Jurnal Ekonomi Syariah Vol. 8. No. 1. Mei 2023
P-ISSN 2548-5032 e-ISSN 2714-769X
Doi: https://doi.org/10.37058/jes.v8i1.6651

Intertemporal Efficiency Analysis on Indonesia Islamic Banks: A Window DEA Approach

Lina Marlina[1], Sudana[2*], Aam Slamet Rusydiiana[3]

[1] Islamic Economics Department, Siliwangi University, Tasikmalaya, Indonesia
[2] Islamic Economics Department, IAI PERSIS, Bandung, Indonesia
[3] Sharia Economics Applied Research and Training (SMART) Indonesia
* sudana@staipibdg.ac.id

Abstract

Introduction to the Problem: Measurement of the level of efficiency of Islamic banks in Indonesia is widely carried out. But almost no one has done research with the DEA window analysis approach.
Purpose/Objective Study: This paper aims to measure the efficiency of Islamic banks in Indonesia
Design/Methodology/Approach: – Using Data Envelopment Analysis (DEA) method and window DEA
Findings: This research shows that the efficiency of Islamic banks that included in observations from 2011-2016 fluctuated with a mean value of 63 percent. From the perspective of efficiency stability analysis through several summary statistics such as standard deviation (SD), Long Distance per Window (LDW), Long Distance per Period (LDP) and Long Distance per Year (LDY), the relatively stable Islamic bank efficiency value is Bank Syariah MandiriSM) and BCA Syariah.
Keywords: Efficiency; Window Analysis; DEA; Islamic Bank.

Introduction

The development of the Islamic banking industry in Indonesia shows a relatively good tendency, although it seems slow. Data for July 2018, based on sharia banking statistics, the number of Islamic banking has reached 13 Islamic Commercial Banks, 21 Islamic Business Units and 168 Islamic Rural Banks with a total network of 2,460 offices throughout Indonesia (Otoritas Jasa Keuangan, 2018).

Meanwhile, according to the Global Islamic Finance Report 2017, the Islamic finance industry in Indonesia is ranked seventh in the world after Malaysia, Iran, Saudi Arabia, UAE, Kuwait and Pakistan. The index value of the Indonesian Islamic finance industry in 2017 is

P-ISSN 2548-5032 e-ISSN 2714-769X
Doi: https://doi.org/10.37058/jes.v8i1.6651

24.21 on a scale of 100 and ranks 7th in the world (GIFR, 2017). In fact, Indonesia is still relatively unable to exploit the existing potential related to the Islamic finance economy.

Apart from these data, the 2016 target launched by Bank Indonesia in achieving a 5% market share has not been satisfactory. The growth that occurs in Islamic banks is not much better when compared to the increase in the market share of Islamic banks themselves. The unattainable target market for sharia banks in 2016 is a phenomenon to evaluate the overall level of efficiency of Islamic banking in Indonesia. Various kinds of obstacles such as competition factors, conversion of Islamic business units into Islamic commercial banks, so that a lot of investment value must be spent, consequently inefficiency becomes an obstacle in head to head with conventional banking.

In assessing efficiency level, Data Envelopment Analysis (DEA) is relatively more used. DEA is widely used to measure the level of technical efficiency and economies of scale of the banking industry and other financial institutions. This is consistent with the research conducted by Rani et al. (2017), Kamarudin, et. al (2016); Ozdemir (2013); Shahreki (2012); and Tsolas and Dimitris (2012). Likewise, Rusydiana (2018a, 2018b), Rusydiana & Sanrego (2018), and Rusydiana & Firmansyah (2017).

But the results in measuring the efficiency of DEA have relative properties. That is, when the data set increases, the measurement results have a different tendency. So, to overcome this problem, Charnes et al. (1985) then introduced the DEA window analysis concept. DEA window analysis or often called DEWA is an extension of DEA or DEA version with time dependency. In relation to looking at variations in the value of intertemporal efficiency, Charnes et al. (1985) then proposed a technique called window analysis in DEA. Window analysis is able to measure the performance of a DMU from time to time by treating it as a different entity in each period.

This study has several objectives. First, it measures the level of efficiency of Islamic banks in Indonesia which are observed, in this case the Sharia Commercial Bank from the period 2011-2016. Second, conduct intertemporal efficiency analysis through the DEA window analysis approach, by looking at results per year (LDY), per window (LDW), and overall (LDP). This is done to verify the results of DEA efficiency which are relative in nature and tend to change when the data set is different.

