

Business Dynamism and Innovation Capability in the European Union Member States in 2018 through the Prism of InterCriteria Analysis

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Abstract. Here we apply the intuitionistic fuzzy sets-based InterCriteria Analysis on the data from the Global Competitiveness Index of 2018, about the two best correlating pillars of competitiveness ‘11 Business Dynamism’ and ‘12 Innovation Capability’ based on the data of the 28 European Union Member States. We get a deeper look on how the eight subindicators of the countries’ business dynamism and the ten subindicators of their innovation capability correlate in between and among each other.

Keywords: InterCriteria analysis, Global Competitiveness Index, Business dynamism, Innovation capability, Intuitionistic fuzzy sets.

1 Introduction

In the end of 2018, the World Economic Forum (WEF) restructured the methodology of its annual Global Competitiveness Index (GCI), now labeled "4.0" [15], preserving some of their traditional twelve pillars of competitiveness, while changing others, not only nominally, but also in terms of their sub-indicators, derived from the databases of various international organizations and WEF itself. 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 WEF’s Global Competitiveness Reports from 2007 to 2017, 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’. Now, we are challenged to research the intercriteria performance of the corresponding two new set of pillars, namely Pillar 11 ‘Business Dynamism’ and Pillar 12 ‘Innovation Capability’, and specifically get a deeper look in the relations between their eight and ten subindicators, respectively.

2 Presentation of the method

InterCriteria Analysis (ICA), originally introduced in 2014, is a method based on intuitionistic fuzzy sets [2] which receives as input datasets of the evaluations of multiple objects against multiple criteria and returns as output a table of detected dependencies in the form of intuitionistic fuzzy pairs [3] between each pair of criteria. These dependencies are interpreted as presence of pairwise correlation (termed positive consonance), lack of correlation (or, negative consonance), and uncertainty (i.e., dissonance). In the original problem formulation that leads to the idea of ICA, measuring against some of the criteria is slower or more expensive than measuring against others, and the decision maker's aim is to accelerate or lower the cost of the overall decision making process by eliminating the costly criteria on the basis of these existing correlations. The use of intuitionistic fuzzy pairs requires the introduction of two thresholds, respectively, for the membership and the non-membership part of the IFP [10], which is to ensure that the precision of the decision taken is not compromised by uncertainty. A detailed presentation of the method is given in [1, 2], and of the various ways of defining these thresholds are presented in [9].

3 Presentation of the input data

In the 2018 GCI, two of the twelve pillars of competitiveness form the countries' innovation ecosystem: Pillar 11 'Business Dynamism' and Pillar 12 'Innovation Capability'. Each of them is formed from a number of subindicators, as given in the Table 1 below.

Table 1. Pillars 11 and 12 (the Innovation Ecosystem) from the 2018 GCI Report.

Pillar / subindicator	Measure
Pillar 11: Business dynamism	0-100 (best)
11.01 Cost of starting a business	% GNI per capita
11.02 Time to start a business	days
11.03 Insolvency recovery rate	cents/\$
11.04 Insolvency regulatory framework	0-16 (best)
11.05 Attitudes toward entrepreneurial risk	1-7 (best)
11.06 Willingness to delegate authority	1-7 (best)
11.07 Growth of innovative companies	1-7 (best)
11.08 Companies embracing disruptive	1-7 (best)
Pillar 12: Innovation capability	0-100 (best)
12.01 Diversity of workforce	1-7 (best)
12.02 State of cluster development	1-7 (best)
12.03 International co-inventions	applications/ million pop.
12.04 Multi-stakeholder collaboration	1-7 (best)
12.05 Scientific publications	H Index
12.06 Patent applications	applications/ million pop.
12.07 R&D expenditures	% GDP
12.08 Quality of research institutions	index
12.09 Buyer sophistication	1-7 (best)
12.10 Trademark applications	applications/ million pop.

We notice that between the pillars 11 and 12 from the previous GCI methodology (until 2018) and those from the new methodology (as of 2018), there are not only nominal differences, but also differences in the selected subindicators that form the pillars. For instance, Pillar 11 ‘Business dynamism’ with 8 subindicators replaces the previous Pillar 11 ‘Business sophistication with nine subindicators, and only one of these remained in the new methodology, 11.06 ‘Willingness to delegate authority’, and another subindicator 12.02 ‘State of cluster development’ was moved from the old pillar 11 to the new Pillar 12. In Pillar 12, it is noticed that the two old subindicators related to research and development – ‘Company spending on R&D’ and ‘University-industry collaboration in R&D’ now are combined in the new subindicator 12.07 ‘R&D expenditures’, and the subindicator ‘Quality of scientific research institutions’ now reads 12.08 ‘Quality of research institutions’. On this basis we cannot draw significant comparisons and conclusions related to the performance of the pair of pillars before and after 2018, but we notice in [9] that under the new GCI methodology, the two ‘Innovation Ecosystem’ pillars again correlate most strongly as their respective predecessors from the previous GCI, collectively called ‘Innovation and Sophistication Factors’, like [5, 7], as identified with the InterCriteria Analysis.

