

# InterCriteria Analysis of the Financial System in the EU Countries

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**Abstract**—The paper presents an analysis of the financial systems of the EU member states which is an actual problem. The paper showcases a new method of analyzing and grading of the connection between the criteria defining the state of the financial systems. The presented multicriteria decision making method is based on two fundamental concepts: Intuitionistic Fuzzy Sets (IFSs) and Index Matrices (IMs). We have named it ‘InterCriteria’ decision making approach. The data for the financial systems of the EU member states is sourced from the World Economic Forum’s Global Competitiveness Reports for 2019. The assessment was made using 12 main drivers, so called Pillars. The main goal is to assess the competitiveness of each EU country.

**Keywords**—intelligent systems; intuitionistic fuzzy sets; index matrices; world economic forum’s; global competitiveness reports; InterCriteria analysis

## I. INTRODUCTION

The financial system of one country, in general, consist of institutions – credit institutions such as banks and markets – such as stock markets. In their activities, they support the economy; they provide the loans to the borrowers, transfer money, take deposits, trading, securities and etc. The financial system is the most controlled system. Their activities are subject of many laws and regulations. In the European Union, the credit institutions are lead in financial system. The economy is still bank-based, although the role of non – financial institutions are increased. During the last years, the EU financial system has changed very much. This year there is new challenges – Brexit. The London market and British financial system have been related to the EU financial system. Nowadays they are two different systems and still looking for the right relationships.

The 2019 edition of The Global Competitiveness Report is covering the 141 economies. According to the authors these economies account 99% of the world’s Gross Domestic Prod-

uct (GDP). The assessment was made using 12 main drivers, so called Pillars. The main goal is to assess the competitiveness of each country [11].

The overall assessment of the results of the report for 2019 is that most countries are far from the trigger who defined their competitiveness. Although during the last 10 years the central banks are injecting significant money – 10 trillion dollars to improve the global economy.

We analyze data in search of correlation between depth and stability in Pillar 9 which is focusing on the financial system. For our research, we use the data for the 27 EU member countries only, without the United Kingdom. The main reason for our decision is that the regulation in these countries are similar. All participants are keeping, more or less, the rules from European central bank – ECB [11].

In the 27 EU members live more than 447 million residents as of 01.2019 – data taken from Eurostat. The GDP level at current prices stands at level of 13 484 billion EUR, [9].

Total assets of credit institutions of EU according data from ECB is 4 848 317 millions EUR [8].

The analysis of the financial systems of the EU country is actual problem or topical issue. This article discuss application of one new method for assessment and analyzing the connections between the criteria that determine the condition of the financial systems, so-called InterCriteria Analysis (ICA). It is based on two fundamental approaches – Intuitionistic Fuzzy Sets (IFSs) and Index Matrices (IMs).

The data for the financial systems of the 27 EU member countries have been taken from the World Economic Forum’s Global Competitiveness Reports for 2019. The assessment was made using 12 main drivers, so called Pillars. The main goal of the Report is to assess the competitiveness of each EU country.

## II. INTERCRITERIA DECISION MAKING APPROACH

The presented multicriteria decision making method is based on two fundamental concepts: intuitionistic fuzzy sets and index matrices. It is called ‘InterCriteria decision making approach’, which is presented in papers [6, 7, 10].

Intuitionistic fuzzy sets defined by Atanassov [1-3] represent an extension of the concept of fuzzy sets, as defined by Zadeh [12], exhibiting function  $\mu_A(x)$  defining the membership of an element  $x$  to the set  $A$ , evaluated in the  $[0, 1]$  interval. The difference between fuzzy sets and intuitionistic fuzzy sets (IFSs) is in the presence of a second function  $\nu_A(x)$  defining the non-membership of the element  $x$  to the set  $A$ , where:

$$\begin{aligned} 0 \leq \mu_A(x) \leq 1, \\ 0 \leq \nu_A(x) \leq 1, \\ 0 \leq \mu_A(x) + \nu_A(x) \leq 1. \end{aligned} \quad (1)$$

The IFS itself is formally denoted by:

$$A = \{ \langle x, \mu_A(x), \nu_A(x) \rangle \mid x \in E \}. \quad (2)$$

Comparison between elements of any two IFSs, say  $A$  and  $B$ , involves pairwise comparisons between their respective elements’ degrees of membership and non-membership to both sets.

