs (salary and material costs); Two outputs: corporate lending and lending to citizens	Output-oriented DEA window analysis model with VRS assumption
Cvetkoska (2017)	Banking sector	2009-2011	8 bank-branches of Komercijalna Banka AD Skopje	Production approach: two inputs (staff: salaries of employees) and material expenses); Two outputs (total number of F/X transactions and domestic payment operations – total transactions); Intermediation approach: Two inputs (deposits structure and operating costs); Two	DEA window analysis model for the three approaches (production, intermediation and profitability);

				outputs (corporate lending and lending to citizens); Profitability approach: Two inputs (interest expenses and commission and fees expenses); Two outputs (interest income, and commission and fees income)	orientation: output; assumption: CRS and VRS; for profitability approach, also is specified input orientation
Cvetkoska and Barisic (2014)	Tourism	2004-2013	15 European countries (Austria, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, France, Greece, Italy, Macedonia, Montenegro, Portugal, Serbia, Slovenia, Spain)	Two inputs: visitor exports and domestic travel and tourism spending; Two outputs: travel and tourism total contribution to GDP, and travel and tourism total contribution to employment	Output-oriented DEA window analysis model with VRS assumption
Cvetkoska and Barisic (2017)	Tourism	2010-2015	11 Balkan countries (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Macedonia, Montenegro, Romania, Serbia, Slovenia, Turkey)	Two inputs: visitor exports and domestic travel and tourism spending; Two outputs: travel and tourism total contribution to GDP, and travel and tourism total contribution to employment	Output-oriented DEA window analysis model with VRS assumption
Cvetkoska and Savic (2017)	Banking sector	2009-2011	8 bank-branches of Komercijalna Banka AD Skopje	Two inputs: personnel (number of employees) and material expenses; Two outputs: corporate lending and deposits structure	Output-oriented DEA window analysis model with VRS assumption (first phase); AHP-DEA validation model (second phase)
Georgieva *et al.* (2016)	Defence sector	2007-2009	36 participating countries in NATO -led mission in Afghanistan, ISAF	Two inputs: total population of each participating country and GDP per capita of the participating countries (in US dollars); One output: number of soldiers (troops) of each participating country per rotation	Output-oriented BCC DEA model

Micajkova (2015)	Insurance sector	2009-2013	11 insurance companies (Albsig, Viner, Evroins, Eurolink, Insig, Kjubi, Kroacija, Osiguritelna Polisa, Sava, Triglav, Unika)	Three inputs: administrative expenses, commission expenses and total capital; Two outputs: gross written premium and gross claims settled	CCR and BCC output-oriented DEA models
Micajkova and Poposka (2013)	Banking sector	2008-2011	15 Macedonian banks	Two inputs: total deposits received and labor costs; Two outputs: loans to banks and customers and investments	CCR and BCC input-oriented DEA models
Naumovska and Cvetkoska (2016)	Banking sector	2007-2013	14 Macedonian banks	Two inputs: deposits (accepted from banks and other clients) and operating costs (cost for salaries, amortization, administrative and other operation costs); Two outputs: loans (issued to banks and other clients), and net interest income	Output-oriented BCC DEA model
Nikolov (2006)	Kindergarten sector	2005	47 public kindergartens; 36 Local-Self Government (LSG) units	Input: earmarked grants (for 2006) per employees (as of 2004); Output: earmarked grants (for 2006) per number of children (as of 2005 September)	DEA models (CRS, VRS, pure scale efficiency; orientation: input)
Petrovska, (2011)	Agriculture	2010	21 pig farms in the Republic of Macedonia	First stage: inputs: feed, labor and other costs; output: total pigs live weight in kg; Second stage: environmental variables and personal characteristics of managers	DEA models (CRS, VRS; input and output perspective)
Stojanoski (2017)	Defence sector	2003-2010 and 2011-2015	2 countries (Iraq and Afghanistan) for the period 2003-2010, and 5 countries (Iraq, Afghanistan, Yemen, Libya and Syria) for the period 2011-2015	Two inputs: US military budget and number of US deployed military forces yearly. Three outputs: number of victims (uniformed official armed forces in each state), number of IDPs and number of refuges.	Input-oriented DEA window analysis model with VRS assumption

3. CONCLUSION

Data envelopment analysis as a non-parametric methodology for measuring the efficiency of decision-making units notes numerous applications in different areas worldwide. According to the DEA bibliography published in 2018, agriculture, banking, supply chain, transportation and public policy are the areas where DEA is applied the most.

The aim of this paper is to present the application of DEA in the Republic of North Macedonia. There have been analyzed 14 papers (7 published in journals, 3 in conference proceedings, 2 master thesis, 1 is a

doctoral dissertation, and 1 is a book). These papers were published/defended in the period 2006-2017. 2017 is characterized as the year with the most published /defended DEA papers (4) applied in the country.

The analyzed papers reflect the possibility of a wide application of DEA in measuring the efficiency of different areas (finance, defence, tourism, education and agriculture). 54% of the analyzed papers are applied in finance.