Table 2. InterCriteria Analysis input with data for the European Union Member States in 2018 (objects) against pillar ‘11 Business dynamism’ and pillar ‘12 Innovation capability’ (criteria).

	Austria	Belgium	Bulgaria	Croatia	Cyprus	Czech Republic	Denmark	Estonia	Finland	France	Germany	Greece	Hungary	Ireland	Italy	Latvia	Lithuania	Luxembourg	Malta	Netherlands	Poland	Portugal	Romania	Slovak Republic	Slovenia	Spain	Sweden	United Kingdom
Pillar 11	69.9	73.8	60.3	55.7	66.9	70.2	79.1	69.3	78.3	69.4	81.6	58	57.2	76.9	65.4	64.3	64.5	65.8	59.2	80.3	61.5	69.7	60.1	64.5	70.3	66.3	79.8	79
11.01	97.5	97.2	99.4	96.4	93.8	99.5	99.9	99.4	99.5	99.7	99.1	98.9	97.3	99.9	93.2	99.1	99.7	99.2	96.4	97.8	94	99	99.8	99.5	100	97.6	99.8	100
11.02	79.4	96.5	77.4	93.5	94.5	91.5	97	97	86.4	97	89.9	87.9	93.5	95.5	94	95	95	83.9	84.3	97	63.3	95.5	88.4	87.9	93.5	87.4	93.5	96
11.03	86.1	91.1	38.8	35.2	78.8	72.1	94.8	43.7	95	79.1	86.8	36.2	47	92.4	69.5	43.2	48.8	47.1	41.8	96.6	67.9	68.7	38.3	50.9	95.5	82.5	84.1	91.7
11.04	68.8	71.9	81.3	75	78.1	81.3	75	87.5	90.6	68.8	93.8	75	62.5	65.6	84.4	75	50	43.8	34.4	71.9	87.5	90.6	81.3	81.3	71.9	75	75	68.8
11.05	45.5	46.1	45.4	32.1	54.8	47.3	55.7	50.6	53.1	46.2	67.5	45.6	33.4	64.7	49.6	44.3	51.5	52.3	57.5	66.6	46.7	46.7	38.5	43.6	42.5	46	66	68.5
11.06	71.9	75.7	48.8	42.7	51.9	66.2	84.9	66.2	79.5	63.2	76.3	48.6	51.2	76.5	48.1	58.7	63.8	74.7	61.3	79.7	51	54.2	47.4	57.2	58.4	56.4	83.8	75.3
11.07	62.2	59.2	48.5	38.2	42.9	55.8	64.7	59.5	64.9	54.7	72.9	38.4	41.6	66.1	47.8	53.5	57.7	68.5	52.3	71.5	46	56.3	47.8	54	58.9	48	74.1	69.4
11.08	47.5	53	43.2	32.4	40.1	47.7	61.1	50.3	57.3	46.7	66.5	33.1	31.5	54.8	36.6	45.7	49.7	56.9	45.9	61.3	35.5	46.7	39	41.9	41.7	37.2	62.5	62.1
Pillar 12	74.3	73.4	43.9	37.7	44.7	57.3	75.4	52.5	76.3	76.1	87.5	45	48	67	65.8	42	47.4	68.2	51	77.5	48.7	53.1	39.6	46.6	57.9	62.9	79.8	79.2
12.01	59	62.7	53.4	38.9	52.3	55.4	65.3	41.4	59.9	57.4	71.9	45.8	29.7	69.8	34.4	51.6	64.9	77.7	62.2	72.7	38.9	63	66.2	48.6	56.4	52.1	73.2	76.6
12.02	66.7	64.9	46.8	30.4	46.3	50.5	63.9	45.6	64.9	63.2	75.4	32.3	46.8	60.8	74.5	46	41.3	67	53.8	72.8	46.6	54.4	34.5	46.6	47.3	54.4	67.6	69.8
12.03	100	99.7	22.9	23.5	22.9	58.2	98.7	52.2	100	77.7	95.2	25.6	53.7	91.7	49.8	25.7	27.1	100	47.6	94.3	29.4	26.1	20.4	41	56.4	46.2	100	79.8
12.04	63.4	63.3	43.3	30.8	40.9	50.6	64.8	49.8	71.2	53.8	95.2	33.3	37.1	63.7	45.4	41	51.4	65.6	48	72.3	34.9	50.5	36.3	43.9	48	40.5	71.6	67.5
12.05	93.5	96.5	79.2	80.3	74.9	87.9	95.6	80	93.4	100	100	89.2	87.7	89.7	100	72.6	76.1	73.4	67.9	100	90.7	88.4	78.9	80.5	81.2	97.9	98	100
12.06	100	87	31.4	32.9	41.4	61.6	98.1	60	100	91.5	100	43.6	55.9	80.7	76.4	39.6	47.1	88.2	57.9	95.9	47	45.5	26.7	42.1	73.9	61.7	100	84.9
12.07	100	81.9	31.9	28.5	15.2	65	100	49.8	96.8	74.4	95.9	31.9	45.9	50.5	44.5	20.8	34.7	42.9	25.6	67.1	33.4	42.6	16.3	39.3	73.7	40.7	100	56.8
12.08	5.23	24.5	2.6	3.6	2.3	23	17.2	2.9	17.7	100	100	16.2	9.9	11.8	90.8	1.3	4	0.5	0.4	40.7	39.8	20.7	10.8	5.8	4.1	100	26.7	100
12.09	45.2	57	39.1	28.6	50.5	32.6	50.7	46.2	62.5	49.8	66.1	35.5	29.7	55.4	48.2	33.7	38.5	66.5	46.2	59.7	40.4	46.5	28.6	33.7	41.5	39.8	61.5	61.4
12.10	100	96.3	88.6	79.3	100	88.4	99.3	97.4	97	92.7	97.3	96.8	83.4	96.6	93.6	87.6	88.3	100	100	99.7	86.3	92.9	77.8	84.9	96.8	95.4	99.1	94.7

