Appendix II
Joint Research Centre (JRC) statistical audit of the 2022 Global Innovation Index

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Conceptual and practical challenges are inevitable when trying to understand and model the fundamentals of innovation at the national level worldwide. Now in its 15th edition, the Global Innovation Index (GII) 2022 takes up these conceptual challenges and also deals with the practical challenges relating to data quality and methodological choices.

This appendix summarizes the comprehensive audit of the GII, conducted for the 12th consecutive year by the European Commission's Competence Centre on Composite Indicators and Scoreboards (COIN) at the Joint Research Centre (JRC) in Ispra.

As in previous editions, the present JRC-COIN audit focuses on the statistical soundness of the multi-level structure of the index as well as on the impact of key modeling assumptions on the results. The independent statistical assessment of the GII provided by the JRC-COIN guarantees the transparency and reliability of the index for both policymakers and other stakeholders, thus facilitating more accurate priority setting and policy formulation in the innovation field.

As in past GII reports, the JRC-COIN analysis complements the economy rankings with confidence intervals for the GII, the Innovation Input Sub-Index and the Innovation Output Sub-Index, in order to better appreciate the robustness of these rankings to the computation methodology. Finally, the JRC-COIN analysis includes an assessment of the added value of the GII and a measure of "distance to the efficiency frontier" of innovation by using data envelopment analysis.

This is a shortened version of the audit. The full audit is available at https://www.wipo.int/edocs/pubdocs/en/wipo-pub-2000-2022-appendix2-en-appendix-ii-full-global-innovation-index-2022-15th-edition.pdf.

Main conclusions

The JRC-COIN analysis suggests that the conceptualized multilevel structure of the GII 2022 – with its 81 indicators, 21 sub-pillars, seven pillars and two sub-indices comprising the overall index – is statistically sound and balanced: that is, each sub-pillar makes a similar contribution to the variation of its respective pillar. The refinements made by the developing team have helped to enhance the already strong statistical coherence in the GII framework, in which the capacity of the 81 indicators to distinguish economies' performance is maintained at the sub-pillar level or higher in all but five cases.

The decision not to impute missing values, which is common practice in comparable contexts and justified on the grounds of transparency and replicability, can at times have an undesirable impact on some economy scores, with the additional negative side-effect that it might encourage economies not to report low data values. The GII team's adoption, in 2016, of a more stringent data coverage threshold (at least 66 percent data availability for each of the input- and output-related indicators, separately) has notably improved confidence in the economy rankings for the GII and the two sub-indices.

Additionally, the GII team's decision, in 2012, to use weights as scaling coefficients during the index development constitutes a significant departure from the traditional, but erroneous, vision of weights as a reflection of indicators' importance in a weighted average. It is hoped that such an approach will be adopted by other developers of composite indicators to avoid situations where bias sneaks in when least expected.

The strong correlations between the GII components are proven not to be a sign of redundancy of information in the GII. For more than 34 percent (up to 67 percent) of the 132 economies included in the GII 2022, the GII ranking and the rankings of any of the seven pillars differ by 10 positions or more. This demonstrates the added value of the GII ranking, which helps to highlight other components of innovation that are not immediately apparent from an analysis of the seven pillars separately. At the same time, this finding points to the value of duly considering the merits of the GII pillars, sub-pillars and their constituent indicators individually. By doing so,

economy-specific strengths and bottlenecks in innovation can be identified and serve as an input for evidence-based policymaking.

To test the impact of the GII modeling assumptions, a number of different models were tested in this audit, based on different approaches to imputing of missing data, aggregation at the pillar level and assignment of weights. Using these models, the 90 percent confidence intervals relating to the ranking positions that an economy might have had under different model assumptions were computed. For the vast majority of economies, these intervals are sufficiently narrow to allow meaningful inferences to be drawn: the intervals comprise 10 or fewer positions for 73 percent (97 out of 132) of the economies. Some caution is needed when considering three economies – Belarus, Brunei Darussalam and Zimbabwe – which have GII rankings that are highly sensitive to the methodological choices. Consequently, their GII ranks – at the 77th (Belarus), 92nd (Brunei Darussalam) and 107th (Zimbabwe) position in the GII classification – should be interpreted cautiously and certainly not taken at face value. This is a remarkable improvement compared to GII versions up to 2016, when more than 40 economies had confidence interval widths of more than 20 positions. The improvement in the confidence that can be placed in the GII 2022 rankings is the direct result of the decision to adopt a more stringent criterion for an economy's inclusion since 2016, which now requires at least 66 percent data availability within each of the two sub-indices. Some caution is also warranted in regard to the Input Sub-Index for five economies – Belarus, the Islamic Republic of Iran, Brunei Darussalam, Uganda and the United Republic of Tanzania – that have 90 percent confidence interval widths of more than 20 positions (up to 27 for both Belarus and the Islamic Republic of Iran). A similar degree of caution is also needed in relation to the Output Sub-Index for five economies – Zimbabwe, Nigeria, the United Republic of Tanzania, Belarus and Côte d'Ivoire – that have 90 percent confidence interval widths of more than 20 positions (up to 29 for Zimbabwe). Compared to the GII 2019, the higher level of data availability in the Output Sub-Index this year has led to a much lower number of economies with very wide intervals (five compared to 13 in the GII 2019 edition), which is a noteworthy improvement.