Jurnal Ekonomi Syariah Vol. 8. No. 1. Mei 2023
P-ISSN 2548-5032 e-ISSN 2714-769X
Doi: https://doi.org/10.37058/jes.v8i1.6651

Methodology

To monitor changes in the level of efficiency of Islamic banks from time to time carried out Window DEA (Charnes et.al, 1985). This study used a three-year window analysis so that for each analysis 72 (3 times 24) DMUs were obtained in which the same DMUs for different periods of time were considered as different DMUs. Therefore, benchmarking is not only done on the DMU peer but also on its own performance. The total number of sharia commercial banks that are the object of research are 8 Islamic banks. The selection of the 8 Islamic banks studied is because only these BUSs have started and have financial reports since 2011.

Data on input and output variables are obtained from the balance sheet and profit and loss of each bank. Two inputs and two outputs are used to measure the efficiency of sharia commercial banks entering observation. As input variables are Depositor Funds/DPK (X1) and Personnel Costs (X2). Meanwhile for the output variable, namely the amount of financing given (Y1) and Operating Income (Y2). The use of deposits and financing in input-output because this study uses an intermediation approach.

The analysis tools used in this study are MaxDEA 7.1 to measure the level of efficiency of all Islamic bank DMUs during the 2011-2016 period. Analysis for efficiency measurement will be carried out 2 times. The first is the calculation of standard efficiency with the CRS or CCR approach introduced by Charnes et al. (1978). The second efficiency calculations with window analysis. In general the mathematical formula used for the DEA window is as follows, where M is the average level of efficiency and K is the length of the window (window length).

$$M_l = \frac{\sum_{t=1}^{M-K+1} \sum_{j=1}^{i+K-1} .E_{i,j}}{K\,x\,(M-K+1)},\ l = 1, L, N$$

As recommended by Cooper et al. (2011), a table of results of the analysis window calculation can be used to simultaneously check relative efficiency stability through several summary statistics such as standard deviation (SD), Long Distance per Window (LDW), Long Distance per Period (LDP) or Long Distance per Year (LDY). These four measurements can be used as an analysis of the efficiency stability achieved by each DMU.

Standard deviation is a standard deviation that measures the large difference in the average level of efficiency of the DMU per window. The smaller the standard deviation value, shows the more stable the efficiency value achieved by each DMU, in this case Islamic banks.

P-ISSN 2548-5032 e-ISSN 2714-769X
Doi: https://doi.org/10.37058/jes.v8i1.6651

Long Distance per Window (LDW) shows the biggest difference from efficiency figures in one window. The smaller LDW value means that the efficiency value achieved by each Islamic bank is more stable, and otherwise.

Long Distance per all Periods (LDP) explains the biggest difference from efficiency figures in all observation periods. The smaller the LDP value indicates the more stable the efficiency value achieved by each Islamic bank, and vice versa. The last is Long Distance per Year (LDY). LDY shows the biggest difference from efficiency figures in one year. Similar to LDW and LDP, the smaller the LDY value indicates the more stable the efficiency value achieved by each DMU, and otherwise.

Results and Discussion

The output-oriented DEA approach is applied to panel data, from 8 Sharia Commercial Banks in Indonesia in 2011-2016. Thus the total number of observations to calculate the efficiency value of all banking units is 48. At the beginning it has been described, that the non-parametric method is divided in two based on the Return to Scale (RTS) assumption, namely Constant Return to Scale (CRS) and Variable Return to Scale (VRS). By estimating the frontier using the CRS and VRS approach, it can decompose the Technical Efficiency on the CRS approach (TE_{CRS}) into the Pure Technical Efficiency (TE_{VRS}) and Scale Efficiency. Frontier efficiency analysis is an analysis of best practice from the entire dataset used using the input-output approach.

The results in the table below illustrate a summary of the average efficiency scores of all Sharia Commercial Banks (BUS) in Indonesia which were included in observations from 2011-2016. Fluctuating Technical Efficiency throughout the study period, with the lowest average value in 2012 at 58 percent.

The table also shows that Islamic Commercial Banks in Indonesia have shown that overall technical efficiency (overall) throughout the study period is 63 percent. It can be read, that through the implementation of better management practices Sharia Commercial Banks in Indonesia can produce output with the same volume (identical volume), using only 63 percent of the total input. In this case Sharia Commercial Banks have less good average efficiency, although they cannot also be called bad.

