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# A DEEPER LOOK IN THE INTERCRITERIA POSITIVE CONSONANCE BETWEEN THE BUSINESS SOPHISTICATION AND INNOVATION PILLARS OF COMPETITIVENESS IN THE EUROPEAN UNION IN 2015-2018

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**Abstract:** *After a series of research on both European and global level, using the instrumentarium of the intuitionistic fuzzy sets-based InterCriteria analysis and data from the annual Global Competitiveness Reports of the World Economic Forum, we have observed that two of the twelve pillars of competitiveness specifically tend to correlate more strongly than any other pair of criteria, namely Pillar 11 'Business Sophistication' and Pillar 12 'Innovation'. This observation has been made when the same selection of countries (EU Member states) have been studied over time, as well when different clusters of countries globally have been selected. In attempt to research in more details this correlation, termed in ICA 'positive consonance', and capture its complexity, we explore how the nine subindicators of Pillar 11 and the seven subindicators of Pillar 12 tend to correlate between each other in the context of the European Union, based on the data for the 28 EU Member States in the last three full years, 2015–2018. In this way, using a decision making tool, which employs intuitionistic fuzzy sets and thus renders account of the inherent uncertainty of the socio-economic processes, we have a deeper look at the different aspects of the European countries innovation and business sophistication.*

## 1. INTRODUCTION

In the last years, a series of research on both European and global level, using the instrumentation of the intuitionistic fuzzy sets-based InterCriteria Analysis has been conducted by the authors [11–14, 16, 28], with data derived from the annual Global Competitiveness Indexes (GCI) of the World Economic Forum (WEF), which give annually the state-of-the-art picture of the national economies in the world with respect to their competitiveness and innovativeness. WEF captures these trends by including in the GCI a weighted average of many different components, grouped in the so called twelve 'pillars of competitiveness' (as shown on Figure 1).

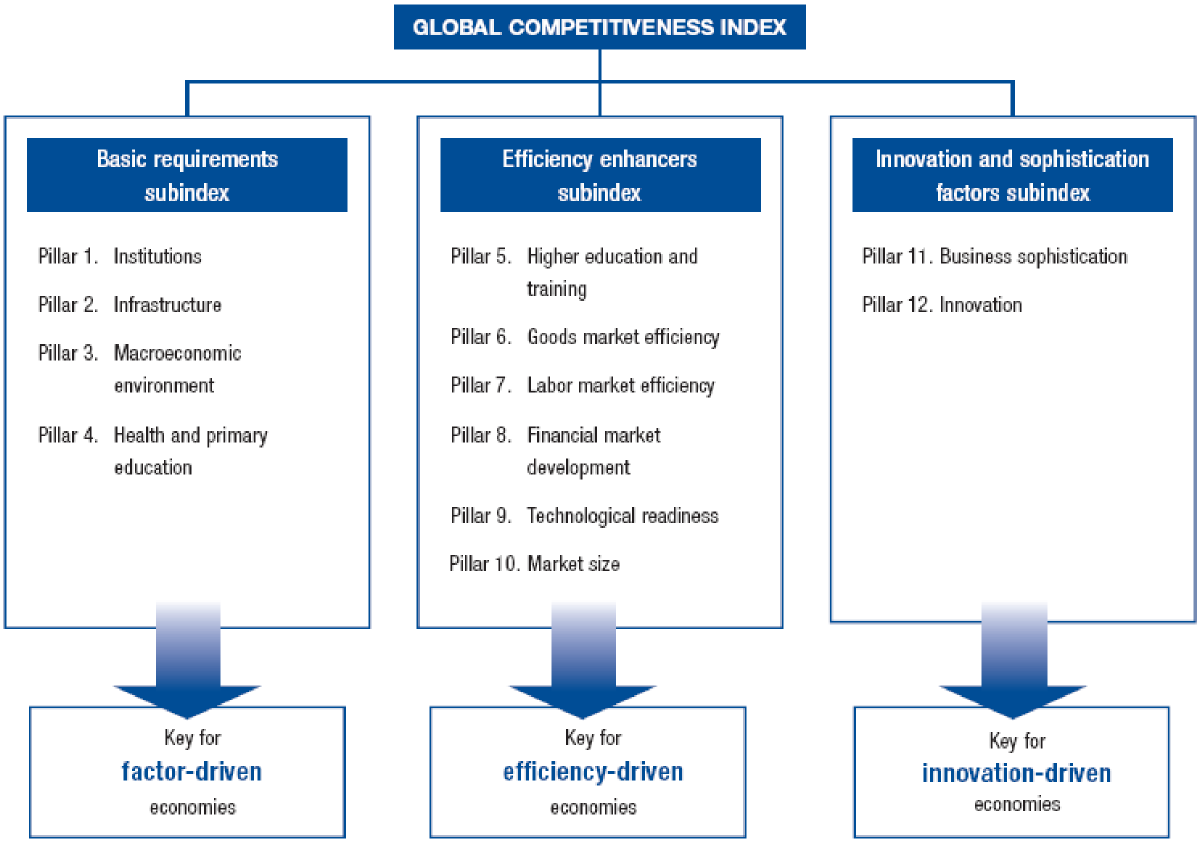



Figure 1. The Global Competitiveness Index framework, [25, p. 6]

Although all of the pillars affect the national economies, they affect different economies in different ways. Following the well-known economic theory of stages of development, the GCI assumes that, in the first stage of its development, national economies are factor-driven and compete on the basis of natural resources and primarily unskilled labour. At this stage of development, competitiveness is primarily ensured by well-operating institutions (Pillar 1), well-developed infrastructure (Pillar 2), stable macroeconomic environment (Pillar 2), and healthy workforce educated at least on the basic level (Pillar 4). With the economic progress of the countries from the increased productivity and wages, the increase of national competitiveness results in transition to the so called efficiency-driven stage of development, when it must begin to develop more-efficient production processes and increase product quality. At this point, the economy's competitiveness is increasingly driven by higher education and training (Pillar 5), goods market efficiency (Pillar 6), labour market efficiency (Pillar 7), financial market development (Pillar 8), technological readiness (Pillar 9), and market size (Pillar 10). Finally, as countries transit towards the innovation-driven stage of their economic development, the ability to sustain higher wages and the associated standard of living is only possible if businesses are able to compete using the most sophisticated production processes (Pillar 11) and by developing new and innovative ones (Pillar 12).

One of the repetitive observations in the preceding steps of our research of applying ICA towards data about the countries' competitiveness (see [11–14, 16, 28]), has been that the most strongly relation exists between the last two pillars from the methodology, 11 'Business sophistication' and 12 'Innovation'. Each of them is computed on the basis of a number of subindicators, respectively:

- *Pillar 11: Business sophistication:* 11.01 Local supplier quantity; 11.02 Local supplier quality; 11.03 State of cluster development; 11.04 Nature of competitive advantage; 11.05 Value chain breadth; 11.06 Control of international distribution; 11.07 Production process sophistication; 11.08 Extent of marketing; 11.09 Willingness to delegate authority.
- *Pillar 12: Innovation:* 12.01 Capacity for innovation; 12.02 Quality of scientific research institutions; 12.03 Company spending on R&D; 12.04 University-industry collaboration in R&D; 12.05 Government procurement of advanced technology products; 12.06 Availability of scientists and engineers; 12.07 PCT patents.

We are thus interested in having a deeper look in the links between the business sophistication and innovation pillars of competitiveness by analysing the InterCriteria positive consonances of the subindicators they are built from. For this purpose and for the sake of comparability, we are investigating the data about the EU Member States from the GCI reports issued in 2015–2018, [25–27]. The paper is organized as follows. Section 2 presents shortly the method of InterCriteria Analysis. Section 3 presents the input data, followed by Section 4 containing the main results of application of ICA on the input data, and discussion.

## 2. THE METHOD OF INTERCRITERIA ANALYSIS

InterCriteria Analysis (ICA) was originally introduced in 2014 [8] as a method based on intuitionistic fuzzy sets [3–6] and index matrices [1, 2], which receives as input a dataset, two-dimensional matrix, with the evaluations of multiple objects against multiple criteria, and returns as output a matrix with calculated dependencies in between the criteria in the form of intuitionistic fuzzy pairs [9], i.e. pairs of numbers that belong to the [0, 1]-interval, whose sum also belongs to that interval. The original motivation behind the ICA was a particular problem from the area of petrochemical industry, involving measurements of crude oil probes against various chemical and physical criteria, and decision making on this basis regarding the petrochemical products and quantities from that shipment of crude oil. The measurement against some of these criteria is inherently slower and/or more expensive than the measurement against some others, hence increasing the overall cost of the business process. The problem required finding patterns of correlation between the cost-favourable and the cost-unfavourable criteria, so that the cost-unfavourable ones may potentially get eliminated from the further decision making process on the basis of these patterns with the cost-favourable criteria, thus speeding up the process or lowering its cost. The process often involves levels of uncertainty, for which reason in developing ICA the apparatus of intuitionistic fuzzy sets was adopted as a more sophisticated extension of the concept of Zadeh's fuzzy sets [27] and a better tool for handling uncertainty.

