Assistant Professor Noyan AYDIN, PhD
E-mail: noyan.aydin@dpu.edu.tr
Associate Professor Mahmut ZORTUK, PhD
E-mail: mahmut.zortuk@dpu.edu.tr
Department of Econometrics, Faculty of Economic and Administrative Sciences, Dumlupınar University, Kütahya, Turkey

MEASURING EFFICIENCY OF FOREIGN DIRECT INVESTMENT IN SELECTED TRANSITION ECONOMIES WITH FUZZY DATA ENVELOPMENT ANALYSIS

Abstract. *In real life because of various reasons, data that are used in efficiency analysis may be imprecise or uncertain, whereas, data are measured with certainty in conventional Data Envelopment Analysis (DEA). In the other hand, sometimes outlier data may also take part in dataset. Therefore, we can use Fuzzy DEA (FDEA) method that is more responsive in situations as mentioned above for measuring efficiency. In FDEA, fuzzy data can be transformed in to interval data by using some techniques such as α-cut level sets. The interval DEA model is used for measuring the relative efficiency of decision maker units (DMUs). In this paper, FDEA method will be used for measuring efficiency of foreign direct investment in 12 transition economies that separated from USSR. Additionally, mini-max regret method (MRM) will be used to compare and rank efficiency intervals of DMUs.*

Keywords: *Fuzzy data envelopment analysis, non-parametric efficiency analysis, foreign direct investment, transition economies.*

JEL Classification: C140, O570, P270.

1. Introduction

Foreign investment is the movement of capital funds from one country to another and realizes in the form of international money, capital markets and direct investments. Foreign Direct Investment (*FDI*) is the establishment of a new production line or buying an already established production line in a country different from its origin with the aim of diffusing its production abroad. The importance of *FDI* has increased in all countries with the globalization process in *1980s*. Especially in mid-*1990s*, *FDI* has been admitted as an important factor for compensating of inadequate domestic capital (Vural and Zortuk, 2011).

Economic growth theories put forward that *FDIs* have positive impacts on economic growth. Some of these effects are employment growth, training of workforce, learning new technologies, ensuring the inflow of foreign currency and evaluation of idle resources. Besides, *FDI* supplies extra capital source if there is a decrease in capital, (Yao & Wei, 2007).

FDI is both affecting and affected factor in macroeconomy. Some of the main determinants of *FDI* are potential domestic market size, natural resources, population, trade regime and openness, privatization, unit labor costs, progress in transition reforms, economic and political stability and economic growth (Resmini, 2000). Especially developing countries see *FDI*s as a fundamental economic factor for achieving economic growth. Therefore, the governments of these countries carry out some regulations on own their economies such as tax incentives, infrastructure incentives and exemptions from import duties in order to enhance *FDI* inflow (Lyroudi et. al, 2004).

The impact of the investment climate on foreign direct investment inflows is particularly highlighted in transition economies. The total volume of *FDI* inflows to transition countries remains small in comparison with other developing countries. However, *FDI* inflows are substantial as a percentage of *GDP*. *FDI* is not the only source of financing or fiscal deficit in transition economies, but also is preferable long-term macroeconomic stability element. In this point, the efficiency of *FDI* inflows can be measured for countries in order to compare (Barrel & Holland, 2000).

Charnes et al. (1978) first introduced Data envelopment analysis *DEA* and it is a linear based non-parametric analysis technique. Besides, it is used for measuring the relative efficiency of a range of *DMUs* which have one or more inputs and one or more outputs. And, advantage of using this technique is that it does not need any supposition on input and output data. But, the conventional models require exact measurement. On the other hand, obtained values of input and output data in real-life are sometimes imprecise or vague (Simar, 2007). Empirical studies use macro-economics data derived from international intuitions or foundations such as *OECD* and *Worldbank*. But, these data may also not be precise or perfectly reliable because of various reasons. The use of these data has increased concerns about measurement error.

The conventional methods are much responsive to measurement error, outliers and missing data. For these reasons, some researchers have suggested different fuzzy methods for overcoming uncertainty in *DEA*. Generally, these methods can be summarized as tolerance method, α –cut level based method, fuzzy ranking method and probability method. Thus, uncertain data can be described as interval/fuzzy numbers with these methods (Guo & Tanaka 2001). As a result, *FDEA* models are favorable to the decision maker and provide different benefits. One of these, the uncertainty in measurement may be at different degrees. Another, *FDEA* technique can be used to overcome missing data, thus, it is observed that the efficiency change beneath different levels of uncertainty (Guo, 2009).