Tabel. 2. CRS Efficiency of BUS in Indonesia 2011-2016

P-ISSN 2548-5032 e-ISSN 2714-769X
Doi: https://doi.org/10.37058/jes.v8i1.6651

CRS EFFICIENCY	2011	2012	2013	2014	2015	2016	Mean
BSM	0,65	0,63	0,64	0,73	0,68	0,61	0,66
BMI	0,75	0,79	0,71	0,71	0,60	0,69	0,71
BRIS	0,74	0,68	0,63	0,65	0,68	0,63	0,67
BNIS	0,61	0,58	0,54	0,53	0,66	0,73	0,61
Mega	0,46	0,36	0,40	0,49	0,53	0,47	0,45
Panin	0,61	0,44	0,66	1,00	0,82	0,88	0,74
BSB	0,83	0,71	0,66	0,73	0,78	0,76	0,75
BCAS	0,47	0,48	0,49	0,53	0,61	0,68	0,54
Mean	0,64	0,58	0,59	0,67	0,67	0,68	0,63

Furthermore, as recommended by Cooper et al. (2011), a table of results of the analysis window calculation can be used for relative efficiency stability analysis through several summary statistics such as standard deviation (SD), Long Distance per Window (LDW), Long Distance per Period (LDP) and Long Distance per Year (LDY). These four measurements can be used as an analysis of the efficiency stability achieved by each DMU. The smaller the fourth value of the measurement above, shows the more stable the efficiency value achieved by each DMU, in this case Islamic banks. The following below are the results of the DEA window analysis for Islamic banks in Indonesia in the period 2011 to 2016. The analysis is divided into in 4 windows with each year length per window is 3 years.

Tabel 3. DEA Window Analysis of BUS in Indonesia 2011-2016

Jurnal Ekonomi Syariah Vol. 8. No. 1. Mei 2023
P-ISSN 2548-5032 e-ISSN 2714-769X
Doi: https://doi.org/10.37058/jes.v8i1.6651

Bank	Window	EFFICIENCY SCORE						SUMMARY MEASURES				
		2011	2012	2013	2014	2015	2016	Mean/Window	MEAN	SD	LDW	LDP
BSM	Window 1	0,86	0,82	0,82				0,83	0,83	0,02	0,15	0,18
	Window 2		0,77	0,74	0,89			0,80				
	Window 3			0,75	0,89	0,82		0,82				
	Window 4				0,92	0,86	0,79	0,86				
	LDY	x	0,05	0,08	0,03	0,04	x	LDY = 0.08				
BMI	Window 1	1,00	1,00	0,87				0,96	0,88	0,06	0,14	0,22
	Window 2		0,99	0,85	0,89			0,91				
	Window 3			0,85	0,89	0,81		0,85				
	Window 4				0,85	0,81	0,78	0,81				
	LDY	x	0,01	0,02	0,04	0,00	x	LDY = 0.04				
BRIS	Window 1	1,00	0,99	0,89				0,96	0,87	0,07	0,27	0,27
	Window 2		1,00	0,91	0,73			0,88				
	Window 3			0,94	0,73	0,78		0,82				
	Window 4				0,80	0,87	0,81	0,83				
	LDY	x	0,01	0,05	0,07	0,09	x	LDY = 0.09				
BNIS	Window 1	0,76	0,72	0,71				0,73	0,72	0,08	0,07	0,25
	Window 2		0,61	0,64	0,67			0,64				
	Window 3			0,65	0,68	0,71		0,68				
	Window 4				0,79	0,86	0,82	0,82				
	LDY	x	0,11	0,07	0,12	0,15	x	LDY = 0.15				
Mega	Window 1	0,74	0,67	0,61				0,67	0,76	0,14	0,23	0,39
	Window 2		0,67	0,61	0,72			0,67				
	Window 3			0,62	0,73	0,85		0,73				
	Window 4				0,88	1,00	1,00	0,96				
	LDY	x	0,00	0,01	0,16	0,15	x	LDY = 0.16				
Panin	Window 1	0,67	0,57	1,00				0,75	0,89	0,12	0,48	0,48
	Window 2		0,52	1,00	1,00			0,84				
	Window 3			1,00	1,00	1,00		1,00				
	Window 4				1,00	0,89	1,00	0,96				
	LDY	x	0,05	0,00	0,00	0,11	x	LDY = 0.11				
BSB	Window 1	1,00	0,92	0,85				0,92	0,88	0,05	0,15	0,20
	Window 2		0,84	0,80	0,82			0,82				
	Window 3			0,80	0,83	0,90		0,84				
	Window 4				0,84	0,92	0,98	0,91				
	LDY	x	0,08	0,05	0,02	0,02	x	LDY = 0.08				
BCAS	Window 1	0,67	0,75	0,74				0,72	0,75	0,04	0,08	0,17
	Window 2		0,76	0,74	0,71			0,74				
	Window 3			0,77	0,72	0,75		0,75				
	Window 4				0,80	0,80	0,84	0,81				
	LDY	x	0,01	0,03	0,09	0,05	x	LDY = 0.09				