The output of ICA are intuitionistic fuzzy pairs, as many as the different pairs of non-equal criteria (i.e. $n(n-1)/2$ pairs for the case of $n$ criteria), and the method of calculating these involves brute-force pairwise comparisons of the values (measurements) in the input table between all pairs of objects against all pairs of criteria, and checking the relation between the respective values in the input table. Depending on that relation (greater than, less than, or equal), three different counters are incremented, attributing to the degree of intuitionistic fuzzy membership, non-membership, or the complementary uncertainty. More formally, this is represented as follows. The input for the ICA is the index matrix M with index sets with $m$ rows $\{C^1, \ldots, C_m\}$ and $n$ columns $\{O^1, \ldots, O^n\}$:

$$M = \begin{array}{c|ccccccc} & O_1 & \ldots & O_k & \ldots & O_l & \ldots & O_n \\ \hline C_1 & a_{C_1,O_1} & \ldots & a_{C_1,O_k} & \ldots & a_{C_1,O_l} & \ldots & a_{C_1,O_n} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ C_i & a_{C_i,O_1} & \ldots & a_{C_i,O_k} & \ldots & a_{C_i,O_l} & \ldots & a_{C_i,O_n} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ C_j & a_{C_j,O_1} & \ldots & a_{C_j,O_k} & \ldots & a_{C_j,O_l} & \ldots & a_{C_j,O_n} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ C_m & a_{C_m,O_1} & \ldots & a_{C_m,O_j} & \ldots & a_{C_m,O_l} & \ldots & a_{C_m,O_n} \end{array},$$

where for every $p$, $q$ ($1 \le p \le m$, $1 \le q \le n$), $C_p$ is a criterion, $O_q$ in an evaluated object, $a_{C_pO_q}$ 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 $R(a_{C_kO_i}, a_{C_kO_j})$. The relation $R$ has dual relation $\bar{R}$, which is true in the cases when relation $R$ is false, and vice versa. Then, let $S^{\mu}_{k,l}$ be the numerical counter for the cases where the relations $R(a_{C_kO_i}, a_{C_kO_j})$ and $R(a_{C_lO_i}, a_{C_lO_j})$ are simultaneously satisfied, and let $S^{\nu}_{k,l}$ be the numerical counter for the cases where simultaneously satisfied are the relations $R(a_{C_kO_i}, a_{C_kO_j})$ and its dual one, $\bar{R}(a_{C_lO_i}, a_{C_lO_j})$. It holds that:

$$0 \le S^{\mu}_{k,l} + S^{\nu}_{k,l} \le \frac{n(n-1)}{2}.$$

For every $k$, $l$, such that $1 \le k \le l \le m$, and for $n \ge 2$, the two intuitionistic fuzzy numbers are defined by:

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

The so constructed pair $\langle \mu_{C_k}, \nu_{C_l} \rangle$ plays the role of the intuitionistic fuzzy evaluation of the relations that can be detected between any pair of criteria $C_k$ and $C_l$ from the set. In this way the input index matrix $M$ that relates the evaluated objects with the evaluating criteria can be transformed to the output index matrix $M^*$ that gives the relations in between the criteria:

$$M^* = \begin{array}{c|ccc} & C_1 & \cdots & C_m \\ \hline C_1 & \langle \mu_{C_1,C_1}, \nu_{C_1,C_1} \rangle & \cdots & \langle \mu_{C_1,C_m}, \nu_{C_1,C_m} \rangle \\ \vdots & \vdots & \ddots & \vdots \\ C_m & \langle \mu_{C_m,C_1}, \nu_{C_1,C_m} \rangle & \cdots & \langle \mu_{C_m,C_m}, \nu_{C_m,C_m} \rangle \end{array}.$$

For practical purposes, $M^*$ can be presented as two tables, one for the membership and one for the non-membership parts of the IF pairs, as we will use later in Section 4. As a final step in interpreting the results from the calculations, the decision maker needs to set two thresholds, for the membership and the non-membership, against which to compare the computed InterCriteria pairs. Let these two thresholds be the numbers $\alpha, \beta \in [0; 1]$. We say that 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, [8].

Obviously, the greater $\alpha$ and/or the smaller $\beta$, the less number of InterCriteria pairs fulfil the requirement for $(\alpha\ \beta)$-positive consonance, but the decision making process is not compromised by the presence of uncertainty. For practical purposes, it is the most informative when either the positive or the negative consonance is as strong as possible, since the cases of dissonance are less to no conclusive for the decision maker [7]. While the current state-of-the-art of the ICA research suggests that setting the thresholds in different decision making problems is rather dependent on the particular solved problem, and often boils down to an expert estimation, various ideas for algorithmic approaches to defining the thresholds have been developed in a particular leg of ICA research [19] and a discussion on the computational complexity and influence of the input's numerical precision on the results of InterCriteria analysis have recently followed [17].

## 3. INPUT DATA

The input data comes in the form of three index matrices for years 2015–2016 [24], 2016–2017 [25] and 2017–2018 [26], comprising 28 labelled rows staying for the analysed European Union Member States and 16 labelled columns for the nine subindicators of Pillar 11 'Business Sophistication' and the seven subindicators of Pillar 2 'Innovation' from the GCI methodology, see Tables 1–3. We will then be interested to examine the nine subindicators of Pillar 11 in between, the seven subindicators of Pillar 12, and finally the subindicators of Pillar 11 across those of Pillar 12.

| **2015-2016** | 11.01 | 11.02 | 11.03 | 11.04 | 11.05 | 11.06 | 11.07 | 11.08 | 11.09 | 12.01 | 12.02 | 12.03 | 12.04 | 12.05 | 12.06 | 12.07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Austria | 5.3 | 6 | 4.9 | 6.1 | 5.5 | 4.9 | 6 | 5.4 | 4.7 | 5.4 | 5.1 | 4.9 | 4.7 | 3.4 | 4.5 | 167.5 |
| Belgium | 5.3 | 5.8 | 4.6 | 5.9 | 5.1 | 4.6 | 6 | 5.4 | 5.1 | 5.3 | 6 | 5.1 | 5.6 | 3.5 | 4.6 | 111.1 |
| Bulgaria | 4.2 | 4.4 | 3.2 | 2.9 | 3.6 | 3.9 | 3.6 | 3.8 | 3.2 | 3.8 | 3.7 | 3.1 | 3 | 3.1 | 3.7 | 6.9 |
| Croatia | 4.6 | 4.5 | 3 | 3.6 | 3.6 | 3.5 | 3.5 | 3.9 | 3.4 | 3.3 | 4 | 3.1 | 3.4 | 2.7 | 3.9 | 10.3 |
| Cyprus | 4.6 | 4.6 | 3.9 | 4.4 | 4.1 | 3.9 | 4.1 | 4.6 | 4 | 3.7 | 4.1 | 3.2 | 4.2 | 3.3 | 4.9 | 10.6 |
| Czechia | 4.9 | 5.3 | 3.9 | 4 | 4.2 | 3.9 | 5.1 | 4.8 | 4.1 | 4.8 | 4.7 | 3.9 | 4 | 3.2 | 4 | 19.4 |
| Denmark | 4.9 | 5.6 | 4.5 | 6.4 | 5.2 | 4.8 | 5.8 | 5.1 | 6.1 | 5.3 | 5.5 | 4.9 | 4.9 | 3.4 | 4.6 | 215.4 |
| Estonia | 4.6 | 5.1 | 3.8 | 3.7 | 3.6 | 4 | 4.1 | 4.4 | 4.5 | 4.7 | 5.2 | 3.8 | 4.4 | 3.9 | 3.9 | 22.4 |
| Finland | 4.2 | 5.4 | 4.9 | 6.1 | 5 | 4.9 | 6.2 | 4.7 | 5.6 | 5.6 | 5.8 | 5.5 | 6 | 3.8 | 6.1 | 294 |
| France | 5.1 | 5.4 | 4.5 | 5.5 | 5.3 | 4.9 | 5.6 | 5.4 | 3.9 | 5.1 | 5.6 | 4.9 | 4.6 | 4 | 4.9 | 121.9 |
| Germany | 5.8 | 6 | 5.5 | 6.1 | 5.9 | 5.5 | 6.2 | 5.5 | 4.9 | 5.6 | 5.8 | 5.5 | 5.3 | 4.3 | 5 | 225.2 |
| Greece | 4.5 | 4.3 | 2.9 | 3.9 | 3.7 | 3.8 | 3.8 | 4.1 | 3.6 | 3.5 | 3.8 | 2.8 | 3.1 | 2.6 | 5.3 | 9.2 |
| Hungary | 4.3 | 4.5 | 3.6 | 3.3 | 3.4 | 3.6 | 3.8 | 3.9 | 3 | 3.1 | 4.8 | 2.9 | 4.3 | 2.9 | 4.2 | 24.8 |
| Ireland | 4.7 | 5.3 | 4.9 | 5.6 | 5 | 4.3 | 5.4 | 5.3 | 4.9 | 5.2 | 5.5 | 4.7 | 5.2 | 3.6 | 5.2 | 86.7 |
| Italy | 5.3 | 5.3 | 5.5 | 6 | 5.2 | 4.3 | 5.2 | 4.5 | 3.1 | 4.5 | 4.7 | 3.8 | 3.7 | 2.8 | 4.8 | 55.2 |
| Latvia | 4.1 | 4.8 | 3.6 | 3.5 | 3.6 | 4 | 4.1 | 4.5 | 4 | 4 | 4.1 | 3.1 | 3.7 | 3 | 3.5 | 13.8 |
| Lithuania | 5.2 | 5.1 | 3.5 | 3.5 | 4.2 | 4.3 | 4.5 | 4.7 | 3.8 | 4.6 | 4.7 | 3.5 | 4.6 | 3.1 | 4.1 | 10.8 |
| Luxembourg | 4 | 5.4 | 5.1 | 5.8 | 4.9 | 4.4 | 5.7 | 5.3 | 5 | 5.4 | 5.1 | 5 | 4.9 | 4.7 | 4.2 | 131.3 |
| Malta | 5 | 4.3 | 4 | 4.2 | 4.2 | 3.8 | 4.5 | 4.2 | 3.9 | 3.9 | 3.9 | 3.3 | 3.9 | 3.6 | 4 | 10.5 |
| Netherlands | 5.2 | 5.6 | 5.2 | 5.9 | 5.4 | 5 | 6.1 | 5.7 | 5.7 | 5.2 | 6 | 4.8 | 5.4 | 3.9 | 4.8 | 208.9 |
| Poland | 5.1 | 4.9 | 3.6 | 3 | 3.9 | 3.6 | 4.2 | 4.5 | 3.8 | 3.9 | 3.9 | 3.1 | 3.5 | 3.1 | 4.2 | 8.6 |
| Portugal | 4.8 | 4.3 | 4.2 | 3.9 | 4.2 | 3.9 | 4.6 | 4.5 | 3.6 | 4.5 | 5.2 | 3.7 | 4.7 | 3.6 | 4.9 | 13.7 |
| Romania | 4.1 | 4.2 | 3.6 | 3.1 | 3.5 | 3.6 | 3.7 | 4 | 3.6 | 4 | 3.7 | 2.9 | 3.6 | 2.9 | 4.1 | 2.7 |
| Slovakia | 4.6 | 4.8 | 3.9 | 3.1 | 4 | 3.5 | 4.6 | 4.5 | 3.5 | 3.8 | 3.9 | 3.3 | 3.4 | 3.1 | 3.8 | 9.2 |
| Slovenia | 4.5 | 4.9 | 3.5 | 4.2 | 3.8 | 4 | 4.4 | 4.3 | 3.9 | 4.4 | 4.8 | 3.7 | 4 | 2.7 | 4.1 | 62.3 |
| Spain | 5.1 | 5.1 | 3.9 | 4.1 | 4.7 | 4.4 | 4.7 | 4.7 | 3.5 | 4.1 | 4.4 | 3.3 | 3.8 | 3.2 | 5 | 38.2 |
| Sweden | 4.6 | 5.5 | 4.8 | 5.9 | 5.6 | 5 | 6.2 | 5.5 | 5.6 | 5.7 | 5.7 | 5.4 | 5.3 | 3.9 | 5 | 312.5 |
| UK | 5.6 | 5.4 | 5.3 | 6 | 5.5 | 5 | 5.9 | 6 | 5 | 5.4 | 6.3 | 4.9 | 5.7 | 3.8 | 4.9 | 89.9 |