Although ranks for a few economies in the GII 2022 overall, or in the two sub-indices, appear to be sensitive to the methodological choices, the published rankings for the vast majority can be considered to be representative of the plurality of scenarios simulated in this audit. Taking the median rank as the benchmark for an economy's expected rank in the realm of the GII's unavoidable methodological uncertainties, 75 percent of the economies are found to shift fewer than three positions with respect to the median rank in the GII, or in the Input and Output Sub-Indices.

In order to offer full transparency and the most complete information possible, Appendix Table 2 reports the GII 2022 Index and Input and Output Sub-Indices' economy ranks together with the simulated 90 percent confidence intervals to allow a better appreciation of the robustness of the results to the choice of weights and aggregation formula and the impact of estimating missing data (where applicable).

All things considered, the present JRC-COIN audit findings confirm that the GII 2022 meets international quality standards for statistical soundness, which indicates that the GII is a reliable benchmarking tool for innovation practices at the economy level around the world.

Finally, the "distance to the efficiency frontier" measure, calculated using data envelopment analysis, can be used both as a measure of efficiency and as a suitable approach to benchmarking economies' multidimensional performance on innovation without imposing a fixed and common set of weights that may not be fair to a particular economy. The decision made by the GII team to abandon the efficiency ratio (ratio of Output to Input Sub-Index) is particularly laudable. In fact, ratios of composite indicators (Output to Input Sub-Index in this case) come with much higher uncertainty than the sum of the components (Input plus Output Sub-Index, equivalent to the GII). For this reason, developers and users of indices alike need to approach efficiency ratios of this nature with great care. The GII should not represent the ultimate and definitive ranking of economies with respect to innovation. On the contrary, the GII is most accurately defined as an ongoing attempt to find metrics and approaches that capture the richness of innovation most effectively, continuously adapting the GII framework to reflect the improved availability of statistics and the theoretical advances in the field. In any case, the GII should be regarded as a sound attempt, based on the principle of transparency, matured over 15 years of constant refinements, to pave the way for better and more informed innovation policies worldwide.

Appendix Table 2 GII 2022 and Input/Output Sub-Indices: Ranks and 90 percent confidence intervals