4 Main results

The input data from Table 2 was analysed with the software for ICA, developed by D. Mavrov [12, 13], freely available from <http://intercriteria.net>, [16]. The

output represents two tables, 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 is objects (in this case 28 countries) against criteria (here, a total of 2 competitiveness indicators and a total of 18 subindicators), the output is two 20×20 matrices. They are both symmetrical according to 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 are the IFPs $\langle 1,0 \rangle$, which represents the perfect ‘truth’.

Here on Table 3 we present the ICA results showing the membership (a) and the non-membership (b) parts of the intercriteria pairwise correlations. As the reader will see from Figure 1, the intercriteria pairs are depicted by points on the intuitionistic fuzzy interpretational triangle [4, 8, 11] very close to or on the hypotenuse, meaning very low uncertainty, hence the non-membership values are almost everywhere complementary to 1 to the respective memberships ones. We will discuss in details the three segments of the table, first, in subsection 4.1, the intercriteria correlations in between the subindicators of Pillar 11 ‘Business dynamism’, second, in subsection 4.2, the intercriteria correlations in between the subindicators of Pillar 12 ‘Innovation capability’, and third, in subsection 4.3, in between the subindicators of pillars 11 and 12. In this way, we will get a better understanding of the factors that form the innovation ecosystem of countries, from the European Union perspective.

Table 3. Results of the InterCriteria Analysis from the input of Table 2 (a) membership, (b) non-membership.