Table 1. Input data for ICA: EU Member states' evaluations against the 12 pillars of competitiveness, year 2015–2016.

| **2016-2017** | 11.01 | 11.02 | 11.03 | 11.04 | 11.05 | 11.06 | 11.07 | 11.08 | 11.09 | 12.01 | 12.02 | 12.03 | 12.04 | 12.05 | 12.06 | 12.07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Austria | 5.5 | 6 | 4.8 | 6.2 | 5.8 | 5.1 | 6.1 | 5.2 | 4.7 | 5.6 | 5.3 | 4.9 | 4.8 | 3.4 | 4.7 | 170.1 |
| Belgium | 5.3 | 5.8 | 4.6 | 5.8 | 5.3 | 4.8 | 6 | 5.3 | 5.1 | 5.4 | 5.9 | 5.1 | 5.3 | 3.5 | 4.8 | 108.5 |
| Bulgaria | 4.4 | 4.6 | 3.6 | 3.2 | 3.8 | 3.5 | 3.8 | 3.9 | 3.2 | 4.3 | 3.9 | 3.5 | 3.4 | 3.3 | 3.9 | 7 |
| Croatia | 4.4 | 4.5 | 3 | 3.6 | 3.6 | 3.5 | 3.7 | 4 | 3.4 | 3.5 | 4 | 3.2 | 2.9 | 2.5 | 3.7 | 9.7 |
| Cyprus | 4.7 | 4.3 | 3.8 | 4.1 | 4.2 | 3.3 | 3.8 | 4.1 | 4 | 3.5 | 3.8 | 2.9 | 3.4 | 2.9 | 4.2 | 10.5 |
| Czechia | 4.8 | 5.2 | 3.8 | 4 | 4.2 | 4.3 | 5 | 4.6 | 4.1 | 4.8 | 4.8 | 4.1 | 3.7 | 3.1 | 3.7 | 21.7 |
| Denmark | 4.9 | 5.5 | 4.6 | 6.3 | 5.2 | 4.9 | 5.8 | 5.1 | 6.1 | 5.3 | 5.6 | 5 | 4.8 | 3.5 | 4.5 | 210.8 |
| Estonia | 4.6 | 5.2 | 3.8 | 3.6 | 3.8 | 3.8 | 4.1 | 4.4 | 4.5 | 4.9 | 5.3 | 3.9 | 4.1 | 3.5 | 4.3 | 18.7 |
| Finland | 4.2 | 5.4 | 4.9 | 5.9 | 5.2 | 5.1 | 6.2 | 4.2 | 5.6 | 5.6 | 5.8 | 5.4 | 5.7 | 3.8 | 6.1 | 291.2 |
| France | 5.1 | 5.5 | 4.6 | 5.9 | 5.5 | 5.2 | 5.7 | 5.6 | 3.9 | 5.4 | 5.8 | 5.2 | 4.3 | 3.8 | 4.7 | 122.9 |
| Germany | 5.7 | 5.9 | 5.4 | 5.9 | 5.8 | 5.6 | 6.1 | 5.5 | 4.9 | 5.7 | 5.8 | 5.6 | 5.4 | 4.5 | 5 | 219.1 |
| Greece | 4.3 | 4.4 | 3 | 4 | 3.8 | 3.7 | 4 | 4.1 | 3.6 | 3.8 | 3.9 | 3.1 | 2.7 | 2.6 | 5.2 | 10.5 |
| Hungary | 3.4 | 4.3 | 3.4 | 3.7 | 3.3 | 3.4 | 3.6 | 3.2 | 3 | 3.8 | 4.5 | 3 | 2.9 | 2.7 | 3.8 | 23.7 |
| Ireland | 4.7 | 5.2 | 4.9 | 5.6 | 5.3 | 4.6 | 6 | 5.1 | 4.9 | 5.3 | 5.6 | 4.8 | 5.1 | 3.6 | 5.2 | 83.8 |
| Italy | 5.2 | 5.3 | 5.4 | 5.8 | 5.3 | 4.3 | 5.2 | 4.6 | 3.1 | 4.7 | 4.7 | 3.9 | 3.7 | 3 | 4.7 | 56.6 |

*Contd.*

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Latvia | 4.2 | 4.8 | 3.5 | 3.4 | 3.8 | 3.9 | 4.1 | 4.5 | 4 | 4.3 | 4.2 | 3.3 | 3.3 | 2.9 | 3.6 | 16.4 |
| Lithuania | 4.9 | 5.1 | 3.3 | 3.6 | 4.2 | 4.2 | 4.5 | 4.6 | 3.8 | 4.9 | 4.6 | 3.9 | 4.1 | 2.9 | 4.1 | 15 |
| Luxembourg | 4.2 | 5.4 | 5.2 | 5.9 | 5 | 4.8 | 5.8 | 5.3 | 5 | 5.4 | 5.2 | 5.2 | 4.7 | 4.6 | 4.1 | 120.9 |
| Malta | 4.9 | 4.4 | 4.2 | 4.3 | 4.3 | 3.6 | 4.6 | 4.5 | 3.9 | 4.4 | 4.2 | 3.7 | 4 | 3.6 | 4 | 19.4 |
| Netherlands | 5.1 | 5.6 | 5.3 | 5.9 | 5.5 | 5.3 | 6.1 | 5.6 | 5.7 | 5.4 | 6 | 5.1 | 5.5 | 3.9 | 4.8 | 208.7 |
| Poland | 4.9 | 4.9 | 3.7 | 3 | 3.8 | 3.7 | 4.3 | 4.6 | 3.8 | 4.1 | 4.1 | 3.4 | 3.3 | 2.9 | 4.3 | 9.7 |
| Portugal | 4.5 | 4.8 | 4.2 | 4 | 4.4 | 3.8 | 4.5 | 4.5 | 3.6 | 4.6 | 5.1 | 3.7 | 4 | 3.4 | 4.6 | 14.4 |
| Romania | 4 | 4.3 | 3.2 | 2.7 | 3.5 | 3 | 3.4 | 4.1 | 3.6 | 4 | 3.8 | 2.8 | 3.3 | 2.3 | 4.1 | 3.4 |
| Slovakia | 4.3 | 4.9 | 3.9 | 3.3 | 4 | 3.5 | 4.9 | 4.3 | 3.5 | 4.2 | 3.9 | 3.3 | 3.3 | 3.1 | 3.6 | 10.5 |
| Slovenia | 4.5 | 5 | 3.5 | 4.4 | 3.8 | 4 | 4.7 | 4.2 | 3.9 | 4.8 | 4.9 | 4.1 | 3.8 | 2.5 | 4.1 | 67.8 |
| Spain | 5 | 5.1 | 4.3 | 4.3 | 4.8 | 4.4 | 4.8 | 4.6 | 3.5 | 4.3 | 4.5 | 3.5 | 3.5 | 3.3 | 4.6 | 37.7 |
| Sweden | 4.6 | 5.7 | 5 | 6.2 | 5.9 | 5.3 | 6.3 | 5.4 | 5.6 | 5.9 | 5.8 | 5.5 | 5.2 | 3.8 | 4.9 | 320 |
| UK | 5.6 | 5.4 | 5.3 | 6 | 5.7 | 5.3 | 5.9 | 5.8 | 5 | 5.4 | 6.3 | 4.9 | 5.5 | 3.8 | 4.9 | 94.5 |