There are no *FDEA* models about measuring efficiency of foreign direct investment of some selected transition economies in the economics literature. The aim of this paper is to contribute to *DMUs* and macroeconomists to take decision properly and effectively about their countries. In this paper at first, basic concepts of fuzzy set theory and α–cut level based FDEA method will be presented. Then, a *FDEA* model will be applied to *DMUs*. At finally, mini-max regret-based method (*MRM*) (Wang et al., 2005) will be used to compare and rank the efficiency intervals of *DMUs*.

2. Literature

2.1 The Relationship between FDI and Macroeconomic Variables

The relation between *FDI* and macroeconomic variables is frequently studied both theoretically and empirically in developing and transition countries. And, the result of many studies showed that inflows of *FDI* had a positive impact on growth.

FDI increases output levels in the host economy. And the level of economic development, as a factor, also plays a key role in coming of *FDI*. Empirical and theoretical evidences show two-way relationship playing an important role in improvement of *FDI*. Market size and its growth, taxes, tariffs, subventions, regulatory regime, privatization policy, economic development, urbanization, human capital, labor costs, governmental and integration policies, international trade agreements and public expenditure and investment etc. are highly kept in view when foreign investors translocate manufacture in the host country. And they affect the volume and direction of *FDI* flows (Morrissey & Rai, 1995).

Agarwal (1995) emphasize that *GDP* is important on *FDI* inflows. Cheng & Kwan (2000) analyzed empirical evidence on governmental abilities and recourses and it found that governments are major catalysts for attraction of inward *FDI*. Milner and Pentecost (1996) put forth that free trade regime contributes positively to *FDI*. Cheng & Kwan (2000) also reported that labor costs have negative effects on *FDI*.

Chowdhury and Mavrotas (2003), they used an innovative econometric method in order to define the direction of the causality between *FDI* and economic growth. According to results of empirical analyses, there is two-way causality between these two variables. Roy and Berg (2006) used time-series data and simultaneous equation model to define this two-way relation. As a result, they saw that *FDIs* had a positive and significant effect on the growth. Değer and Emsen (2006), they examined the relationship between *FDI* and economic growth in transition economies. According to results, they observed that *FDIs* have positive effects on transition economies. Ekinci (2011), he looked at whether a long-term relation between *FDIs* and economic growth in Turkey. As a consequence, a two way relationship between *FDIs* and economic growth was found.

2.2 Fuzzy DEA

Conventional data envelopment analysis (*DEA*) needs precise data, which may not always be probable in real life. Sengupta (1992) used tolerance approach within the fuzzy logic and applied it in constraints and objective function. Triantis and Girod (1998) transformed fuzzy inputs and outputs through different function types for describing membership. Guo and Tanaka (2001) transformed fuzzy constraints into precise constraints by using probability level method. Wang, Luo, and Liang (2009) established *FDEA* models to overcome uncertainty and fuzziness in input and output data where exist in *DEA*.

Lertworasirikul, Fang, Joines, and Nuttle (2003) suggested a probability fuzzy model by trapezoidal numbers. They also used a credibility fuzzy technique in models. And they enlarged these techniques to *BCC* models. Wu, Yang, and Liang (2006) also carried out probability models. Garcia, Schirru, and Melo (2005) operated a probability model in effects analysis (*FMEA*) and failure mode. Wen and Li (2009) used credibility measuring approach to obtain *CCR* models.

Kao and Liu (2000b, 2003) transformed fuzzy inputs and outputs into intervals using α-cut level approach within the framework of Zadeh's extension principle (Zadeh, 1978) and constructed precise DEA models for the intervals. They transformed the *FDEA* model and used the ranking fuzzy numbers technique suggested by Chen and Klein (1997) to get the efficiency measurement of $DMUs$. Based on *DEA* models for α-cut technique, Liu (2008) developed a *FDEA* model for choosing of flexible manufacturing systems ($FMSs$).

Saati, Menariani and Jahanshahloo (2002) used *CCR* model by using probability approach and interval approach by α-cut level sets. This using was enlarged in Saati and Memariani (2005) using an interval of weights beneath a given α-cut technique. Entani, Maeda and Tanaka (2002) and Wang, Greatbanks, and Yang (2005) also transformed fuzzy data into intervals by using α-cut technique in their interval models.

Triantis and Girod (1998) and Triantis (2003) presented a method to calculate non-radial efficiencies. Jahanshahloo, Soleimani-damaneh and Nasrabadi (2004) enlarged a slack-based efficiency measurement and built a nonlinear model for *FDEA*.