(a)	Pillar 11	11.01	11.02	11.03	11.04	11.05	11.06	11.07	11.08	Pillar 12	12.01	12.02	12.03	12.04	12.05	12.06	12.07	12.08	12.09	12.10
Pillar 11	1.000	0.627	0.616	0.854	0.503	0.749	0.825	0.849	0.841	0.841	0.741	0.767	0.762	0.857	0.714	0.794	0.802	0.675	0.783	0.690
11.01	0.627	1.000	0.561	0.598	0.418	0.545	0.640	0.669	0.648	0.579	0.680	0.511	0.561	0.638	0.505	0.548	0.608	0.516	0.521	0.455
11.02	0.616	0.561	1.000	0.593	0.399	0.566	0.598	0.585	0.598	0.561	0.542	0.516	0.513	0.595	0.561	0.545	0.563	0.548	0.545	0.487
11.03	0.854	0.598	0.593	1.000	0.444	0.669	0.772	0.743	0.717	0.804	0.656	0.757	0.749	0.772	0.706	0.765	0.762	0.667	0.741	0.669
11.04	0.503	0.418	0.399	0.444	1.000	0.447	0.397	0.431	0.437	0.442	0.360	0.442	0.370	0.429	0.508	0.405	0.468	0.550	0.439	0.389
11.05	0.749	0.545	0.566	0.669	0.447	1.000	0.746	0.751	0.807	0.749	0.733	0.712	0.656	0.772	0.608	0.704	0.630	0.595	0.802	0.709
11.06	0.825	0.640	0.598	0.772	0.397	0.746	1.000	0.868	0.884	0.804	0.751	0.733	0.815	0.876	0.608	0.799	0.780	0.556	0.746	0.701
11.07	0.849	0.669	0.585	0.743	0.431	0.751	0.868	1.000	0.910	0.817	0.804	0.772	0.780	0.913	0.624	0.783	0.759	0.579	0.775	0.690
11.08	0.841	0.648	0.598	0.717	0.437	0.807	0.884	0.910	1.000	0.796	0.820	0.751	0.746	0.910	0.606	0.754	0.722	0.574	0.783	0.672
Pillar 12	0.841	0.579	0.561	0.804	0.442	0.749	0.804	0.817	0.796	1.000	0.704	0.862	0.839	0.852	0.772	0.915	0.833	0.720	0.825	0.685
12.01	0.741	0.680	0.542	0.656	0.360	0.733	0.751	0.804	0.820	0.704	1.000	0.709	0.659	0.796	0.561	0.659	0.624	0.553	0.741	0.648
12.02	0.767	0.511	0.516	0.757	0.442	0.712	0.733	0.772	0.751	0.862	0.709	1.000	0.788	0.820	0.754	0.812	0.754	0.680	0.796	0.669
12.03	0.762	0.561	0.513	0.749	0.370	0.656	0.815	0.780	0.746	0.839	0.659	0.788	1.000	0.812	0.667	0.899	0.860	0.603	0.757	0.693
12.04	0.857	0.638	0.595	0.772	0.429	0.772	0.876	0.913	0.910	0.852	0.796	0.820	0.812	1.000	0.653	0.815	0.783	0.608	0.812	0.696
12.05	0.714	0.505	0.561	0.706	0.508	0.608	0.608	0.624	0.606	0.772	0.561	0.754	0.667	0.653	1.000	0.717	0.725	0.873	0.659	0.532
12.06	0.794	0.548	0.545	0.765	0.405	0.704	0.799	0.783	0.754	0.915	0.659	0.812	0.899	0.815	0.717	1.000	0.857	0.653	0.783	0.701
12.07	0.802	0.608	0.563	0.762	0.468	0.630	0.780	0.759	0.722	0.833	0.624	0.754	0.860	0.783	0.725	0.857	1.000	0.661	0.701	0.648
12.08	0.675	0.516	0.548	0.667	0.550	0.595	0.556	0.579	0.574	0.720	0.553	0.680	0.603	0.608	0.873	0.653	0.661	1.000	0.598	0.450
12.09	0.783	0.521	0.545	0.741	0.439	0.802	0.746	0.775	0.783	0.825	0.741	0.796	0.757	0.812	0.659	0.783	0.701	0.598	1.000	0.751
12.10	0.690	0.455	0.487	0.669	0.389	0.709	0.701	0.690	0.672	0.685	0.648	0.669	0.693	0.696	0.532	0.701	0.648	0.450	0.751	1.000

(b)	Pillar 11	11.01	11.02	11.03	11.04	11.05	11.06	11.07	11.08	Pillar 12	12.01	12.02	12.03	12.04	12.05	12.06	12.07	12.08	12.09	12.10
Pillar 11	0.000	0.344	0.341	0.143	0.418	0.246	0.169	0.146	0.153	0.156	0.254	0.220	0.217	0.138	0.257	0.188	0.185	0.307	0.206	0.288
11.01	0.344	0.000	0.373	0.376	0.484	0.426	0.331	0.302	0.323	0.394	0.291	0.452	0.394	0.333	0.442	0.410	0.354	0.442	0.444	0.500
11.02	0.341	0.373	0.000	0.368	0.489	0.392	0.360	0.373	0.360	0.399	0.415	0.434	0.429	0.362	0.378	0.399	0.386	0.397	0.407	0.455
11.03	0.143	0.376	0.368	0.000	0.479	0.328	0.225	0.254	0.280	0.196	0.341	0.233	0.233	0.225	0.267	0.220	0.228	0.317	0.251	0.312
11.04	0.418	0.484	0.489	0.479	0.000	0.474	0.524	0.489	0.484	0.481	0.561	0.471	0.534	0.492	0.394	0.503	0.450	0.362	0.476	0.516
11.05	0.246	0.426	0.392	0.328	0.474	0.000	0.249	0.243	0.188	0.249	0.262	0.275	0.323	0.222	0.362	0.278	0.357	0.386	0.188	0.270
11.06	0.169	0.331	0.360	0.225	0.524	0.249	0.000	0.127	0.111	0.193	0.243	0.254	0.164	0.119	0.362	0.183	0.206	0.426	0.243	0.278
11.07	0.146	0.302	0.373	0.254	0.489	0.243	0.127	0.000	0.085	0.180	0.190	0.214	0.198	0.082	0.347	0.198	0.228	0.402	0.214	0.288
11.08	0.153	0.323	0.360	0.280	0.484	0.188	0.111	0.085	0.000	0.201	0.175	0.235	0.233	0.085	0.365	0.228	0.265	0.407	0.206	0.307
Pillar 12	0.156	0.394	0.399	0.196	0.481	0.249	0.193	0.180	0.201	0.000	0.294	0.127	0.143	0.146	0.201	0.069	0.156	0.265	0.167	0.296
12.01	0.254	0.291	0.415	0.341	0.561	0.262	0.243	0.190	0.175	0.294	0.000	0.278	0.320	0.198	0.410	0.323	0.362	0.429	0.249	0.331
12.02	0.220	0.452	0.434	0.233	0.471	0.275	0.254	0.214	0.235	0.127	0.278	0.000	0.183	0.167	0.209	0.161	0.225	0.294	0.185	0.302
12.03	0.217	0.394	0.429	0.233	0.534	0.323	0.164	0.198	0.233	0.143	0.320	0.183	0.000	0.167	0.288	0.082	0.116	0.362	0.217	0.275
12.04	0.138	0.333	0.362	0.225	0.492	0.222	0.119	0.082	0.085	0.146	0.198	0.167	0.167	0.000	0.317	0.167	0.204	0.373	0.177	0.283
12.05	0.257	0.442	0.378	0.267	0.394	0.362	0.362	0.347	0.365	0.201	0.410	0.209	0.288	0.317	0.000	0.241	0.238	0.101	0.307	0.423
12.06	0.188	0.410	0.399	0.220	0.503	0.278	0.183	0.198	0.228	0.069	0.323	0.161	0.082	0.167	0.241	0.000	0.122	0.315	0.193	0.265
12.07	0.185	0.354	0.386	0.228	0.450	0.357	0.206	0.228	0.265	0.156	0.362	0.225	0.116	0.204	0.238	0.122	0.000	0.312	0.280	0.323
12.08	0.307	0.442	0.397	0.317	0.362	0.386	0.426	0.402	0.407	0.265	0.429	0.294	0.362	0.373	0.101	0.315	0.312	0.000	0.378	0.516
12.09	0.206	0.444	0.407	0.251	0.476	0.188	0.243	0.214	0.206	0.167	0.249	0.185	0.217	0.177	0.307	0.193	0.280	0.378	0.000	0.222
12.10	0.288	0.500	0.455	0.312	0.516	0.270	0.278	0.288	0.307	0.296	0.331	0.302	0.275	0.283	0.423	0.265	0.323	0.516	0.222	0.000