Table 2. Input data for ICA: EU Member states' evaluations against the 12 pillars of competitiveness, year 2016–2017.

| **2016-2017** | 11.01 | 11.02 | 11.03 | 11.04 | 11.05 | 11.06 | 11.07 | 11.08 | 11.09 | 12.01 | 12.02 | 12.03 | 12.04 | 12.05 | 12.06 | 12.07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Austria | 5.4 | 6 | 4.9 | 6.3 | 5.9 | 5.2 | 6.1 | 5.2 | 5.4 | 5.6 | 5.4 | 4.9 | 4.8 | 3.3 | 4.5 | 174.7 |
| Belgium | 5.1 | 5.6 | 4.8 | 5.9 | 5.3 | 4.8 | 6 | 5.5 | 5.6 | 5.5 | 5.8 | 5.2 | 5.3 | 3.6 | 4.5 | 110.4 |
| Bulgaria | 4.5 | 4.4 | 3.7 | 3.2 | 3.7 | 3.3 | 3.7 | 4 | 3.9 | 4.2 | 3.9 | 3.6 | 3.4 | 3.3 | 3.6 | 7.4 |
| Croatia | 4.1 | 4.6 | 2.9 | 3.7 | 3.7 | 3.6 | 3.7 | 4.1 | 3.7 | 3.4 | 3.8 | 3 | 2.7 | 2.3 | 3.6 | 9.5 |
| Cyprus | 4.8 | 4.6 | 3.6 | 4.3 | 4.3 | 3.7 | 4 | 4.2 | 4.2 | 3.7 | 4.2 | 3 | 3.4 | 3.1 | 4.6 | 16.6 |
| Czechia | 4.9 | 5.5 | 3.9 | 3.9 | 4.3 | 4.2 | 4.8 | 4.7 | 5 | 4.9 | 5 | 4.2 | 3.9 | 3 | 3.8 | 24.4 |
| Denmark | 4.9 | 5.6 | 4.7 | 6.2 | 5.2 | 5 | 5.8 | 5 | 6.2 | 5.3 | 5.6 | 5 | 4.8 | 3.6 | 4.4 | 214.1 |
| Estonia | 4.7 | 5.3 | 3.7 | 3.9 | 3.9 | 3.8 | 4.2 | 4.4 | 5 | 4.9 | 5.3 | 3.8 | 3.9 | 3.5 | 4.3 | 27.2 |
| Finland | 4.4 | 5.4 | 5 | 5.7 | 5.1 | 5.1 | 6.1 | 4.2 | 5.9 | 5.6 | 5.8 | 5.3 | 5.6 | 4 | 6 | 265.1 |
| France | 5 | 5.5 | 4.7 | 5.7 | 5.4 | 5.1 | 5.6 | 5.4 | 4.8 | 5.5 | 5.8 | 5.2 | 4.2 | 3.6 | 4.6 | 126.6 |
| Germany | 5.7 | 5.8 | 5.4 | 5.8 | 5.6 | 5.5 | 5.9 | 5.5 | 5.5 | 5.8 | 5.7 | 5.6 | 5.4 | 4.9 | 5.2 | 218.9 |
| Greece | 4.2 | 4.4 | 3 | 4 | 3.8 | 3.8 | 4 | 4.2 | 4 | 3.9 | 3.9 | 3.1 | 2.5 | 2.5 | 5.2 | 11.1 |
| Hungary | 3.6 | 4.3 | 3.5 | 3.7 | 3.5 | 3.7 | 3.5 | 3.3 | 4 | 3.8 | 4.7 | 3.1 | 3.4 | 2.8 | 3.6 | 24.7 |
| Ireland | 4.7 | 5.2 | 4.8 | 5.4 | 5 | 4.5 | 5.7 | 5.1 | 5.6 | 5.2 | 5.4 | 4.8 | 5 | 3.4 | 4.8 | 89.9 |
| Italy | 5.2 | 5.2 | 5.3 | 5.8 | 5.3 | 4.3 | 5.2 | 4.6 | 3.7 | 4.9 | 4.8 | 3.9 | 3.8 | 3 | 4.5 | 57.5 |
| Latvia | 4.2 | 4.9 | 3.4 | 3.4 | 3.8 | 3.9 | 4.1 | 4.5 | 4.4 | 4.2 | 4.2 | 3.2 | 3.1 | 2.7 | 3.4 | 11.8 |
| Lithuania | 4.9 | 5 | 3.4 | 3.6 | 4.1 | 4.1 | 4.5 | 4.7 | 4.7 | 4.8 | 4.5 | 3.9 | 4.1 | 2.9 | 4.1 | 15.9 |
| Luxembourg | 4.2 | 5.3 | 5 | 5.9 | 5 | 4.9 | 5.9 | 5.2 | 5.5 | 5.6 | 5.1 | 5.2 | 4.8 | 4.7 | 4 | 129.3 |
| Malta | 5.1 | 4.6 | 4.3 | 4.4 | 4.4 | 3.8 | 4.8 | 4.7 | 4.8 | 4.7 | 4.1 | 3.8 | 4 | 3.8 | 4 | 26.5 |
| Netherlands | 5.2 | 5.8 | 5.4 | 6 | 5.5 | 5.4 | 6.2 | 5.6 | 5.8 | 5.7 | 6.1 | 5.2 | 5.6 | 4.1 | 4.9 | 211.9 |
| Poland | 4.7 | 4.9 | 3.8 | 3 | 3.8 | 3.7 | 4.2 | 4.7 | 4.1 | 4.1 | 4.2 | 3.4 | 3.2 | 3.1 | 4.2 | 10.5 |
| Portugal | 4.5 | 4.9 | 4.2 | 4.1 | 4.4 | 3.8 | 4.6 | 4.6 | 4.2 | 4.6 | 5.2 | 3.8 | 4.2 | 3.5 | 4.7 | 15.4 |
| Romania | 3.8 | 4.4 | 3 | 2.7 | 3.6 | 2.7 | 3.4 | 4.1 | 3.4 | 3.7 | 4 | 2.8 | 3.1 | 2.3 | 3.8 | 3.9 |
| Slovakia | 4.1 | 5 | 3.8 | 3.4 | 4 | 3.6 | 4.8 | 4.4 | 4.5 | 4.3 | 3.8 | 3.4 | 3.3 | 3.2 | 3.5 | 11.3 |
| Slovenia | 4.8 | 5.3 | 3.7 | 4.3 | 3.9 | 4.1 | 4.7 | 4.3 | 4.4 | 4.8 | 4.9 | 4.2 | 3.8 | 2.6 | 3.9 | 71.9 |
| Spain | 4.9 | 5.1 | 4.3 | 4.3 | 4.8 | 4.3 | 4.8 | 4.6 | 4.4 | 4.3 | 4.6 | 3.5 | 3.5 | 3.1 | 4.5 | 39 |
| Sweden | 4.8 | 5.7 | 5 | 6 | 5.7 | 5.5 | 6.1 | 5.5 | 6.2 | 5.8 | 5.7 | 5.6 | 5.2 | 4.2 | 4.8 | 317.9 |
| UK | 5.3 | 5.4 | 5.4 | 5.9 | 5.6 | 5.3 | 5.9 | 5.8 | 5.5 | 5.5 | 6.3 | 5.1 | 5.4 | 3.9 | 4.9 | 99.1 |

Table 3. Input data for ICA: EU Member states' evaluations against the 12 pillars of competitiveness, year 2017–2018.

## 4. MAIN RESULTS

The input data from Tables 1–3 were analysed with the open source software for InterCriteria Analysis, developed by D. Mavrov [20–22]. The output represents two tables per year, for the membership and the non-membership parts of the intuitionistic fuzzy pairs that stand collectively for the intuitionistic fuzzy consonance / dissonance between each pair of criteria. While the input are matrices of objects (in this case 28 countries) against criteria (here, 16 subindicators), the output represents two 16×16 matrices for each of the three years. As it follows easily from the ICA algorithm, the output matrices are symmetrical regarding the main diagonal, as in the ICA method the InterCriteria consonance between criteria $C_i$ and $C_j$ is identical with the InterCriteria consonance between $C_j$ and $C_i$. Also, along the main diagonal all the elements form the IFPs $\langle 1, 0 \rangle$, which represent the perfect 'truth' since every criterion in the set perfectly correlates with itself.