Wang and Chin (2011) presented fuzzy expected value approach for *DEA* in their paper. In this paper, fuzzy variables were used as weighted and they measured the best and the worst efficiency values of *DMUs* by their expected values.

3. Methodology

3.1. Fuzzy Set Theory

Bellman and Zadeh (1970) introduced modeling optimization problems for fuzzy set theory which is a generalization of classical set theory. In this theory, it is used interval [0, 1] instead of discrete set {0, 1}. Zadeh (1978), from based on this theory, defined a fuzzy set for every level of membership. Membership function is as follows:

$$\tilde{A} = \{(x, u_A(x)) | x \in Z\}, \tag{1}$$

In here, Z changes in the [0,1]. But, if T ={0,1}, the set is nonfuzzy (Triantis and Girod 1998). Thus, a fuzzy set can be specified exactly by a number between 0 and 1, which represents degree of membership (Mugera 2013).

Linear, triangular, trapezoidal or Gaussian membership functions can be used for symbolizing fuzzy numbers. But, triangular ones are generally preferred. Kao & Liu (2000a) described triangular membership functions as follows:

$$F(x) = \begin{cases} 0, \ x < x_L \\ \frac{x - x_L}{x_M - x_L}, x_L \leq x \leq x_M \\ \frac{x_M - x}{x_U - x_M}, x_M \leq x \leq x_U \\ 0, \ x > x_U \end{cases} \tag{2}$$

In here, x_M is the center, x_L is the lower value and x_U is the upper value. The α-cut level of a fuzzy set is an imprecise subset of x. Each level is a closed interval which can be symbolized as $[L(\alpha), U(\alpha)]$. In here, $L(\alpha)$ and $U(\alpha)$ are the lower and upper bounds at a defined α-cut level and they can be characterized as: (Kao and Liu 2000b)

$$\forall \alpha \in [0,1], F_\alpha = [L = \alpha(x_M - x_L) + x_L, U = x_U - \alpha(x_U - x_M)] \tag{3}$$

3.2 The Fuzzy DEA Method: The α-cut level based method

FDEA models show some unfavorable features. For example, interval *DEA* models with α-cut level approach require the ranking of *DMUs*. To overcome this drawback, we use α-cut level based method with mini-max regret method in efficiency analysis which places in this paper.

The α–cut level method is commonly used *FDEA* model. The main purpose of this method is to transform *FDEA* models into parametric models in order to get the lower bounds and upper bounds of the α-cut level of membership functions of performance values. In this model, the inputs and the outputs can be fluctuate between upper (free) and lower (impossible) bounds (Triantis & Girod, 1998). It is generated the interval efficiency for *DMUs* to solve the model at given level of α-cut set. Suppose that there are n *DMUs* and every *DMU* uses changing quantity of m dissimilar fuzzy inputs for obtaining s dissimilar fuzzy outputs. For instance, DMU_j uses amounts x_{ij} of inputs to obtain amounts y_{rj} of outputs. In the model formula, x_{ik} and y_{rk} show the input and output numbers or values for DMU_k. Where $\left[X_{ij}^L, X_{ij}^U\right]$ α-cut level is form of the fuzzy inputs and $\left[Y_{ij}^L, Y_{ij}^U\right]$ is α-cut level form of the fuzzy outputs. In order to solve the fuzzy model, Wang et al. (2005) suggested the under mentioned model to calculate the lower bound θ_k^L and the upper bound θ_k^U of fuzzy efficiency value for a specific α-cut level. Let

$$\theta_k = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}}, \quad k = 1, \dots \dots, n \tag{4}$$

be the efficiency of DMU_k. This mathematical expression (4) is transformed into interval data as follows:

$$\theta_k = \frac{\sum_{r=1}^{s} u_r [y_{rk}^L, y_{rk}^U]}{\sum_{i=1}^{m} v_i \, [x_{ik}^L, y_{ik}^U]} = \frac{\sum_{r=1}^{s} u_r y_{rk}^L \, , \sum_{r=1}^{s} u_r y_{rk}^U}{\sum_{i=1}^{m} v_i x_{ik}^L \, , \sum_{i=1}^{m} v_i x_{ik}^U} = \left[\frac{\sum_{r=1}^{s} u_r y_{rk}^L}{\sum_{i=1}^{m} v_i x_{ik}^U}, \frac{\sum_{r=1}^{s} u_r y_{rk}^U}{\sum_{i=1}^{m} v_i x_{ik}^L}\right] \tag{5}$$