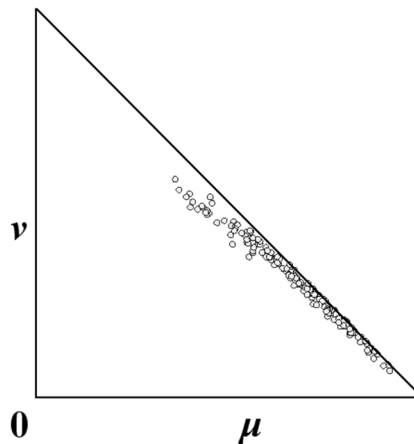


Fig. 1. Results of the InterCriteria Analysis (Tables 3 (a,b)) plotted as points on the intuitionistic fuzzy interpretational triangle.

4.1 ICA results for the subindicators within Pillar ‘11 Business dynamism’

In the frames of Pillar 11 ‘Business dynamism’ the results from application of ICA (Table 4, Figure 2) highest intercriteria positive consonances are detected in between three of the eight subindicators: 11.06 ‘Willingness to delegate authority’, 11.07

‘Growth of innovative companies’ and 11.08 ‘Companies embracing disruptive ideas’. These three (out of a total of 28) pairs also form a well clustered group of the top 10% highest positive consonances in this selection. It is noteworthy that these three criteria form an intercriteria correlation triple, as proposed in [6, 14].

It is noteworthy that these three criteria also are among the best correlating with the aggregated Pillar 11 itself, where one other subindicator 11.03 ‘Insolvency recovery rate’ is the one that exhibits highest positive consonance with Pillar 11, while in the same time exhibiting dissonance and weak positive consonance with the rest subindicators in the pillar.

One criterion, subindicator 11.04 ‘Insolvency regulatory framework’ exhibits strong negative consonance with all the rest ones in the pillar, and with the pillar itself, and two other subindicators, exhibit dissonance to weak negative consonance, namely 11.01 ‘Cost of starting a business’ and 11.02 ‘Time to start a business’.

The subindicator 11.05 ‘Attitudes toward entrepreneurial risk’ is also worth commenting, as it exhibits negative consonance or dissonance with the first four subindicators in the pillar, and positive consonance with the last three, especially subindicator 11.08 ‘Companies embracing disruptive ideas’.

Table 4. ICA pairs of the subindicators (criteria) in Pillar 11, sorted ascendingly with respect to their distance (‘d’) from the intuitionistic fuzzy truth (i.e. point $\langle 1,0 \rangle$).