The results of the calculation of the DEA window analysis for 8 sharia commercial banks (BUS) in Indonesia during the period in 2011-2016 can be seen in the following table. For example, BNIS has relatively no significant changes from 2011-2013 in the first window (with

efficiency values of 76%, 72% and 71%), according to 2012-2014 in the second window (with efficiency values of 61%, 64% and 67 %) also between 2013-2015 in the third window (with efficiency values of 65%, 68% and 71%). The BNIS experienced a slight increase in efficiency values in the fourth window of 2014-2016 with efficiency values of 79%, 86% and 82%. This DMU is a sharia bank with the lowest average efficiency value of 72% compared to other DMUs observed.

The relatively similar conditions are those experienced by BCAS. BCAS Bank has relatively no significant changes from 2011-2013 in the first window (with efficiency values of 76%, 72% and 71%), according to 2012-2014 in the second window (with efficiency values of 61%, 64% and 67%) also between 2013-2015 in the third window (with efficiency values of 65%, 68% and 71%). The BNIS experienced a slight increase in efficiency values in the fourth window of 2014-2016 with efficiency values of 79%, 86% and 82%.

Based on the analysis of the DEA window, Islamic commercial banks with the highest average value during the study period from 2011-2016 is Panin Bank with an average efficiency value of 89%. Furthermore, Bank Syariah Bukopin (BSB) and Bank Muamalat followed with an average efficiency value of 88%.

From the perspective of efficiency stability analysis through several summary statistics such as standard deviation (SD), Long Distance per Window (LDW), Long Distance per Period (LDP) and Long Distance per Year (LDY), Islamic banks that are relatively stable are efficiency banks. Bank Syariah Mandiri (BSM) and BCA Syariah. BSM has a statistical value of 0.02 for SD, 0.08 for LDY, 0.15 for LDW and 0.18 for LDP. Meanwhile BCA Syariah has a statistical value of 0.04 for SD, 0.09 for LDY, 0.08 for LDW and 0.17 for LDP. The difference is, if BSM has an average efficiency value of 0.83 during the observation period, BCA Syariah only has an average of 0.75 or lower than most other Islamic banks.

Conclusion

The results of the study illustrate the average efficiency score of all Islamic Commercial Banks (BUS) in Indonesia included in the observations from 2011-2016 fluctuating throughout the study period, with an average value of 63 percent. The time dropped to 58% in 2012, the average efficiency of Islamic banks was small little by little again has increased. This can be explained by a number of things, starting from a fairly high level of competition, management of

P-ISSN 2548-5032 e-ISSN 2714-769X
Doi: https://doi.org/10.37058/jes.v8i1.6651

bank management, until micro and macro turmoil originating from within and outside the country that affects the level of efficiency of Islamic banks in Indonesia. This result is slightly different from the findings of Nurfalah et al. (2018) which states that Islamic banking is relatively more stable compared to conventional banking in facing both internal and external shock.

Based on the analysis of the DEA window, Islamic commercial banks with the highest average value during the study period from 2011-2016 is Panin Bank with an average efficiency value of 89%. Furthermore, Bank Syariah Bukopin (BSB) and Bank Muamalat with an average efficiency value of 88%. This result is not much different from the measurement results with the standard CRS approach. The difference is that the average efficiency value of the DEA window analysis is relatively higher compared to the results of the standard CRS model. This can be understood because the more observations are processed, the more it will produce lower efficiency values. The strength of the DEA window analysis model is that it can measure efficiency stability through several measurement statistics.