The second concept on which the proposed method relies is the concept of index matrix, a matrix which features two index sets. The theory behind the index matrices is described in [4, 5]. Here we will start with the index matrix  $M$  with index sets with  $m$  rows  $\{C_1, \dots, C_m\}$  and  $n$  columns  $\{O_1, \dots, O_n\}$ :

$$M = \begin{array}{c|cccccc} & O_1 & \dots & O_k & \dots & O_l & \dots & O_n \\ \hline C_1 & a_{C_1, O_1} & \dots & a_{C_1, O_k} & \dots & a_{C_1, O_l} & \dots & a_{C_1, O_n} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ C_i & a_{C_i, O_1} & \dots & a_{C_i, O_k} & \dots & a_{C_i, O_l} & \dots & a_{C_i, O_n} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ C_j & a_{C_j, O_1} & \dots & a_{C_j, O_k} & \dots & a_{C_j, O_l} & \dots & a_{C_j, O_n} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ C_m & a_{C_m, O_1} & \dots & a_{C_m, O_k} & \dots & a_{C_m, O_l} & \dots & a_{C_m, O_n} \end{array} \quad (3)$$

where for every  $p, q$  ( $1 \leq p \leq m, 1 \leq q \leq n$ ),  $C_p$  is a criterion (in our case, one of the twelve pillars),  $O_q$  in an evaluated object,  $a_{C_p, O_q}$  is the evaluation of the  $q$ -th object against the  $p$ -th criterion, and it is defined as a real number or another object that is comparable according to relation  $R$  with all the rest elements of the index matrix  $M$ , so that for each  $i, j, k$  it holds the relation  $R(a_{C_k, O_p}, a_{C_k, O_j})$ . The relation  $R$  has dual relation  $\bar{R}$ , which is true in the cases when relation  $R$  is false, and vice versa.

For the needs of our decision-making method, pairwise comparisons between every two different criteria are made along all evaluated objects. During the comparison, it is maintained one counter of the number of times when the relation  $R$  holds,

and another counter for the dual relation.

Let  $S_{k,l}^\mu$  be the number of cases in which the relations  $R(a_{C_k, O_i}, a_{C_k, O_j})$  and  $R(a_{C_l, O_i}, a_{C_l, O_j})$  are simultaneously satisfied. Let also  $S_{k,l}^\nu$  be the number of cases in which the relations  $R(a_{C_k, O_i}, a_{C_k, O_j})$  and its dual  $\bar{R}(a_{C_l, O_i}, a_{C_l, O_j})$  are simultaneously satisfied. As the total number of pairwise comparisons between the object is  $n(n-1)/2$ , it is seen that there hold the inequalities:

$$0 \leq S_{k,l}^\mu + S_{k,l}^\nu \leq \frac{n(n-1)}{2}. \quad (4)$$

For every  $k, l$ , such that  $1 \leq k \leq l \leq m$ , and for  $n \geq 2$  two numbers are defined:

$$\mu_{C_k, C_l} = 2 \frac{S_{k,l}^\mu}{n(n-1)}, \quad \nu_{C_k, C_l} = 2 \frac{S_{k,l}^\nu}{n(n-1)}. \quad (5)$$

The pair constructed from these two numbers plays the role of the intuitionistic fuzzy evaluation of the relations that can be established between any two criteria  $C_k$  and  $C_l$ . In this way the index matrix  $M$  that relates evaluated objects with evaluating criteria can be transformed to another index matrix  $M^*$  that gives the relations among the criteria:

$$M^* = \begin{array}{c|ccc} & C_1 & \dots & C_m \\ \hline C_1 & \langle \mu_{C_1, C_1}, \nu_{C_1, C_1} \rangle & \dots & \langle \mu_{C_1, C_m}, \nu_{C_1, C_m} \rangle \\ \vdots & \vdots & \ddots & \vdots \\ C_m & \langle \mu_{C_m, C_1}, \nu_{C_m, C_1} \rangle & \dots & \langle \mu_{C_m, C_m}, \nu_{C_m, C_m} \rangle \end{array} \quad (6)$$

The final step of the algorithm is to determine the degrees of correlation between the criteria, depending on the user’s choice of  $\mu$  and  $\nu$ . We call these correlations between the criteria: ‘positive consonance’, ‘negative consonance’ or ‘dissonance’.