C1	C2	μ	ν	d
11.07	11.08	0.910	0.085	0.124
11.06	11.08	0.884	0.111	0.161
11.06	11.07	0.868	0.127	0.183
11.05	11.08	0.807	0.188	0.269
11.03	11.06	0.772	0.225	0.320
11.05	11.07	0.751	0.243	0.348
11.05	11.06	0.746	0.249	0.355
11.03	11.07	0.743	0.254	0.361
11.03	11.08	0.717	0.280	0.398
11.01	11.07	0.669	0.302	0.448
11.03	11.05	0.669	0.328	0.466
11.01	11.08	0.648	0.323	0.477
11.01	11.06	0.640	0.331	0.489
11.02	11.06	0.598	0.360	0.540

C1	C2	μ	ν	d
11.02	11.08	0.598	0.360	0.540
11.02	11.03	0.593	0.368	0.549
11.01	11.03	0.598	0.376	0.550
11.02	11.07	0.585	0.373	0.558
11.01	11.02	0.561	0.373	0.576
11.02	11.05	0.566	0.392	0.584
11.01	11.05	0.545	0.426	0.623
11.04	11.05	0.447	0.474	0.728
11.03	11.04	0.444	0.479	0.733
11.04	11.08	0.437	0.484	0.743
11.04	11.07	0.431	0.489	0.750
11.01	11.04	0.418	0.484	0.757
11.02	11.04	0.399	0.489	0.775
11.04	11.06	0.397	0.524	0.799

4.2 ICA results for the subindicators within Pillar 12 ‘Innovation capability’

In the frames of Pillar 12 ‘Innovation capability’, as show on Table 5, Figure 3, the highest intercriteria positive consonances are detected between the pairs 12.03 ‘International co-inventions’ and 12.06 ‘Patent applications’, 12.03 ‘International co-inven-

tions' and 12.07 'R&D expenditures', 12.06 'Patent applications' and 12.07 'R&D expenditures', and 12.05 'Scientific publications' and 12.08 'Quality of research institutions'. Interestingly, these four (out of a total of 45) pairs also form a well clustered group of the top 10% highest positive consonances in this selection, and out of these four, 12.03, 12.06 and 12.07 also form an intercriteria correlation triple.

In Pillar 12, six out of ten subindicators exhibit high positive consonance (with $\mu \geq 0.8$) with the aggregate pillar, namely 12.02 'State of cluster development', 12.03 'International co-inventions', 12.04 'Multi-stakeholder collaboration', 12.06 'Patent applications', 12.07 'R&D expenditures', 12.09 'Buyer sophistication'. Three subindicators exhibit dissonance, namely 12.01 'Diversity of workforce', 12.08 'Quality of research institutions', and 12.10 'Trademark applications'.

Strongest negative consonance is exhibited between 12.01 'Diversity of workforce' and 12.10 'Trademark applications', on one hand, and 12.05 'Scientific publications' and 12.08 'Quality of research institutions', on the other (see the bottom of Table 5).

Interesting other observations are that the only criterion with which 12.08 'Quality of research institutions' exhibits strong positive consonance is criterion 12.05 'Scientific publications', and none of the rest.

Table 5. ICA pairs of the subindicators (criteria) in Pillar 12 'Innovation capability', sorted ascendingly with respect to their distance ('d') from the IF truth.

C1	C2	μ	ν	d
12.03	12.06	0.899	0.082	0.130
12.05	12.08	0.873	0.101	0.162
12.03	12.07	0.860	0.116	0.182
12.06	12.07	0.857	0.122	0.188
12.02	12.04	0.820	0.167	0.245
12.02	12.06	0.812	0.161	0.248
12.04	12.06	0.815	0.167	0.249
12.03	12.04	0.812	0.167	0.251
12.04	12.09	0.812	0.177	0.258
12.02	12.09	0.796	0.185	0.275
12.02	12.03	0.788	0.183	0.279
12.01	12.04	0.796	0.198	0.284
12.06	12.09	0.783	0.193	0.290
12.04	12.07	0.783	0.204	0.298
12.02	12.05	0.754	0.209	0.323
12.03	12.09	0.757	0.217	0.326
12.02	12.07	0.754	0.225	0.333
12.09	12.10	0.751	0.222	0.334
12.01	12.09	0.741	0.249	0.359
12.05	12.07	0.725	0.238	0.364
12.05	12.06	0.717	0.241	0.372
12.06	12.10	0.701	0.265	0.399
12.01	12.02	0.709	0.278	0.402