For the purpose of visualization of the results, we present here the output tables for the first year in the period only (Table 4, (a) for membership and (b) for non-membership). The rest output matrices can be easily produces by the interested reader using the presented input datasets for 2016–2017, 2017–2018 using the freely available software for ICA. On the next Table 5 we present the accumulated ICA results for all the 120 InterCriteria pairs composed of distinct criteria in the pair, for all the three years, including, in addition to the membership ($\mu$) and non-membership ($\nu$) also the measure of distance ($d$) of the intuitionistic fuzzy InterCriteria pair to the intuitionistic fuzzy 'Truth' in the form of the intuitionistic fuzzy pair $\langle 1, 0 \rangle$.

| μ | 11.01 | 11.02 | 11.03 | 11.04 | 11.05 | 11.06 | 11.07 | 11.08 | 11.09 | 12.01 | 12.02 | 12.03 | 12.04 | 12.05 | 12.06 | 12.07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11.01 | 1.00 | 0.65 | 0.64 | 0.62 | 0.72 | 0.61 | 0.66 | 0.66 | 0.52 | 0.61 | 0.61 | 0.61 | 0.59 | 0.55 | 0.55 | 0.59 |
| 11.02 | 0.65 | 1.00 | 0.71 | 0.73 | 0.78 | 0.79 | 0.82 | 0.80 | 0.73 | 0.80 | 0.76 | 0.80 | 0.73 | 0.67 | 0.58 | 0.81 |
| 11.03 | 0.64 | 0.71 | 1.00 | 0.76 | 0.79 | 0.73 | 0.80 | 0.75 | 0.68 | 0.75 | 0.72 | 0.77 | 0.75 | 0.75 | 0.64 | 0.74 |
| 11.04 | 0.62 | 0.73 | 0.76 | 1.00 | 0.77 | 0.70 | 0.79 | 0.71 | 0.70 | 0.73 | 0.70 | 0.75 | 0.71 | 0.62 | 0.61 | 0.76 |
| 11.05 | 0.72 | 0.78 | 0.79 | 0.77 | 1.00 | 0.80 | 0.86 | 0.82 | 0.69 | 0.79 | 0.75 | 0.80 | 0.73 | 0.71 | 0.67 | 0.78 |
| 11.06 | 0.61 | 0.79 | 0.73 | 0.70 | 0.80 | 1.00 | 0.80 | 0.79 | 0.72 | 0.80 | 0.76 | 0.77 | 0.76 | 0.70 | 0.64 | 0.82 |
| 11.07 | 0.66 | 0.82 | 0.80 | 0.79 | 0.86 | 0.80 | 1.00 | 0.83 | 0.74 | 0.84 | 0.78 | 0.84 | 0.79 | 0.73 | 0.66 | 0.84 |
| 11.08 | 0.66 | 0.80 | 0.75 | 0.71 | 0.82 | 0.79 | 0.83 | 1.00 | 0.74 | 0.79 | 0.78 | 0.77 | 0.78 | 0.72 | 0.63 | 0.75 |
| 11.09 | 0.52 | 0.73 | 0.68 | 0.70 | 0.69 | 0.72 | 0.74 | 0.74 | 1.00 | 0.78 | 0.74 | 0.75 | 0.78 | 0.71 | 0.57 | 0.76 |
| 12.01 | 0.61 | 0.80 | 0.75 | 0.73 | 0.79 | 0.80 | 0.84 | 0.79 | 0.78 | 1.00 | 0.79 | 0.87 | 0.81 | 0.73 | 0.62 | 0.82 |
| 12.02 | 0.61 | 0.76 | 0.72 | 0.70 | 0.75 | 0.76 | 0.78 | 0.78 | 0.74 | 0.79 | 1.00 | 0.80 | 0.87 | 0.71 | 0.65 | 0.83 |
| 12.03 | 0.61 | 0.80 | 0.77 | 0.75 | 0.80 | 0.77 | 0.84 | 0.77 | 0.75 | 0.87 | 0.80 | 1.00 | 0.79 | 0.76 | 0.61 | 0.83 |
| 12.04 | 0.59 | 0.73 | 0.75 | 0.71 | 0.73 | 0.76 | 0.79 | 0.78 | 0.78 | 0.81 | 0.87 | 0.79 | 1.00 | 0.74 | 0.67 | 0.81 |
| 12.05 | 0.55 | 0.67 | 0.75 | 0.62 | 0.71 | 0.70 | 0.73 | 0.72 | 0.71 | 0.73 | 0.71 | 0.76 | 0.74 | 1.00 | 0.58 | 0.70 |
| 12.06 | 0.55 | 0.58 | 0.64 | 0.61 | 0.67 | 0.64 | 0.66 | 0.63 | 0.57 | 0.62 | 0.65 | 0.61 | 0.67 | 0.58 | 1.00 | 0.67 |
| 12.07 | 0.59 | 0.81 | 0.74 | 0.76 | 0.78 | 0.82 | 0.84 | 0.75 | 0.76 | 0.82 | 0.83 | 0.83 | 0.81 | 0.70 | 0.67 | 1.00 |

(a)

| v | 11.01 | 11.02 | 11.03 | 11.04 | 11.05 | 11.06 | 11.07 | 11.08 | 11.09 | 12.01 | 12.02 | 12.03 | 12.04 | 12.05 | 12.06 | 12.07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11.01 | 0.00 | 0.24 | 0.27 | 0.30 | 0.19 | 0.28 | 0.26 | 0.24 | 0.39 | 0.31 | 0.30 | 0.28 | 0.34 | 0.36 | 0.35 | 0.35 |
| 11.02 | 0.24 | 0.00 | 0.19 | 0.20 | 0.13 | 0.11 | 0.10 | 0.12 | 0.20 | 0.12 | 0.15 | 0.10 | 0.20 | 0.24 | 0.33 | 0.13 |
| 11.03 | 0.27 | 0.19 | 0.00 | 0.17 | 0.13 | 0.19 | 0.13 | 0.15 | 0.25 | 0.18 | 0.19 | 0.15 | 0.19 | 0.17 | 0.27 | 0.21 |
| 11.04 | 0.30 | 0.20 | 0.17 | 0.00 | 0.16 | 0.22 | 0.17 | 0.22 | 0.25 | 0.22 | 0.25 | 0.18 | 0.25 | 0.31 | 0.32 | 0.21 |
| 11.05 | 0.19 | 0.13 | 0.13 | 0.16 | 0.00 | 0.11 | 0.08 | 0.09 | 0.24 | 0.15 | 0.18 | 0.13 | 0.21 | 0.21 | 0.25 | 0.17 |
| 11.06 | 0.28 | 0.11 | 0.19 | 0.22 | 0.11 | 0.00 | 0.11 | 0.11 | 0.19 | 0.11 | 0.14 | 0.13 | 0.16 | 0.20 | 0.25 | 0.11 |
| 11.07 | 0.26 | 0.10 | 0.13 | 0.17 | 0.08 | 0.11 | 0.00 | 0.11 | 0.21 | 0.11 | 0.16 | 0.08 | 0.17 | 0.20 | 0.26 | 0.13 |
| 11.08 | 0.24 | 0.12 | 0.15 | 0.22 | 0.09 | 0.11 | 0.11 | 0.00 | 0.17 | 0.14 | 0.14 | 0.14 | 0.16 | 0.19 | 0.27 | 0.19 |
| 11.09 | 0.39 | 0.20 | 0.25 | 0.25 | 0.24 | 0.19 | 0.21 | 0.17 | 0.00 | 0.17 | 0.20 | 0.17 | 0.17 | 0.21 | 0.34 | 0.20 |
| 12.01 | 0.31 | 0.12 | 0.18 | 0.22 | 0.15 | 0.11 | 0.11 | 0.14 | 0.17 | 0.00 | 0.17 | 0.06 | 0.15 | 0.20 | 0.31 | 0.15 |
| 12.02 | 0.30 | 0.15 | 0.19 | 0.25 | 0.18 | 0.14 | 0.16 | 0.14 | 0.20 | 0.17 | 0.00 | 0.12 | 0.07 | 0.22 | 0.26 | 0.13 |
| 12.03 | 0.28 | 0.10 | 0.15 | 0.18 | 0.13 | 0.13 | 0.08 | 0.14 | 0.17 | 0.06 | 0.12 | 0.00 | 0.14 | 0.16 | 0.29 | 0.12 |
| 12.04 | 0.34 | 0.20 | 0.19 | 0.25 | 0.21 | 0.16 | 0.17 | 0.16 | 0.17 | 0.15 | 0.07 | 0.14 | 0.00 | 0.20 | 0.26 | 0.17 |
| 12.05 | 0.36 | 0.24 | 0.17 | 0.31 | 0.21 | 0.20 | 0.20 | 0.19 | 0.21 | 0.20 | 0.22 | 0.16 | 0.20 | 0.00 | 0.32 | 0.25 |
| 12.06 | 0.35 | 0.33 | 0.27 | 0.32 | 0.25 | 0.25 | 0.26 | 0.27 | 0.34 | 0.31 | 0.26 | 0.29 | 0.26 | 0.32 | 0.00 | 0.28 |
| 12.07 | 0.35 | 0.13 | 0.21 | 0.21 | 0.17 | 0.11 | 0.13 | 0.19 | 0.20 | 0.15 | 0.13 | 0.12 | 0.17 | 0.25 | 0.28 | 0.00 |