$\theta_k$value is an interval number, and it is expressed as follows:

$$\theta_k^U = \frac{\sum_{r=1}^{s} u_r y_{rk}^U}{\sum_{i=1}^{m} v_i x_{ik}^L} \leq 1, \quad k = 1 \dots\dots, n \tag{6}$$

$$\theta_k^L = \frac{\sum_{r=1}^{s} u_r y_{rk}^L}{\sum_{i=1}^{m} v_i x_{ik}^U} > 0, \quad k = 1 \dots\dots, n \tag{7}$$

It is built the under mentioned fractional model for measuring the upper and lower efficiency bounds of DMU_k ,:

$$max\ \theta_{k_0}^U = \frac{\sum_{r=1}^{s} u_r y_{rk_0}^U}{\sum_{i=1}^{m} v_i x_{ik_0}^L} \tag{8}$$

$$s.t. \quad \theta_k^U = \frac{\sum_{r=1}^{s} u_r y_{rk}^U}{\sum_{i=1}^{m} v_i x_{ik}^L} \leq 1, \quad k = 1, \dots \dots, n \quad , \quad u_r, v_i \geq \varepsilon \quad \forall r, i.$$

$$max\ \theta_{k_0}^L = \frac{\sum_{r=1}^{s} u_r y_{rk_0}^L}{\sum_{i=1}^{m} v_i x_{ik_0}^U} \tag{9}$$

$$s.t.\ \ \theta_k^U = \frac{\sum_{r=1}^{s} u_r y_{rk}^U}{\sum_{i=1}^{m} v_i x_{ik}^L} \leq 1, \quad k = 1, \dots\dots, n \quad , \quad u_r, v_i \geq \varepsilon \quad \forall r, i.$$

The fractional model can be facilitated as under mentioned *Linear Model Transformation* which was used by Charnes-Cooper:

$$max\ \theta_{k_0}^U = \sum_{r=1}^{s} u_r y_{rk_0}^U \tag{10}$$

$$s.t. \quad \sum_{i=1}^{m} v_i x_{ik_0}^L = 1,$$

$$\sum_{r=1}^{s} u_r y_{rk}^U - \sum_{i=1}^{m} v_i x_{ik}^L \leq 0, \quad k = 1, \dots, n \quad , \quad u_r, v_i \geq \varepsilon \quad \forall r, i.$$

$$max\ \theta_{k_0}^L = \sum_{r=1}^{s} u_r y_{rk_0}^L \tag{11}$$

$$s.t. \quad \sum_{i=1}^{m} v_i x_{ik_0}^U = 1,$$

$$\sum_{r=1}^{s} u_r y_{rk}^U - \sum_{i=1}^{m} v_i x_{ik}^L \leq 0, \quad k = 1, \dots, n \quad , \quad u_r, v_i \geq \varepsilon \quad \forall r, i.$$

$\theta_{k_0}^U$ means that the upper bound of the best probable relative efficiency of DMU_k and $\theta_{k_0}^L$ also means that the lower bound of the best probable relative efficiency of DMU_k. And so, these values generate a probable best relative efficiency interval $\left[\theta_{k_0}^L, \theta_{k_0}^U\right]$ under given α-cut level sets.

It should be considered that it is used only one production frontier for all α-cut levels. Because, if we use variable production frontiers for each α-cut levels, then the efficiency values cannot be compare.

3.3 A Mini-Max Regret-Based Method for Comparing and Ranking Interval Efficiencies

The efficiency value for each *DMU* is qualified by an interval in interval efficiency models. And if the centers of interval values are the same although the widths of them are dissimilar, the efficiency values are not directly comparable (Saati et al., 2002). So, we need a technique for comparing and ranking *DMUs*. Mini-max regret method (*MRM*) was developed by Wang et al. 2005 to resolve the lack of this. In this way, the efficiency intervals of *DMUs* can be compared and ranked. This method can explain as follows:

$W_i = [w_i^L, w_i^U]$ is the efficiency intervals of n *DMUs*. If $w_i^L < max_{j\neq i}(w_j^U)$, there will be the regret or the decrement of efficiency for DMU_i. So, the maximum regret (r) or the decrement of efficiency for DMU_i will be able to show as follows:

$$max(r_i) = max_{j\neq i}(w_j^U) - w_i^L \tag{12}$$

On the contrary if $w_i^L \geq max_{j\neq i}(w_j^U)$, there will be no regret or loss of efficiency $(r_i = 0)$. At this case we have,

$$max(r_i) = max[max_{j\neq i}(w_j^U) - w_i^L, 0] \tag{13}$$

And so, the best efficiency interval can be determined through mini-max regret criterion as follows:

$$min(max(r_i)) = min\{max[max_{j\neq i}(w_j^U) - w_i^L, 0]\} \tag{14}$$

The maximum decrements of efficiency are relative values. These values are calculated according to the maximum efficiency intervals and cannot be used to rank directly. To create a ranking for efficiency intervals, the under mentioned eliminating stages are used (Wang et al., 2005):

i. Calculate the maximum decrement of efficiency for all efficiency intervals and select the smallest of them. Let it be W_{i_1},

ii. Eliminate W_{i_1} and recalculate the maximum decrement of efficiency for every efficiency interval from remaining efficiency intervals.

iii. Repeat this eliminating process until there will be only one efficiency interval W_{i_n}. And obtain the last efficiency ranking for all *DMUs* respectively: $W_{i_1} > W_{i_2} >..> W_{i_n}$.

4. Efficiency Measurement of Foreign Direct Investment via FDEA

In this part of the paper, we will study to measure efficiency of *FDI* of 12 transition economies for 2011 by output-oriented and α-cut level based *FDEA*. In analysis, we use *FDI* as output variable and use GDP, population (POP) and global competitiveness index (*GCI*) as input variables. We suppose that GCI represents all the effect on *FDI* except *GDP* and *POP*.

Although $n \leq 30$, one-sample K-S normality test values are also given in table 1 in order to choose the technique of computing the correlation. According to table 1 and within the framework of the alpha level of significance (0,05), only *GDP* variable has not normal distribution due to the fact that the p value (0,025) is smaller than the significance level (0,05). In this case, null hypothesis

($H_0 = test\ distribution\ is\ normal$) is rejected and so, it must be used a non-parametric test for correlation analysis.

Table 1 - Normality Test

One-Sample Kolmogorov-Smirnov Test		FDI	GDP	POP	GCI
N		12	12	12	12
Normal Parameters[a]	Mean	7,00	2,01	2,03	4,08
	Std. Deviation	1,50	5,25	4,02	0,31
Most Extreme Differences	Absolute	0,32	0,42	0,37	0,12
	Positive	0,32	0,42	0,37	0,10
	Negative	-	-	-	-
Kolmogorov-Smirnov Z		1,13	1,47	1,28	0,43
Asymp. Sig. (2-tailed)		0,15	0,02	0,07	0,99

Note: *a. Test distribution is Normal.* ***Source:*** *Authors' calculation.*

Non-parametric Spearman's correlation test values are given in table 2. According to the test, it is seen that there is a positive and strong relation is between out variable (*FDI*) and input variables (*POP*, *GCI* and *GDP*). Because, correlation coefficients are bigger than 0,50 and correlations are significant at the 0.05 level (2-tailed) or at the 0.01 level (2-tailed).

Table 2 – Non-parametric Correlation Test

Spearman's rho		***FDI***	***GDP***	***POP***	***GCI***
FDI	Correlation Coefficient	1,000	,895**	,601*	,606*
	Sig. (2-tailed)	.	,000	,049	0,41
	N	12	12	12	12
GDP	Correlation Coefficient	,895**	1,000	,490	,650*
	Sig. (2-tailed)	,000	.	,106	,022
	N	12	12	12	12
POP	Correlation Coefficient	,601*	,490	1,000	,203
	Sig. (2-tailed)	,049	,106	.	,527
	N	12	12	12	12
GCI	Correlation Coefficient	,606*	,650*	,203	1,000
	Sig. (2-tailed)	,041	,022	,527	.
	N	12	12	12	12

Note: ** Correlation is significant at the 0.05 level (2-tailed) ** Correlation is significant at the 0.01 level (2-tailed)* ***Source:*** *Authors' calculation.*

Table 3 - *CRS* Efficiency Values (*FDEA* & *DEA*)