Let  $\alpha, \beta \in [0, 1]$  be given, so that  $\alpha + \beta \leq 1$ . We call those criteria  $C_k$  and  $C_l$  are in:

- $(\alpha, \beta)$ -positive consonance, if  $\mu_{C_k, C_l} > \alpha$  and  $\nu_{C_k, C_l} < \beta$ ;
- $(\alpha, \beta)$ -negative consonance, if  $\mu_{C_k, C_l} < \beta$  and  $\nu_{C_k, C_l} > \alpha$ ;
- $(\alpha, \beta)$ -dissonance, otherwise.

Obviously, the larger  $\alpha$  and/or the smaller  $\beta$ , the less number of criteria may be simultaneously connected with the relation of  $(\alpha, \beta)$ -positive consonance. For practical purposes, it carries the most information when either the positive or the negative consonance is as large as possible, while the cases of dissonance are less informative and can be skipped.

## III. DATA ANALYSIS

In this paper, we chose to analyze only Pillar 9 ‘Financial system’. The Pillar 9 consists of 9 indicators that separate in two groups. The value of some of the indicators is a result of

non- statistical data. The participants, in the survey, had been asked to evaluate some indexes such as – soundness of the banks, financing of SME’s and venture capital availability. Although the value of these indexes is subjective one, they are in correlation with others indexes and support the overall assessment.

The Pillar 9 separates the criteria in two sections – Depth and Stability. Short description for each of the indicators or criteria is as follows:

**Depth** is the first group of criteria. It consists of 5 criteria:

1) “Domestic credit to private sector by banks as % of GDP”– This index or criteria and its value show the economic development and prosperity of the country. Its high value is a sign for strong economy;

2) „Financing of SMEs“ – The authors published the results of the survey in the report. They want to know is it easy to finance small and medium enterprises;

3) “Venture capital availability”– In the report, the authors published the results of the survey. They want to know how easy it is for start-up entrepreneurs with innovative but risky projects to obtain equity funding;

4) “Market capitalization as % of GDP”– This indicator shows the development of the economy of the country, because the development of an economy’s financial markets is closely related to its overall development;

5) “Insurance premium volume as % of GDP” – This indicator shows the development of the insurance sector and known as a penetration rate.

**Stability** – this is the second group of criteria. It consists of 4 main criteria:

1) “Soundness of the banks” – In the report, the authors published the results of the survey. They want to know how the participants assess the soundness of their banks;

2) “Non-performing loans as % of total loan” – The ratio of bank non-performing loans to total gross loans measures bank health and efficiency by identifying problems with asset quality in the loan portfolio. A high ratio may a signal for deterioration of the credit portfolio;

3) “Credit Gap in %” – This indicator is known, as a Basel gap and many studies, researchers have found that this indicator can be used as an early warning signal for upcoming banking crises;

4) “Bank’s regulatory capital ratio as % of total risk weighed assets”– This indicator measures bank capital adequacy.

#### IV. EXPERIMENTAL RESULTS

Based on the experimental research the values of nine parameters have been obtained:

1 – Domestic credit to private sector by banks as % of GDP;

2 – Financing of SMEs;

3 – Venture capital availability;

4 – Market capitalization as % of GDP;

5 – Insurance premium volume as % of GDP;

6 – Soundness of the banks;

7 – Non-performing loans as % of total loan;

8 – Credit Gap in %;

9 – Bank’s regulatory capital ratio as % of total risk weighed assets.

In this paper the parameters of the financial systems of the EU member states have been detail analyzed applying the multicriteria decision making method – the InterCriteria approach. The achieved results are presented in Table 1 and Table 2.