(b)

Table 4. Results of application of ICA on the data from Table 1, year 2015–2016, membership parts (a) and non-membership parts (b)

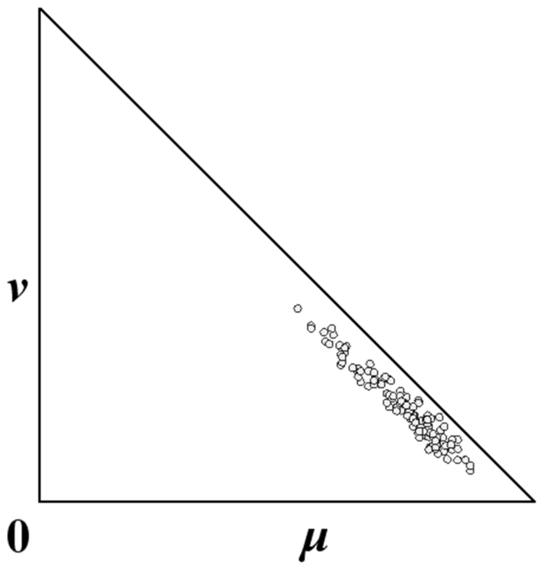
| $C_i$ | $C_j$ | 2015–2016 | | | 2016–2017 | | | 2017–2018 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $\mu$ | $\nu$ | $d$ | $\mu$ | $\nu$ | $d$ | $\mu$ | $\nu$ | $d$ |
| 11.01 | 11.02 | 0.648 | 0.243 | 0.428 | 0.704 | 0.225 | 0.372 | 0.706 | 0.196 | 0.353 |
| 11.01 | 11.03 | 0.640 | 0.267 | 0.448 | 0.683 | 0.246 | 0.402 | 0.701 | 0.209 | 0.365 |
| 11.01 | 11.04 | 0.616 | 0.302 | 0.488 | 0.653 | 0.267 | 0.438 | 0.701 | 0.222 | 0.372 |
| 11.01 | 11.05 | 0.720 | 0.190 | 0.339 | 0.722 | 0.180 | 0.331 | 0.772 | 0.156 | 0.276 |
| 11.01 | 11.06 | 0.608 | 0.278 | 0.480 | 0.696 | 0.241 | 0.388 | 0.714 | 0.204 | 0.351 |
| 11.01 | 11.07 | 0.664 | 0.265 | 0.428 | 0.672 | 0.267 | 0.423 | 0.706 | 0.214 | 0.364 |
| 11.01 | 11.08 | 0.664 | 0.235 | 0.410 | 0.733 | 0.185 | 0.325 | 0.730 | 0.177 | 0.323 |
| 11.01 | 11.09 | 0.521 | 0.392 | 0.619 | 0.574 | 0.360 | 0.558 | 0.627 | 0.288 | 0.471 |
| 11.01 | 12.01 | 0.611 | 0.312 | 0.499 | 0.648 | 0.267 | 0.442 | 0.690 | 0.222 | 0.381 |
| 11.01 | 12.02 | 0.608 | 0.299 | 0.493 | 0.651 | 0.278 | 0.446 | 0.677 | 0.251 | 0.409 |
| 11.01 | 12.03 | 0.611 | 0.283 | 0.481 | 0.653 | 0.280 | 0.446 | 0.677 | 0.233 | 0.398 |
| 11.01 | 12.04 | 0.593 | 0.339 | 0.530 | 0.667 | 0.259 | 0.422 | 0.677 | 0.241 | 0.403 |
| 11.01 | 12.05 | 0.548 | 0.357 | 0.576 | 0.614 | 0.299 | 0.488 | 0.627 | 0.296 | 0.476 |
| 11.01 | 12.06 | 0.548 | 0.352 | 0.573 | 0.646 | 0.272 | 0.447 | 0.622 | 0.288 | 0.476 |
| 11.01 | 12.07 | 0.590 | 0.352 | 0.540 | 0.638 | 0.317 | 0.482 | 0.688 | 0.262 | 0.407 |
| 11.02 | 11.03 | 0.706 | 0.193 | 0.351 | 0.749 | 0.193 | 0.317 | 0.749 | 0.180 | 0.309 |
| 11.02 | 11.04 | 0.733 | 0.198 | 0.333 | 0.746 | 0.172 | 0.307 | 0.757 | 0.164 | 0.293 |
| 11.02 | 11.05 | 0.778 | 0.135 | 0.260 | 0.783 | 0.116 | 0.246 | 0.815 | 0.122 | 0.222 |
| 11.02 | 11.06 | 0.788 | 0.111 | 0.239 | 0.852 | 0.082 | 0.169 | 0.807 | 0.108 | 0.221 |
| 11.02 | 11.07 | 0.817 | 0.103 | 0.210 | 0.839 | 0.103 | 0.192 | 0.817 | 0.095 | 0.206 |
| 11.02 | 11.08 | 0.796 | 0.116 | 0.235 | 0.778 | 0.148 | 0.267 | 0.746 | 0.159 | 0.299 |
| 11.02 | 11.09 | 0.730 | 0.196 | 0.333 | 0.717 | 0.220 | 0.358 | 0.762 | 0.156 | 0.285 |
| 11.02 | 12.01 | 0.802 | 0.124 | 0.234 | 0.828 | 0.090 | 0.194 | 0.817 | 0.098 | 0.207 |
| 11.02 | 12.02 | 0.765 | 0.151 | 0.280 | 0.796 | 0.135 | 0.244 | 0.783 | 0.153 | 0.266 |
| 11.02 | 12.03 | 0.804 | 0.098 | 0.219 | 0.841 | 0.095 | 0.185 | 0.802 | 0.116 | 0.230 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 11.02 | 12.04 | 0.733 | 0.196 | 0.331 | 0.780 | 0.153 | 0.268 | 0.759 | 0.161 | 0.290 |
| 11.02 | 12.05 | 0.675 | 0.238 | 0.403 | 0.720 | 0.196 | 0.342 | 0.696 | 0.235 | 0.385 |
| 11.02 | 12.06 | 0.577 | 0.325 | 0.534 | 0.661 | 0.259 | 0.426 | 0.624 | 0.288 | 0.474 |
| 11.02 | 12.07 | 0.815 | 0.130 | 0.226 | 0.804 | 0.148 | 0.246 | 0.807 | 0.146 | 0.242 |
| 11.03 | 11.04 | 0.757 | 0.175 | 0.300 | 0.738 | 0.180 | 0.318 | 0.770 | 0.159 | 0.280 |
| 11.03 | 11.05 | 0.786 | 0.132 | 0.252 | 0.820 | 0.095 | 0.204 | 0.836 | 0.108 | 0.197 |
| 11.03 | 11.06 | 0.730 | 0.185 | 0.327 | 0.772 | 0.172 | 0.285 | 0.783 | 0.140 | 0.258 |
| 11.03 | 11.07 | 0.796 | 0.130 | 0.241 | 0.804 | 0.143 | 0.242 | 0.841 | 0.095 | 0.185 |
| 11.03 | 11.08 | 0.754 | 0.153 | 0.290 | 0.754 | 0.167 | 0.297 | 0.765 | 0.148 | 0.278 |
| 11.03 | 11.09 | 0.677 | 0.249 | 0.407 | 0.688 | 0.249 | 0.399 | 0.735 | 0.201 | 0.332 |
| 11.03 | 12.01 | 0.754 | 0.177 | 0.303 | 0.754 | 0.175 | 0.302 | 0.812 | 0.116 | 0.221 |
| 11.03 | 12.02 | 0.722 | 0.193 | 0.338 | 0.735 | 0.196 | 0.329 | 0.762 | 0.172 | 0.294 |
| 11.03 | 12.03 | 0.770 | 0.153 | 0.277 | 0.759 | 0.188 | 0.305 | 0.791 | 0.135 | 0.249 |
| 11.03 | 12.04 | 0.749 | 0.185 | 0.312 | 0.788 | 0.156 | 0.263 | 0.812 | 0.122 | 0.224 |
| 11.03 | 12.05 | 0.749 | 0.169 | 0.303 | 0.807 | 0.114 | 0.224 | 0.796 | 0.143 | 0.249 |
| 11.03 | 12.06 | 0.643 | 0.270 | 0.448 | 0.698 | 0.228 | 0.378 | 0.698 | 0.228 | 0.378 |
| 11.03 | 12.07 | 0.735 | 0.214 | 0.340 | 0.770 | 0.188 | 0.297 | 0.799 | 0.161 | 0.258 |
| 11.04 | 11.05 | 0.770 | 0.164 | 0.283 | 0.788 | 0.108 | 0.238 | 0.839 | 0.103 | 0.192 |
| 11.04 | 11.06 | 0.701 | 0.220 | 0.371 | 0.780 | 0.140 | 0.261 | 0.810 | 0.127 | 0.229 |
| 11.04 | 11.07 | 0.786 | 0.167 | 0.271 | 0.783 | 0.151 | 0.264 | 0.810 | 0.124 | 0.227 |
| 11.04 | 11.08 | 0.706 | 0.217 | 0.365 | 0.704 | 0.198 | 0.357 | 0.714 | 0.206 | 0.352 |
| 11.04 | 11.09 | 0.704 | 0.249 | 0.387 | 0.712 | 0.212 | 0.358 | 0.757 | 0.193 | 0.311 |
| 11.04 | 12.01 | 0.728 | 0.225 | 0.353 | 0.757 | 0.164 | 0.293 | 0.780 | 0.161 | 0.272 |
| 11.04 | 12.02 | 0.696 | 0.251 | 0.395 | 0.759 | 0.169 | 0.294 | 0.749 | 0.198 | 0.320 |
| 11.04 | 12.03 | 0.746 | 0.183 | 0.313 | 0.762 | 0.172 | 0.294 | 0.743 | 0.190 | 0.320 |
| 11.04 | 12.04 | 0.709 | 0.246 | 0.381 | 0.735 | 0.185 | 0.323 | 0.757 | 0.185 | 0.306 |
| 11.04 | 12.05 | 0.619 | 0.315 | 0.494 | 0.690 | 0.212 | 0.375 | 0.714 | 0.233 | 0.369 |
| 11.04 | 12.06 | 0.606 | 0.317 | 0.506 | 0.672 | 0.235 | 0.404 | 0.677 | 0.257 | 0.412 |
| 11.04 | 12.07 | 0.765 | 0.206 | 0.313 | 0.847 | 0.093 | 0.179 | 0.849 | 0.119 | 0.192 |
| 11.05 | 11.06 | 0.799 | 0.108 | 0.228 | 0.810 | 0.103 | 0.217 | 0.847 | 0.095 | 0.181 |
| 11.05 | 11.07 | 0.860 | 0.085 | 0.164 | 0.839 | 0.093 | 0.186 | 0.860 | 0.085 | 0.164 |
| 11.05 | 11.08 | 0.823 | 0.087 | 0.198 | 0.780 | 0.114 | 0.247 | 0.791 | 0.135 | 0.249 |
| 11.05 | 11.09 | 0.690 | 0.238 | 0.391 | 0.669 | 0.235 | 0.406 | 0.757 | 0.188 | 0.307 |
| 11.05 | 12.01 | 0.786 | 0.153 | 0.264 | 0.778 | 0.119 | 0.252 | 0.812 | 0.124 | 0.225 |
| 11.05 | 12.02 | 0.746 | 0.183 | 0.313 | 0.743 | 0.161 | 0.303 | 0.775 | 0.177 | 0.286 |
| 11.05 | 12.03 | 0.802 | 0.130 | 0.237 | 0.759 | 0.151 | 0.284 | 0.791 | 0.148 | 0.256 |
| 11.05 | 12.04 | 0.728 | 0.214 | 0.347 | 0.772 | 0.135 | 0.265 | 0.791 | 0.156 | 0.261 |
| 11.05 | 12.05 | 0.712 | 0.209 | 0.356 | 0.749 | 0.146 | 0.290 | 0.754 | 0.193 | 0.313 |
| 11.05 | 12.06 | 0.675 | 0.246 | 0.408 | 0.706 | 0.193 | 0.351 | 0.725 | 0.220 | 0.352 |
| 11.05 | 12.07 | 0.783 | 0.175 | 0.278 | 0.775 | 0.151 | 0.271 | 0.831 | 0.143 | 0.222 |
| 11.06 | 11.07 | 0.802 | 0.114 | 0.229 | 0.847 | 0.103 | 0.185 | 0.833 | 0.090 | 0.189 |
| 11.06 | 11.08 | 0.786 | 0.106 | 0.239 | 0.823 | 0.106 | 0.206 | 0.783 | 0.143 | 0.260 |
| 11.06 | 11.09 | 0.720 | 0.185 | 0.336 | 0.735 | 0.204 | 0.334 | 0.772 | 0.156 | 0.276 |
| 11.06 | 12.01 | 0.799 | 0.111 | 0.230 | 0.841 | 0.095 | 0.185 | 0.860 | 0.077 | 0.160 |
| 11.06 | 12.02 | 0.765 | 0.140 | 0.274 | 0.831 | 0.108 | 0.201 | 0.823 | 0.135 | 0.223 |
| 11.06 | 12.03 | 0.767 | 0.130 | 0.266 | 0.854 | 0.090 | 0.171 | 0.847 | 0.098 | 0.182 |
| 11.06 | 12.04 | 0.759 | 0.164 | 0.291 | 0.794 | 0.153 | 0.257 | 0.788 | 0.148 | 0.258 |
| 11.06 | 12.05 | 0.701 | 0.201 | 0.360 | 0.759 | 0.164 | 0.291 | 0.741 | 0.206 | 0.331 |
| 11.06 | 12.06 | 0.643 | 0.254 | 0.438 | 0.714 | 0.220 | 0.360 | 0.706 | 0.222 | 0.368 |