Alpha Level	***0,20***		***0,40***		***0,60***		***0,80***		***1***		***Average Bound***		***Conv. CRS Scor***	***MRA Rank. 1-12***
	FDEA Bound													
DMU	***L***	***U***	***L***	***U***	***L***	***U***	***L***	***U***	***L***	***U***	***L***	***U***		
1	100	100	100	100	100	100	100	100	100	100	***100***	***100***	***100***	*1*
2	1,7	100	2,1	100	3,1	100	6,2	100	78,7	78,7	18,4	95,7	78,7	*8*
3	1,7	100	2,2	100	3,3	100	6,5	100	100	100	22,7	100	***100***	*9*
4	10,6	96,5	13,9	93,5	20,2	91,5	37,3	90,7	96,3	96,3	35,7	93,7	96,3	*4*
5	1,1	100	1,4	100	2,1	100	4	100	40,7	40,7	9,86	88,1	40,7	*11*
6	2,8	98,6	3,7	97,5	5,4	96,9	10,6	96,7	97	97	23,9	97,3	97	*7*
7	3,5	97,7	4,5	95,9	6,6	94,9	12,5	91,9	56,4	56,4	16,7	87,4	56,4	*6*
8	30,6	100	39,1	100	54,3	100	89	100	100	100	62,6	100	***100***	*2*
9	16,8	98,2	21,5	96	30,1	91,6	50,3	83	61,9	61,9	36,1	86,1	61,9	*3*
10	0,1	97,9	0,1	95,6	0,1	92,9	0,1	88,5	1,5	1,5	0,38	75,3	1,5	*5*
11	3,6	100	4,7	100	7	100	13,4	100	84,7	84,7	22,7	96,9	84,7	*12*
12	0,7	100	0,9	100	1,3	100	2,5	100	39,7	39,7	9,02	87,9	39,7	*10*

Note 1*: DMUs: 1-Russia, 2-Armenia, 3-Kyrgyz, 4-Azerbaijan, 5-Estonia, 6-Georgia, 7-Lithuania, 8-Kazakhstan, 9-Ukraine, 10-Tajikistan, 11-Latvia, 12-Moldova*
Note 2*: L & U: Lower & Upper Bounds, Conv.: Conventional, MRM: Mini-Max Regret Method (1: Best, 12: Worst)* **Source:** *Authors' calculation.*

In table 3, CRS efficiency values are shown as both conventional *DEA* and *FDEA*. According to the output-oriented conventional *DEA CRS* values, Russian Federation, Kyrgyz Republic and Kazakhstan countries are relatively more effective about reaching *FDI* by selected inputs. But, *FDEA* average bounds are indicates that only Russian Federation is effective. Namely, both lower and upper bound *CRS* values which are obtained by output-oriented and α-cut level based *FDEA* values have values of hundred.

In this paper, mini-max regret method was used to obtain an efficiency ranking for DMU. According to this method, relatively *MRM* ranking is obtained as follows:

Russia Rep. >Kazakhstan >Ukraine >Azerbaijan >Tajikistan > Lithuania > Georgia > Armenia > Kyrgyz Rep. > Moldova > Estonia >Latvia

5. Conclusion

FDI is both affecting and affected factor in macro-economy. And so, transition economies see *FDIs* as a fundamental economic factor for achieving economic growth. In this context, the efficiency of *FDI* inflows can be measured for countries in order to compare. In related literature we see that non-parametric or parametric techniques can be used in analysis. In this paper, we prefer using a non-parametric method to using a parametric method for measuring efficiency of foreign direct investment.

DEA is a non-parametric relative efficiency analysis method for comparing units. But, it is not appropriate to use conventional *DEA* if there are outliers, missing data and measurement errors. For this reasons, *FDEA* can be used for overcoming this impreciseness and ambiguity in *DEA*. Thus, interval or fuzzy numbers can be used to describe uncertain information or imprecise data by this method. In *FDEA*, tolerance, α –cut level, fuzzy ranking and probability methods can be used. In this paper, we prefer to use a α–cut level based *FDEA* for measuring efficiency of foreign direct investment in 12 transition economies that separated from USSR for the year 2011. Additionally, mini-max regret-based method (*MRM*) was used to compare and rank the efficiency intervals of *DMUs*.

As a result of the *FDEA* analysis, we see that Russia Federation is efficient country among 12 countries. But this method cannot be used to rank inefficient countries directly. To obtain a ranking for efficiency intervals we used *MRM* method. As a result of this method, countries are ordered according to their level of relative efficiency.