C1	C2	μ	ν	d
12.07	12.09	0.701	0.280	0.410
12.03	12.10	0.693	0.275	0.412
12.04	12.10	0.696	0.283	0.416
12.02	12.08	0.680	0.294	0.434
12.03	12.05	0.667	0.288	0.441
12.02	12.10	0.669	0.302	0.448
12.05	12.09	0.659	0.307	0.459
12.07	12.08	0.661	0.312	0.461
12.01	12.03	0.659	0.320	0.468
12.06	12.08	0.653	0.315	0.468
12.01	12.06	0.659	0.323	0.470
12.04	12.05	0.653	0.317	0.470
12.07	12.10	0.648	0.323	0.477
12.01	12.10	0.648	0.331	0.483
12.01	12.07	0.624	0.362	0.522
12.03	12.08	0.603	0.362	0.537
12.04	12.08	0.608	0.373	0.541
12.08	12.09	0.598	0.378	0.552
12.01	12.05	0.561	0.410	0.601
12.01	12.08	0.553	0.429	0.619
12.05	12.10	0.532	0.423	0.631
12.08	12.10	0.450	0.516	0.754

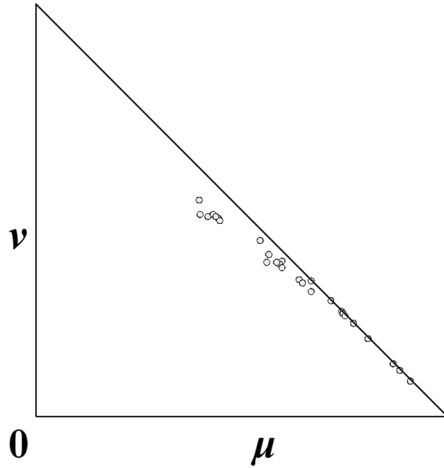


Fig. 2. Results of the ICA between the subindicators (criteria) in Pillar 11, plotted as points on the IF triangle

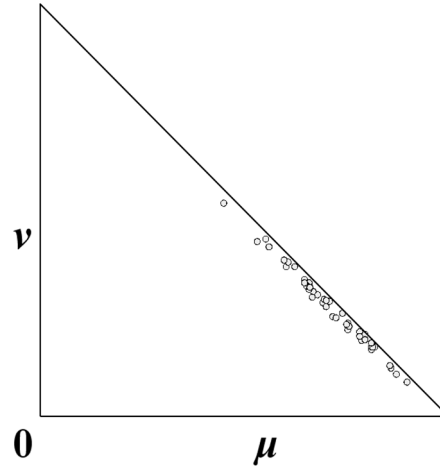


Fig. 3. Results of the ICA between the subindicators (criteria) in Pillar 12, plotted as points on the IF triangle

4.3 ICA results for the subindicators between Pillar ‘11 Business dynamism’ and Pillar 12 ‘Innovation capability’

Given that Pillar ‘11 Business dynamism’ and Pillar 12 ‘Innovation capability’ are the top correlation of all the twelve pillars of competitiveness in the WEF’s GCI, it is interesting to investigate which of the subindicators of both pillars exhibit highest inter-criteria positive consonance (Table 6).

We first notice, just as in section 4.1, that the three subindicators of pillar 11, 11.01 ‘Cost of starting a business’, 11.02 ‘Time to start a business’ and 11.04 ‘Insolvency regulatory framework’ tend to exhibit negative consonance to dissonance with all the subindicators in Pillar 12. Similar is the behaviour of subindicators 12.05 ‘Scientific publications’ and 12.08 ‘Quality of research institutions’ with respect to all the subindicators in Pillar 11. Other negative consonances or dissonances are observed between the pairs 11.03 ‘Insolvency recovery rate’ and 12.01 ‘Diversity of workforce’, or 11.05 ‘Attitudes toward entrepreneurial risk’ and 12.03 ‘International co-inventions’, or 11.05 ‘Attitudes toward entrepreneurial risk’ and 12.07 ‘R&D expenditures’.

The strongest notable intercriteria positive consonances are between criterion 12.04 ‘Multi-stakeholder collaboration’, on one hand, and the three subindicators 11.06 ‘Willingness to delegate authority’, 11.07 ‘Growth of innovative companies’ and 11.08 ‘Companies embracing disruptive ideas’. High ($\mu \geq 0.8$) are the consonances also in the pairs 11.07 ‘Growth of innovative companies’ and 12.01 ‘Diversity of workforce’; 11.08 ‘Companies embracing disruptive ideas’ and 12.01 ‘Diversity of workforce’; 11.06 ‘Willingness to delegate authority’ and 12.03 ‘International co-inventions’; 11.05 ‘Attitudes toward entrepreneurial risk’ and 12.09 ‘Buyer sophistication’, as well as 11.06 ‘Willingness to delegate authority’ and 12.06 ‘Patent applications’ with $\mu = 0.799$.

Table 6. ICA pairs formed by the subindicators in Pillar 11 and those in Pillar 12, sorted ascendingly with respect to their distance ('d') from the IF truth.