From the perspective of efficiency stability analysis through several summary statistics such as standard deviation (SD), Long Distance per Window (LDW), Long Distance per Period (LDP) and Long Distance per Year (LDY), Islamic banks that are relatively efficiency is stable are Bank Syariah Mandiri (BSM) and BCA Syariah.

According to Rusydiana (2016), there are several factors that have become obstacles to the development of the Islamic banking industry in Indonesia. Some of them are: 1) Inadequate capital of Sharia Banks; 2) Weak understanding of practitioners of Islamic banks; 3) Lack of government support and 4) Trust & public interest in Islamic banks tend to be low (Rusydiana, 2016). Therefore related parties need improvement in terms of capital, improving the quality of Islamic bank HR, and no less important is the support of the government and related stakeholders.

References

Asmild, M., Paradi, J.C., Aggarwall, V., and Schaffnit, C. (2004), "Combining DEA window analysis with the malmquist index approach in a study of the Canadian banking industry", *Journal of Productivity Analysis* Vol. 21, pp. 67-89.

Bergendahl, G. (1998), "DEA and benchmarks: An application to Nordic banks", *Annals of Operations Research* Vol. 82, pp. 233-249.

Chung, S.H., Lee, A.H.I., Kang, H.Y., and Lai, C.W. (2008), "A DEA window analysis on the product family mix selection for a semiconductor fabricator", *Expert Systems with Applications* Vol. 35, pp. 379-388.

Cullinane, K. and Wang, T. (2010), "The efficiency analysis of container port production using DEA panel data approaches", *Operational Research Spectrum* Vol. 32, pp. 717-738.

Dastgir, M., Momeni, M., Daneshvar, S., and Sarokolaei, M.A. (2012), "Analyzing financial statements by using window data envelopment analysis model (output oriented BCC): Evidence from Iran", *Journal of Basic and Applied Scientific Research,* Vol. 2, No. 12, pp. 49-55.

Farrell, M.L. (1957). "The Measurement of Productive Efficiency", *Journal of The Royal Statistical Society*, 120, p.253-281.

Hemmasi, A., Talaeipour, M., Khadami, H.E., Farzipoor, R.S., and Pourmousa, S.H. (2011), "Using DEA window analysis for performance evaluation of Iranian wood panels industry", *African Journal of Agricultural Research,* Vol. 6, No. 7, pp. 1802-1806.

Islamic Banker Association.(2017). *Global Islamic Finance Report 2017*.

Jia, T. and Yuan, H. (2017), "The application of DEA window analysis in the assessment of influence on operational efficiencies after the establishment of branched hospitals", *Health Services Research* Vol. 17, pp. 265.

Kamarudin, F., Sufian, F., and Nassir, A.M. (2016). "Global financial crisis, ownership and bank profit efficiency in the Bangladesh's state owned and private commercial banks", *Contaduria y Administracion*, Vol. 61, pp.705-745.

Kisielewska, M., Guzowska, M., Nellis, J.G., and Zarzecki, D. (2005), "Polish banking industry efficiency: DEA window analysis approach", *International Journal of Banking and Finance*, Vol. 3, Issue 1, pp. 15-31.

Klopp, G. (1985), "The analysis of the efficiency of production system with multiple inputs and outputs", Ph.D thesis at University of Illinois Chicago, Industrial and Systems Engineering College, USA.

Mahadevan, R. (2002), "A DEA approach to understanding the productivity growth of Malaysia's manufacturing industries", *Asia Pacific Journal of Management* Vol. 19, pp. 587-600.

Maidamisa, A.A., Ahmad, R., and Ismail, A.A.M. (2012), "A comparative analysis of window width selection technique in data envelopment analysis", *International Journal of Computer Applications*, Vol. 41, No. 5, pp. 21-26.

Nurfalah, I., Rusydiana, A.S., Laila, N., and Cahyono, E.F. (2018), "Early warning to banking crises in the dual financial system in Indonesia: The markov switching approach", *JKAU: Islamic Economics*, Vol.31, No.2, pp.133-156.

Oscar, Yazar (2008), *Health Care Benchmarking and Performance Evaluation: An Assessment using Data Envelopment Analysis*. Springer, Newton MA.

Otoritas Jasa Keuangan. (2018). *Statistik Perbankan Syariah Indonesia*JuliTahun 2018.