In the review there have been included papers that we have found through Google Scholar and through personal contacts with researchers, yet a limitation of this paper is that there may exist more papers with DEA applications in the Republic of North Macedonia that are not covered in the literature review.

The applicability of DEA for measuring the efficiency in various areas of society as well as social phenomena and trends is our next challenge for further research.

REFERENCES

[1] Anderson, D.R., Sweeny, D.J., Williams, T.A., & Wisniewski, M. (2009). An introduction to management science: Quantitative approaches to decision making. London: Cengage Learning EMEA.

[2] Atanasova-Pacemska, T., & Timovski, R. (2014). Effectiveness determination of higher education using linear programming. In Book of Proceedings of XIV International Symposium (SYMORG 2014): New business models and sustainable competitiveness, Publisher: University of Belgrade, Faculty of Organizational Sciencies, Belgrade, 1192-1198.

[3] Charnes, A., Cooper, W.W., & Rhodes, E.L., (1978). Measuring efficiency of decision-making units. European Journal of Operational Research, 2(6), 429-444. doi:10.1016/0377-2217(78)90138-8.

[4] Cooper, W.W., Seiford, L.M., & Tone, K., (2007). Data envelopment analysis: A comprehensive text with models, applications, references and DEA-solver software. (2 ed.). New York: Springer Science + Business Media, LLC.

[5] Cvetkoska, V. (2010). A two-stage approach for measuring efficiency by applying the DEA and AHP methods, Master Thesis, Faculty of Organizational Sciences, Beograd, Serbia. (on Serbian)

[6] Cvetkoska, V. (2013). Methods and models of multi-criteria decision making in management: An empirical study on evaluation of the efficiency of certain organizational units in the Republic of Macedonia, Ph.D. Thesis, Skopje: Ss. Cyril and Methodius University in Skopje, Faculty of Economics–Skopje, (on Macedonian).

[7] Cvetkoska, V. (2015). Evaluating the relative efficiency of bank branches by using the COOPER-framework. In the Proceedings of SYM-OP-IS 2015, Serbia, 105-108.

[8] Cvetkoska, V. (2017). Applying multi-criteria decision making in banking: The case of Komercijalna banka AD Skopje. Saarbrucken: LAMBERT Academic Publishing.

[9] Cvetkoska, V., & Barisic, P. (2014). Measuring the efficiency of certain uropean ountries in tourism: DEA window analysis. In Book of Proceedings of the International May Conference on Strategic Management – IMKSM2014, Bor, Serbia, 77-86.

[10] Cvetkoska, V., & Barisic, P. (2017). The efficiency of the tourism industry in the Balkans. Proceedings of the Faculty of Economics in East Sarajevo – Journal of Economics and Business, 14, 31-41.

[11] Cvetkoska, V., & Savic, G. (2017). Efficiency of bank branches: empirical evidence from a two-phase research approach, Economic Research-Ekonomska Istraživanja. 30(1), 318-333, DOI: 10.1080/1331677X.2017.1305775

[12] Emrouzejad, A., & Yang, G-l. (2018). A survey and analysis of the first 40 years of scholarly literature in DEA: 1978-2016. Socio-Economic Planning Sciences, 61, 4-8.

[13] Georgieva, L., Naumovski, T., & Cvetkoska, V. (2016). Measuring the efficiency of participating countries in NATO led mission in Afghanistan, ISAF: Non-parametric approach. Proceedings of the XLIII International Symposium on Operational Research (SYM-OP-IS 2016), Serbia, 479-482.

[14] Hillier, F. S., & Lieberman, G. J. (2010). Introduction to operations 4esearch. (9th ed.). New York: McGraw-Hill.

[15] Micajkova, V. (2015). Efficiency of Macedonian insurance companies: A DEA approach. Journal of Investment and Management, 4(2), 61-67. doi: 10.11648/j.jim.20150402.1.

[16] Micajkova, V., & Poposka, K. (2013). Efficiency of Macedonian banks: A DEA approach. Research Journal of Finance and Accounting, 4(12), 141-149.

[17] Naumovska, E., & Cvetkoska, V. (2016). Efficiency of the Macedonian banking sector. Yugoslav Journal of Operations Research, 26(3), 317-329.

[18] Nikolov, M. (2006). Measuring performance of kindergartens in Macedonia with data envelopment analysis – DEA. CEA Journal of Economics, 1(2), 25-35.

[19] Petrovska, M. (2011). Efficiency of pig farm production in the Republic of Macedonia: Data envelopment analysis approach, Master Thesis, Swedish University of Agricultural Sciences, Faculty of Natural Resources and Agricultural Sciences.

[20] Stojanoski, O. (2017). US national security policy and characteristics of military intervention in Middle East after September 11, Ph.D. Thesis, Skopje: Facility of Philosophy, Department of Security, Defence and Peace Studies, (on Macedonian).