REFERENCES

[1]**Agarwal, Jamuna P. (1996),** ***Implications of FDI Flows into The European Transition Economies for Developing Countries***; Paper presented at the European Economic Association Conference, Prague;

[2]**Barrell, Ray and Dawn Holland (2000),** ***Foreign Direct Investment and Enterprise Restructuring in Central Europe***. Economics of Transition, 8(2): 477-504;

[3]**Bellman, Richard E. and Lotfi A. Zadeh (1970),** ***Decision Making in a Fuzzy Environment.*** Management Science, 17(4): 141-164;

[4]**Charnes, Abraham, William W. and Edwardo Rhodes** (1978), ***Measuring the Efficiency of Decision Making Units***. European Journal of Operational Research, 2(6): 429-444;

[5]**Chen, Chie B. and Cerry M. Klein (1997),*****A Simple Approach to Ranking a Group of Aggregated Fuzzy Utilities.*** IEEE Transactions on Systems, Man & Cybernetics Part B: Cybernetics, 27(1): 26-35;

[6]**Cheng, Leonard K. and Yum K. Kwan (2000)** ,***What are the Determinants of the Location of Foreign Direct Investment? The Chinese Experience***. Journal of international Economics, 51(2): 379-400;

[7]**Chowdhury, Abdur and George Mavrotas (2003),** ***FDI and Growth: What Causes What?.*** Helsínquia WIDER Conference on Sharing global prosperity 03-15;
[8]**Değer, M. Kemal and Ö.Selçuk Emsen (2006),** ***Foreign Direct Investments and Economics Growth Relationships in Transition Economies: Panel Data Analysis.*** Journal of Economics and Administrative Sciences, 7(2): 121-137;
[9]**Ekinci, Aykut (2011),** ***The Effect of Foreign Direct Investment on the Employment and Economic Growth: The Case of Turkey (1980-2010).*** Journal of Economics and Administrative Sciences, 6(2): 71-96;
[10]**Entani, Tomoe, Yutaka Maeda and Hideo Tanaka (2002), Dual Models of Interval DEA and Its Extension to Interval Data.** European Journal of Operational Research, 136(1): 32-45;
[11]**Garcia, Pauli A.A., Roberto Schirru and Ferreira F. Melo (2005),** ***A Fuzzy Data Envelopment Analysis Approach for FMEA.*** Progress in Nuclear Energy, 46(3-4): 359-373;
[12]**Guo, Peijun and Hideo Tanaka (2001),** ***Fuzzy DEA: A Perceptual Evaluation Method.*** Fuzzy Sets and Systems, 119(1): 149-160;
[13]**Guo, Peijun (2009),** ***Fuzzy Data Envelopment Analysis and Its Application to Location Problems.*** Information Sciences, 179(6): 820-829;
[14]**Jahanshahloo, Gholam R., Majid Soleimani-D. and Ebrahim Nasrabadi (2004),** ***Measure of Efficiency in DEA with Fuzzy Input–Output Levels: A Methodology for Assessing, Ranking and Imposing of Weights Restrictions***. Applied Mathematics and Computation, 156(1): 175-187;
[15]**Kao, Chiang and Shiang-Tai Liu (2000b),** ***Fuzzy Efficiency Measures in Data Envelopment Analysis***. Fuzzy Sets and Systems, 113(3): 427-437;
[16]**Kao, Chiang and Shiang-Tai Liu (2003),** ***A Mathematical Programming Approach to Fuzzy Efficiency Ranking.*** International Journal of Production Economics, 86(2): 45-154;
[17]**Lertworasirikul, Saowanee, Shu-Cherng Fang, Jeffrey A. Joines and Henry L.W. Nuttle (2003),** ***Fuzzy Data Envelopment Analysis: A Possibility Approach.*** Fuzzy Sets and Systems, 139(2): 379-394;
[18]**Lertworasirikul, Saowanee, Shu-Cherng Fang, Henry L.W. Nuttle and Jeffrey A. Joines (2003),** ***Fuzzy BCC Model for Data Envelopment Analysis***. Fuzzy Optimization and Decision Making, 2(4): 337-358;
[19]**Liu, Shiang-Tai (2008),** ***A Fuzzy DEA/AR Approach to the Selection of Flexible Manufacturing Systems***. Computers & Industrial Engineering, 54(1): 66-76;
[20]**Lyroudi, Katerina, John Papanastasiou and Athanasios Vamvakidis (2004),** ***Foreign Direct Investment and Economic Growth in Transition Economies.*** South Eastern Europe Journal of Economics, 2(1): 97-110;
[21]**Maeda, Yutaka, Tomoe Entani and Hideo Tanaka (1998),** ***Fuzzy DEA with Interval Efficiency.*** Paper presented at Proceedings of 6th European Congress on Intelligent Techniques and Soft Computing, Aachen;