C1	C2	μ	ν	d
11.07	12.04	0.913	0.082	0.120
11.08	12.04	0.910	0.085	0.124
11.06	12.04	0.876	0.119	0.172
11.06	12.03	0.815	0.164	0.247
11.08	12.01	0.820	0.175	0.251
11.06	12.06	0.799	0.183	0.272
11.07	12.01	0.804	0.190	0.273
11.05	12.09	0.802	0.188	0.273
11.07	12.06	0.783	0.198	0.294
11.07	12.03	0.780	0.198	0.296
11.08	12.09	0.783	0.206	0.299
11.06	12.07	0.780	0.206	0.301
11.07	12.09	0.775	0.214	0.311
11.07	12.02	0.772	0.214	0.313
11.05	12.04	0.772	0.222	0.318
11.03	12.04	0.772	0.225	0.320
11.03	12.06	0.765	0.220	0.322
11.03	12.07	0.762	0.228	0.329
11.07	12.07	0.759	0.228	0.331
11.08	12.06	0.754	0.228	0.335
11.03	12.02	0.757	0.233	0.337
11.08	12.02	0.751	0.235	0.342
11.03	12.03	0.749	0.233	0.343
11.08	12.03	0.746	0.233	0.345
11.06	12.01	0.751	0.243	0.348
11.06	12.09	0.746	0.243	0.352
11.03	12.09	0.741	0.251	0.361
11.06	12.02	0.733	0.254	0.369
11.05	12.01	0.733	0.262	0.374
11.08	12.07	0.722	0.265	0.384
11.05	12.10	0.709	0.270	0.397
11.03	12.05	0.706	0.267	0.397
11.05	12.02	0.712	0.275	0.399
11.05	12.06	0.704	0.278	0.406
11.06	12.10	0.701	0.278	0.408
11.07	12.10	0.690	0.288	0.423
11.01	12.01	0.680	0.291	0.433
11.08	12.10	0.672	0.307	0.449
11.03	12.10	0.669	0.312	0.455
11.03	12.08	0.667	0.317	0.460
11.05	12.03	0.656	0.323	0.472
11.03	12.01	0.656	0.341	0.485
11.01	12.04	0.638	0.333	0.492
11.07	12.05	0.624	0.347	0.511
11.05	12.07	0.630	0.357	0.515
11.01	12.07	0.608	0.354	0.528
11.05	12.05	0.608	0.362	0.534
11.06	12.05	0.608	0.362	0.534
11.08	12.05	0.606	0.365	0.537
11.02	12.04	0.595	0.362	0.543
11.05	12.08	0.595	0.386	0.559
11.04	12.08	0.550	0.362	0.578
11.02	12.05	0.561	0.378	0.580
11.07	12.08	0.579	0.402	0.582
11.02	12.07	0.563	0.386	0.583
11.08	12.08	0.574	0.407	0.589
11.01	12.03	0.561	0.394	0.590
11.02	12.08	0.548	0.397	0.602
11.02	12.06	0.545	0.399	0.605
11.01	12.06	0.548	0.410	0.611
11.02	12.09	0.545	0.407	0.611
11.06	12.08	0.556	0.426	0.616
11.02	12.01	0.542	0.415	0.618
11.04	12.05	0.508	0.394	0.630
11.02	12.03	0.513	0.429	0.649
11.02	12.02	0.516	0.434	0.650
11.01	12.09	0.521	0.444	0.653
11.01	12.08	0.516	0.442	0.655
11.01	12.05	0.505	0.442	0.663
11.01	12.02	0.511	0.452	0.666
11.02	12.10	0.487	0.455	0.686
11.04	12.07	0.468	0.450	0.696
11.04	12.02	0.442	0.471	0.730
11.04	12.09	0.439	0.476	0.736
11.01	12.10	0.455	0.500	0.740
11.04	12.04	0.429	0.492	0.754
11.04	12.06	0.405	0.503	0.779
11.04	12.10	0.389	0.516	0.800
11.04	12.03	0.370	0.534	0.826
11.04	12.01	0.360	0.561	0.851

5 Conclusion

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 Global Competitiveness Index 2018 of the World Economic Forum according to the

two traditionally most correlating pillars of competitiveness 11 ‘Business dynamism’ and 12 ‘Innovation capability’, and more specifically the eight and ten, respectively, subindicators on which these pillars are based. While the European competitiveness based on the WEF GCI reports has been discussed in a series of works over the years, and in some sense has been a playground for ICA innovation with many new ideas of theoretical nature stemming from the results of the application of the method on these data, this is the first time when we analyse the subindicators that build these two most strongly related pillars of competitiveness, and thus outline dependencies that aim to shed light on these aspects of national economic competitiveness. The detected pairwise relations between these factors of business dynamism and innovation capability are considered informative for the national decision and policy makers, especially in the light of the World Economic Forum’s traditional appeal to them to identify the transformative forces in the national economies and strengthen them to drive future economic growth.

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