TABLE I. MEMBERSHIP PAIRS OF THE INTUITIONISTIC FUZZY INTERCRITERIA CORRELATIONS

$\mu$	1	2	3	4	5	6	7	8	9
1	1.000	0.569	0.560	0.689	0.655	0.520	0.462	0.406	0.446
2	0.569	1.000	0.855	0.680	0.597	0.766	0.132	0.628	0.615
3	0.560	0.855	1.000	0.680	0.600	0.717	0.166	0.625	0.625
4	0.689	0.680	0.680	1.000	0.791	0.640	0.326	0.505	0.578
5	0.655	0.597	0.600	0.791	1.000	0.535	0.418	0.449	0.465
6	0.520	0.766	0.717	0.640	0.535	1.000	0.169	0.680	0.597
7	0.462	0.132	0.166	0.326	0.418	0.169	1.000	0.298	0.280
8	0.406	0.628	0.625	0.505	0.449	0.680	0.298	1.000	0.618
9	0.446	0.615	0.625	0.578	0.465	0.597	0.280	0.618	1.000

TABLE II. NON-MEMBERSHIP PAIRS OF THE INTUITIONISTIC FUZZY INTERCRITERIA CORRELATIONS

$\nu$	1	2	3	4	5	6	7	8	9
1	0.000	0.391	0.388	0.308	0.338	0.449	0.532	0.591	0.548
2	0.391	0.000	0.065	0.277	0.357	0.169	0.822	0.329	0.338
3	0.388	0.065	0.000	0.265	0.342	0.200	0.782	0.320	0.317
4	0.308	0.277	0.265	0.000	0.206	0.326	0.665	0.489	0.412
5	0.338	0.357	0.342	0.206	0.000	0.428	0.569	0.542	0.523
6	0.449	0.169	0.200	0.326	0.428	0.000	0.794	0.286	0.372
7	0.532	0.822	0.782	0.665	0.569	0.794	0.000	0.692	0.708
8	0.591	0.329	0.320	0.489	0.542	0.286	0.692	0.000	0.372
9	0.548	0.338	0.317	0.412	0.523	0.372	0.708	0.372	0.000

The results show a strong relation between the parameter pairs:

1 (‘Domestic credit to private sector by banks as % of GDP’) – 4 (‘Market capitalization as % of GDP’);

1 (‘Domestic credit to private sector by banks as % of GDP’) – 5 (‘Refresh time’);

- 2 ('Financing of SMEs') – 3 ('Venture capital availability');
- 2 ('Financing of SMEs') – 4 ('Market capitalization as % of GDP');
- 2 ('Financing of SMEs') – 6 ('Soundness of the banks');
- 3 ('Venture capital availability') – 4 ('Market capitalization as % of GDP');
- 3 ('Venture capital availability') – 6 ('Soundness of the banks');
- 4 ('Market capitalization as % of GDP') – 5 ('Insurance premium volume as % of GDP');
- 4 ('Market capitalization as % of GDP') – 6 ('Soundness of the banks');
- 6 ('Soundness of the banks') – 8 ('Credit Gap in %').

The geometrical visualization of the InterCriteria correlations onto the intuitionistic fuzzy interpretational triangle is shown on Fig. 1.

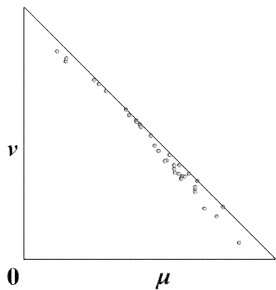


Figure 1. Intuitionistic fuzzy interpretational triangle with results of the InterCriteria analysis

## V. CONCLUSION

The analysis of the financial systems of the EU country is an actual problem or topical issue. This paper proposed the application of an original method for assessment and analyzing the connections between different criteria, which determine the condition of the financial systems.

The analysis show close positive correlation between criteria 3 'Venture capital availability' and 2 'Financing of SME's'. The main reason for this is that the data for indexes had been

taken after a survey. They show the ability of small or start up to find money to finance their business.

On the other hand, there are small positive connections between criteria 6 'Soundness of the bank' and 7 'Non-performing loans as % of total loan'. This is due to the meaning of these criteria. If one bank is in good condition the level of its non-performing loans is very small.

The present paper proves the application of one original multicriteria decision making approach – the InterCriteria Analysis, which focuses upon the relations between the criteria, giving the ability to conduct in-depth analysis and establish relations between the indicators in the financial systems, which are not apparent at first glance.

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