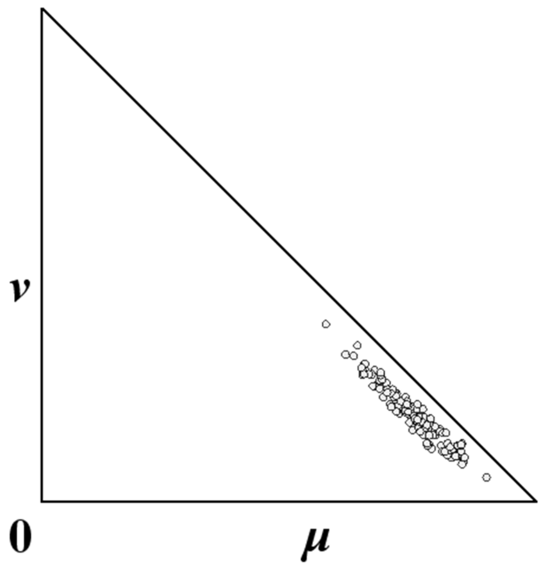
| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 11.06 | 12.07 | 0.820 | 0.114 | 0.213 | 0.847 | 0.114 | 0.191 | 0.873 | 0.090 | 0.156 |
| 11.07 | 11.08 | 0.833 | 0.106 | 0.197 | 0.775 | 0.151 | 0.271 | 0.794 | 0.130 | 0.244 |
| 11.07 | 11.09 | 0.741 | 0.212 | 0.335 | 0.735 | 0.212 | 0.339 | 0.815 | 0.127 | 0.225 |
| 11.07 | 12.01 | 0.844 | 0.108 | 0.190 | 0.823 | 0.106 | 0.206 | 0.854 | 0.079 | 0.166 |
| 11.07 | 12.02 | 0.783 | 0.164 | 0.272 | 0.783 | 0.159 | 0.269 | 0.770 | 0.164 | 0.283 |
| 11.07 | 12.03 | 0.844 | 0.085 | 0.178 | 0.839 | 0.114 | 0.197 | 0.828 | 0.093 | 0.195 |
| 11.07 | 12.04 | 0.791 | 0.169 | 0.269 | 0.810 | 0.140 | 0.237 | 0.812 | 0.122 | 0.224 |
| 11.07 | 12.05 | 0.728 | 0.201 | 0.339 | 0.751 | 0.175 | 0.304 | 0.759 | 0.175 | 0.297 |
| 11.07 | 12.06 | 0.664 | 0.265 | 0.428 | 0.709 | 0.228 | 0.369 | 0.672 | 0.254 | 0.415 |
| 11.07 | 12.07 | 0.844 | 0.127 | 0.201 | 0.849 | 0.119 | 0.192 | 0.841 | 0.119 | 0.198 |
| 11.08 | 11.09 | 0.743 | 0.175 | 0.310 | 0.706 | 0.220 | 0.367 | 0.733 | 0.185 | 0.325 |
| 11.08 | 12.01 | 0.788 | 0.140 | 0.254 | 0.762 | 0.151 | 0.282 | 0.778 | 0.148 | 0.267 |
| 11.08 | 12.02 | 0.775 | 0.143 | 0.266 | 0.765 | 0.161 | 0.285 | 0.749 | 0.183 | 0.311 |
| 11.08 | 12.03 | 0.767 | 0.143 | 0.273 | 0.770 | 0.161 | 0.281 | 0.767 | 0.151 | 0.277 |
| 11.08 | 12.04 | 0.783 | 0.159 | 0.269 | 0.754 | 0.169 | 0.299 | 0.767 | 0.159 | 0.282 |
| 11.08 | 12.05 | 0.720 | 0.190 | 0.339 | 0.717 | 0.183 | 0.337 | 0.722 | 0.209 | 0.348 |
| 11.08 | 12.06 | 0.632 | 0.272 | 0.458 | 0.648 | 0.257 | 0.435 | 0.643 | 0.275 | 0.451 |
| 11.08 | 12.07 | 0.754 | 0.193 | 0.313 | 0.738 | 0.204 | 0.332 | 0.725 | 0.228 | 0.357 |
| 11.09 | 12.01 | 0.780 | 0.167 | 0.276 | 0.741 | 0.183 | 0.317 | 0.807 | 0.127 | 0.231 |
| 11.09 | 12.02 | 0.735 | 0.201 | 0.332 | 0.741 | 0.196 | 0.325 | 0.757 | 0.183 | 0.304 |
| 11.09 | 12.03 | 0.754 | 0.169 | 0.299 | 0.749 | 0.193 | 0.317 | 0.796 | 0.135 | 0.244 |
| 11.09 | 12.04 | 0.783 | 0.167 | 0.274 | 0.778 | 0.156 | 0.272 | 0.804 | 0.140 | 0.241 |
| 11.09 | 12.05 | 0.714 | 0.214 | 0.357 | 0.717 | 0.214 | 0.355 | 0.762 | 0.177 | 0.297 |
| 11.09 | 12.06 | 0.574 | 0.344 | 0.547 | 0.630 | 0.296 | 0.474 | 0.630 | 0.296 | 0.474 |
| 11.09 | 12.07 | 0.765 | 0.201 | 0.310 | 0.759 | 0.198 | 0.312 | 0.817 | 0.148 | 0.235 |
| 12.01 | 12.02 | 0.786 | 0.167 | 0.271 | 0.815 | 0.103 | 0.212 | 0.807 | 0.140 | 0.239 |
| 12.01 | 12.03 | 0.870 | 0.063 | 0.144 | 0.899 | 0.050 | 0.112 | 0.902 | 0.032 | 0.103 |
| 12.01 | 12.04 | 0.810 | 0.146 | 0.240 | 0.849 | 0.077 | 0.169 | 0.836 | 0.106 | 0.195 |
| 12.01 | 12.05 | 0.730 | 0.204 | 0.338 | 0.765 | 0.143 | 0.275 | 0.802 | 0.146 | 0.246 |
| 12.01 | 12.06 | 0.616 | 0.312 | 0.495 | 0.683 | 0.230 | 0.392 | 0.669 | 0.254 | 0.417 |
| 12.01 | 12.07 | 0.817 | 0.153 | 0.238 | 0.820 | 0.119 | 0.216 | 0.860 | 0.103 | 0.174 |
| 12.02 | 12.03 | 0.799 | 0.124 | 0.236 | 0.825 | 0.111 | 0.207 | 0.804 | 0.140 | 0.241 |
| 12.02 | 12.04 | 0.870 | 0.074 | 0.149 | 0.836 | 0.093 | 0.188 | 0.844 | 0.098 | 0.184 |
| 12.02 | 12.05 | 0.706 | 0.217 | 0.365 | 0.759 | 0.167 | 0.293 | 0.735 | 0.222 | 0.345 |
| 12.02 | 12.06 | 0.648 | 0.265 | 0.440 | 0.698 | 0.222 | 0.375 | 0.722 | 0.212 | 0.349 |
| 12.02 | 12.07 | 0.833 | 0.127 | 0.210 | 0.817 | 0.140 | 0.230 | 0.817 | 0.156 | 0.240 |
| 12.03 | 12.04 | 0.794 | 0.138 | 0.248 | 0.841 | 0.114 | 0.195 | 0.831 | 0.098 | 0.196 |
| 12.03 | 12.05 | 0.759 | 0.161 | 0.290 | 0.791 | 0.135 | 0.249 | 0.796 | 0.148 | 0.252 |
| 12.03 | 12.06 | 0.611 | 0.294 | 0.487 | 0.685 | 0.257 | 0.406 | 0.664 | 0.257 | 0.423 |
| 12.03 | 12.07 | 0.831 | 0.116 | 0.205 | 0.847 | 0.116 | 0.193 | 0.847 | 0.114 | 0.191 |
| 12.04 | 12.05 | 0.741 | 0.196 | 0.325 | 0.783 | 0.135 | 0.255 | 0.788 | 0.153 | 0.261 |
| 12.04 | 12.06 | 0.675 | 0.262 | 0.418 | 0.725 | 0.204 | 0.342 | 0.728 | 0.206 | 0.342 |
| 12.04 | 12.07 | 0.807 | 0.172 | 0.259 | 0.786 | 0.169 | 0.273 | 0.812 | 0.156 | 0.244 |
| 12.05 | 12.06 | 0.585 | 0.320 | 0.524 | 0.651 | 0.259 | 0.435 | 0.669 | 0.265 | 0.423 |
| 12.05 | 12.07 | 0.698 | 0.254 | 0.394 | 0.738 | 0.198 | 0.329 | 0.765 | 0.209 | 0.315 |
| 12.06 | 12.07 | 0.667 | 0.280 | 0.436 | 0.685 | 0.262 | 0.410 | 0.696 | 0.265 | 0.403 |