Ozdemir, Asli. (2013). "Integrating analytic network process and data envelopment analysis for efficiency measurement of Turkish commercial banks". *Banks and Bank Systems Volume 8 issue 2*, 2013.Pjevcevic, D., Radonjic, A., Hrle, Z., and Colic, V. (2012), "DEA window analysis for measuring port efficiencies in Serbia", *Traffic Management Review*, Vol. 24, No. 1, pp. 63-72.

Rani, L., Rusydiana, A., and Widiastuti, T.(2017). "Comparative analysis of Islamic bank's productivity and conventional bank's in Indonesia period 2008-2016". In*1st International Conference on Islamic Economics, Business and Philanthropy (ICIEBP 2017),* pp. 118-123.

Repkova, Iveta. (2014), "Efficiency of the Slovak commercial banks applying the DEA window analysis", *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering,* Vol. 8, No. 5, pp. 1342-1347.

Rusydiana, Aam S. (2018a). "Indeks malmquist untuk pengukuran efisiensi dan produktivitas bank syariah di Indonesia", *Jurnal Ekonomi dan Pembangunan LIPI*, Vol.26, No.1, pp.47-58.

Rusydiana, Aam S.(2018b). "Efisiensi dan stabilitas bank umum syariah di Indonesia". *Jurnal Akuntabilitas,* Vol 11 No 2, pp.203-222.

Rusydiana, Aam S.(2016). "Analisis masalah pengembangan perbankan syariah di Indonesia: Aplikasi metode analytic network process". *Esensi: Jurnal Bisnis dan Manajemen,* Vol.6, No.2, pp.237-246.

Rusydiana, Aam S., and Yulizar D. Sanrego, (2018). "Mesuring the performance of Islamic banking in Indonesia: An application of Maslahah efficiency quadrant (MEQ)". *Journal of Monetary Economics and Finance, Vol 3 Special Issue, pp.103-130.*

Rusydiana, Aam S., and Irman Firmansyah, (2017). "Efficiency versus Maqasid sharia index: An application on Indonesia Islamic bank". *Shirkah Journal of Economics and Business, Vol 2 No 2, 2017.*

Shahooth, Khalid & Battall, Hussien. (2006), "Data envelopment analysis and window analysis in measuring and analyzing the relative cost efficiency of 24 Islamic banking institutions", *Scientific Journal of Administrative Development*, Vol.4, pp.134-156.

Shahreki, Javad, Nazar Dahmardeh and Mohammad Ali Ghasemi. (2012). "Efficiency Evaluation Bank Sepah Branches in Sistan and Baluchestan Province Using Data Envelopment Analysis". *Interdisciplinary Journal of Contemporary Research in Business Vol. 4 No. 2*, June 2012.

Shawtari, F.A., Ariff, M., and Razak, S.H.A. (2015), "Efficiency assessment of banking sector in Yemen using data envelopment window analysis: A comparative analysis of Islamic and conventional banks", *Benchmarking: An International Journal*, Vol. 22, Issue 6, pp. 1115-1140.

Sufian, F. and Majid, M.Z.A. (2007), "Deregulation, consolidation and banks efficiency in Singapore: Evidence from event study window approach and tobit analysis", *International Review on Economics*Vol. 54, pp. 261-283.

Sufian, F. (2007), "Trends in the efficiency of Singapore's commercial banking groups: A non-stochastic frontier DEA window analysis approach", *International Journal of Productivity and Performance Management,* Vol. 56, Issue 2, pp. 99-136.

Tatje, E.G., and Lovell, C.A.K. (1997), "A DEA-based analysis of productivity change and intertemporal managerial performance", *Annals of Operations Research* Vol. 73, pp. 177-189.

Tsolas, Ioannis E. and Dimitris I. Giokas. (2012). "Bank branch efficiency evaluation by means of least absolute deviations and DEA". *Managerial FinanceVol 38 No. 8,* 2012.

Tulkens, H., and vanden Eeckaut, P. (1995), "Nonparametric efficiency, progress and regress measures for panel-data: Methodological aspects", *European Journal of Operational Research,* Vol. 80, No.3, pp.474-499.

Weng, S.J., Wu, T., Blackhurst, J., and Mackulak, G. (2009), "An extended DEA model for hospital performance evaluation and improvement", *Health Service Outcomes Research Method*Vol. 9, pp. 39-53.

Zimkova, E. (2014), "Window analysis of super-efficiency change: Case of the Slovak banking system", Proceedings of International Scientific Conference, Poland 27-31 August 2014, pp. 294-300.