[22]**Milner, Chris and Eric Pentecost (1996),** ***Locational Advantage and US Foreign Direct Investment in the UK;*** Applied Economics, 28(5): 605-615;
[23]**Morrissey, Oliver and Yogesh Rai (1995),** ***The GATT Agreement on Trade Related Investment Measures: Implications for Developing Countries and their Relationship with Transnational Corporations***. Journal of Development Studies, 31(5): 702-724;
[24]**Mugera, Amin W. (2013),** ***Measuring Technical Efficiency of Dairy Farms with Imprecise Data: A Fuzzy Data Envelopment Analysis Approach;*** Australian Journal of Agricultural and Resource Economics, 57(4): 501-520;
[25]**Punyangarm, Varathorn, Saowanee Lertworasirikul, Patcharaporn Yanpirat and Peerayuth Charnsethikul (2006),** ***A Credibility Approach for Fuzzy Stochastic Data Envelopment Analysis (FSDEA).*** Paper presented at the Proceedings of the 7th Asia Pacific Industrial Engineering and Management Systems Conference, Bangkok;
[26]**Resmini, Laura (2000),** ***The Determinants of Foreign Direct Investment in the CEECs: New Evidence from Sectoral Patterns***; The Economics of Transition, the European Bank for Reconstruction and Development, 8(3): 665-689;
[27]**Roy, Atrayee G. and Hendrik F.Van den Berg (2006),** ***Foreign Direct Investment and Economic Growth: A Time-Series Approach.*** Global Economy Journal, 6(7): 1-19;
[28]**Saati, Mohtadi S., Azizollah Menariani and Gholam R. Jahanshahloo (2002),** ***Efficiency Analysis and Ranking of DMUs with Fuzzy Data***. Fuzzy Optimization and Decision Making, 1(3): 255-267;
[29]**Saati, Mohtadi S. and Azizollah Memariani (2005),** ***Reducing Weight Flexibility in Fuzzy DEA.*** Applied Mathematics and Computation, 161(2): 611-622;
[30]**Sengupta, Jati K. (1992),** ***A Fuzzy Systems Approach in Data Envelopment Analysis.*** Computers & Mathematics with Applications, 24(8-9): 259-266.;
[31]**Simar, Leopord (2007),** ***How to Improve the Performances of DEA/FDH Estimators in The Presence of Noise***?. Journal of Productivity Analysis, 28(3): 183-201;
[32]**Soleimani-Damaneh, Majid, Gholam R. Jahanshahloo and Saeid Abbasbandy (2006),** ***Computational and Theoretical Pitfalls in Some Current Performance Measurement Techniques and a New Approach***. Applied Mathematics and Computation, 181(2): 1199-1207;
[33]**Triantis, Konstantinos P. and Oliver A. Girod (1998),** ***A Mathematical Programming Approach for Measuring Technical Efficiency in a Fuzzy Environment.*** Journal of Productivity Analysis, 10(1): 85-102;

[34]**Triantis, Konstantinos P.(2003),** ***Fuzzy Non-Radial Data Envelopment Analysis (DEA) Measures of Technical Efficiency in Support of an Integrated Performance Measurement System.*** International Journal of Automotive Technology and Management, 3(3-4): 328-353;
[35]**Vural, İ.Yaşar and Mahmut Zortuk (2011),** ***Foreign Direct Investment as a Determining Factor in Turkey's Export Performance.*** Eurasian Journal of Business and Economics, 4(7): 13-23;
[36]**Wang, Ying-Ming, Richard Greatbanks and Jian Bo Yang (2005),** ***Interval Efficiency Assessment Using Data Envelopment Analysis***. Fuzzy Sets and Systems, 153(3): 347-370;
[37]**Wang, Ying-Ming, Ying Luo, and Liang Liang (2009),** ***Fuzzy Data Envelopment Analysis Based Upon Fuzzy Arithmetic with an Application to Performance Assessment of Manufacturing Enterprises.*** Expert Systems with Applications, 36(3): 5205-5211;
[38]**Wang, Ying-Ming, Kwai-Sang Chin (2011),** ***Fuzzy Data Envelopment Analysis: A Fuzzy Expected Value Approach.*** Expert Systems with Applications, 38(9): 11678-11685;
[39]**Wen, Meilin and Huaishu Li (2009),** ***Fuzzy Data Envelopment Analysis (DEA): Model and Ranking Method.*** Journal of Computational and Applied Mathematics, 223(2): 872-878;
[40]**Yao, Shujie and Kailei Wei (2007),** ***Economic Growth in The Presence of FDI: The Perspective of Newly Industrializing Economies***. Journal of Comparative Economics, 35(2007): 211-234;
[41]**Zadeh, Lotfi A. (1978),** ***Fuzzy Sets as a Basis for A Theory of Possibility.*** Fuzzy Sets and Systems, 1(1): 3-28.