Table 5. Accumulated ICA results for all the 120 InterCriteria pairs composed of distinct criteria in the pair, for all the three investigated years

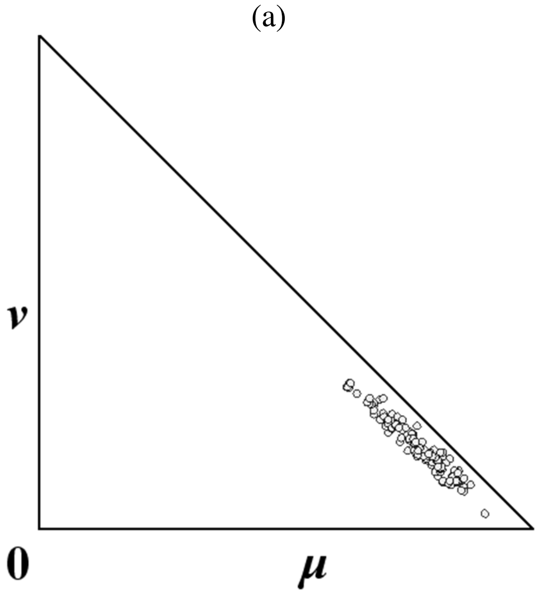
The information from Table 5 is also visualized on the Figure 2 (a)–(c) below, where each of the 120 InterCriteria pairs composed of distinct subindicators only is presented as a point in the intuitionistic fuzzy interpretational triangle [10, 18]




(a)




(b)




(c)

Figure 2. Results of the ICA applied to the subindicators in Pillars 11 and 12, plotted as points on the intuitionistic fuzzy interpretational triangle for year 2015–2016 in (a), year 2016–2017 in (b), and year 2017–2018 in (c).

In the frames of Pillar 11 ‘Business sophistication’, the most strongly correlating subindicators are 11.05 ‘Value chain breadth’ and 11.07 ‘Production process sophistication’, i.e. they exhibit highest pairwise positive consonances with the rest of the subindicators. Next in the line is subindicator 11.06 ‘Control of international distribution’. For comparison, the subindicator in

Pillar 11 that exhibits least positive consonance is 11.01 ‘Local supplier quantity’ with highest values with 11.05 ‘Value chain breadth’.
In the frames of Pillar 12 ‘Innovation’, the most strongly correlating subindicators are 12.01 ‘12.01 Capacity for innovation’, 12.03 ‘Company spending on R&D’ and 12.04 ‘University-industry collaboration in R&D’, with the strongest positive consonance exhibited by the pair 12.01 and 12.03. In this group, one subindicator exhibits particularly low positive consonance with the rest of the criteria, namely 12.06 ‘Availability of scientists and engineers’.
Probably the most interesting is the case of how the nine subindicators of Pillar 11 correlate with the seven subindicators of Pillar 12, across the pillars, as this may shed light on which of both pillars’ ‘ingredients’ are responsible for the traditionally high correlation detected between the aggregated Pillars 11 and 12, as recorded in our previous research based on the same selection of countries. We immediately notice that the two least correlating subindicators from the two pillars, 11.01 and 12.06, tend to correlate most weakly across the pillars as well. However, there is no immediate candidate for a whole subindicator from one of the pillars that correlates strongly enough with those from the other pillar. The most strongly exhibited InterCriteria positive consonances in all the three years are observed between the following pairs:

- 11.06 ‘Control of international distribution’ and 12.07 ‘PCT patents’
- 11.06 ‘Control of international distribution’ and 12.01 ‘Capacity for innovation’
- 11.07 ‘Production process sophistication’ and 12.01 ‘Capacity for innovation’
- 11.04 ‘Nature of competitive advantage’ and 12.07 ‘PCT patents’
- 11.06 ‘Control of international distribution’ and 12.03 ‘Company spending on R&D’
- 11.07 ‘Production process sophistication’ and 12.07 ‘PCT patents’.

A closer look at the results further shows the presence of highly correlating InterCriteria triples, in addition to the pairs, as explained in [15, 23].

## 5. CONCLUSIONS

In the present paper, we apply the intuitionistic-fuzzy sets based method of InterCriteria Analysis on the data about the 28 European Union Member States derived from the World Economic Forum’s Global Competitiveness Indices of the three yearly periods 2015–2018. Specifically, we get a deeper look on the two pillars of competitiveness that exhibit traditionally highest correlation, 11 ‘Business sophistication’ and 12 ‘Innovation’ by investigating the subindicators on which these pillars are based. The detected pairwise relations between these ‘ingredients’ of business sophistication and innovation capability are considered informative for the national decision and policy makers, in the light of the World Economic Forum’s traditional appeal to them to identify which are the transformative forces of their national economies and strengthen them in order to foster future economic growth.

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