	GII 2022		Input Sub-Index		Output Sub-Index	
	Rank	Interval	Rank	Interval	Rank	Interval
Switzerland	1	[1, 1]	3	[2, 4]	1	[1, 1]
United States	2	[2, 3]	2	[2, 4]	5	[4, 7]
Sweden	3	[2, 3]	4	[2, 5]	2	[2, 3]
United Kingdom	4	[4, 4]	7	[5, 9]	3	[2, 3]
Netherlands	5	[5, 8]	10	[7, 13]	6	[6, 8]
Republic of Korea	6	[5, 9]	16	[10, 18]	4	[4, 5]
Singapore	7	[5, 11]	1	[1, 1]	14	[13, 17]
Germany	8	[5, 9]	12	[11, 16]	7	[5, 7]
Finland	9	[7, 10]	6	[5, 7]	9	[9, 11]
Denmark	10	[9, 11]	8	[7, 11]	10	[9, 11]
China	11	[8, 12]	21	[17, 24]	8	[5, 8]
France	12	[11, 12]	13	[12, 16]	11	[9, 11]
Japan	13	[13, 13]	11	[8, 14]	12	[12, 13]
Hong Kong, China	14	[14, 22]	5	[4, 8]	25	[18, 32]
Canada	15	[14, 19]	9	[8, 12]	23	[23, 25]
Israel	16	[14, 21]	22	[14, 25]	16	[14, 22]
Austria	17	[15, 20]	17	[14, 21]	21	[19, 21]
Estonia	18	[15, 21]	15	[10, 21]	22	[22, 24]
Luxembourg	19	[15, 20]	20	[17, 23]	18	[15, 21]
Iceland	20	[15, 20]	24	[23, 26]	17	[14, 17]
Malta	21	[18, 23]	27	[27, 28]	13	[12, 15]
Norway	22	[21, 24]	14	[11, 19]	29	[27, 30]
Ireland	23	[21, 23]	25	[22, 26]	19	[18, 21]
New Zealand	24	[24, 28]	23	[20, 26]	28	[26, 29]
Australia	25	[24, 28]	19	[15, 20]	32	[31, 32]
Belgium	26	[24, 28]	26	[23, 26]	24	[24, 27]
Cyprus	27	[25, 28]	29	[28, 30]	20	[18, 22]
Italy	28	[23, 28]	31	[30, 34]	15	[14, 17]
Spain	29	[29, 30]	28	[27, 29]	26	[25, 27]
Czech Republic	30	[29, 31]	33	[31, 36]	27	[22, 30]
United Arab Emirates	31	[30, 36]	18	[16, 22]	52	[51, 57]
Portugal	32	[30, 32]	32	[31, 34]	31	[29, 31]
Slovenia	33	[33, 35]	30	[29, 32]	35	[35, 38]
Hungary	34	[32, 35]	36	[34, 38]	34	[33, 34]
Bulgaria	35	[32, 37]	47	[42, 51]	30	[27, 33]
Malaysia	36	[35, 37]	35	[32, 36]	37	[37, 38]
Türkiye	37	[34, 38]	49	[43, 56]	33	[32, 34]
Poland	38	[37, 39]	41	[37, 43]	36	[35, 36]
Lithuania	39	[37, 40]	34	[31, 36]	47	[45, 48]
India	40	[39, 41]	42	[38, 46]	39	[37, 41]
Latvia	41	[40, 41]	39	[37, 43]	42	[41, 44]
Croatia	42	[42, 42]	45	[42, 49]	40	[40, 43]
Thailand	43	[43, 45]	48	[42, 54]	44	[43, 46]
Greece	44	[43, 46]	44	[41, 49]	49	[47, 49]
Mauritius	45	[43, 59]	40	[38, 55]	54	[52, 66]
Slovakia	46	[45, 50]	54	[49, 56]	45	[43, 52]
Russian Federation	47	[43, 50]	46	[39, 52]	50	[47, 51]
Viet Nam	48	[44, 49]	59	[54, 62]	41	[39, 44]
Romania	49	[45, 50]	56	[51, 60]	43	[41, 48]
Chile	50	[46, 50]	43	[41, 46]	57	[55, 57]
Saudi Arabia	51	[50, 58]	37	[35, 39]	65	[62, 71]
Qatar	52	[51, 65]	38	[37, 47]	67	[65, 75]
Iran (Islamic Republic of)	53	[49, 60]	73	[64, 91]	38	[36, 40]
Brazil	54	[50, 55]	58	[49, 63]	53	[52, 54]
Serbia	55	[51, 58]	55	[47, 59]	58	[56, 62]
Republic of Moldova	56	[52, 58]	78	[72, 82]	46	[43, 47]
Ukraine	57	[48, 59]	75	[64, 80]	48	[39, 51]
Mexico	58	[54, 58]	70	[59, 72]	55	[54, 56]
Philippines	59	[55, 61]	76	[68, 80]	51	[50, 53]
Montenegro	60	[58, 63]	51	[49, 59]	72	[64, 72]
South Africa	61	[60, 64]	69	[62, 72]	61	[59, 62]
Kuwait	62	[62, 78]	66	[63, 77]	66	[64, 77]
Colombia	63	[62, 67]	63	[54, 65]	70	[69, 71]
Uruguay	64	[58, 72]	57	[49, 62]	76	[66, 79]
Peru	65	[63, 77]	52	[47, 64]	81	[80, 83]
North Macedonia	66	[64, 75]	60	[54, 69]	77	[70, 81]

Appendix Table 2 Continued

	GII 2022		Input Sub-Index		Output Sub-Index	
	Rank	Interval	Rank	Interval	Rank	Interval
Morocco	67	[61, 71]	87	[83, 89]	56	[51, 57]
Costa Rica	68	[61, 70]	67	[62, 72]	71	[61, 74]
Argentina	69	[62, 71]	77	[67, 78]	62	[61, 63]
Bosnia and Herzegovina	70	[67, 76]	64	[58, 75]	75	[72, 76]
Mongolia	71	[67, 76]	81	[77, 88]	64	[58, 67]
Bahrain	72	[68, 83]	50	[44, 64]	86	[84, 94]
Tunisia	73	[66, 81]	89	[80, 91]	59	[58, 68]
Georgia	74	[66, 78]	61	[56, 69]	82	[72, 83]
Indonesia	75	[70, 76]	72	[65, 79]	74	[71, 74]
Jamaica	76	[68, 78]	88	[81, 91]	60	[58, 67]
Belarus	77	[56, 79]	86	[63, 90]	63	[52, 74]
Jordan	78	[74, 79]	71	[65, 78]	78	[76, 79]
Oman	79	[77, 84]	62	[54, 65]	87	[85, 97]
Armenia	80	[72, 80]	82	[78, 87]	73	[65, 73]
Panama	81	[79, 83]	83	[79, 90]	80	[75, 80]
Uzbekistan	82	[81, 87]	68	[66, 76]	91	[85, 93]
Kazakhstan	83	[79, 93]	65	[60, 71]	97	[86, 102]
Albania	84	[84, 85]	80	[74, 82]	89	[86, 89]
Sri Lanka	85	[80, 87]	102	[92, 106]	68	[66, 77]
Botswana	86	[85, 95]	74	[69, 84]	94	[94, 108]
Pakistan	87	[82, 97]	111	[98, 112]	69	[68, 83]
Kenya	88	[85, 97]	103	[100, 108]	79	[78, 81]
Egypt	89	[85, 93]	97	[94, 99]	83	[81, 84]
Dominican Republic	90	[88, 93]	90	[86, 95]	92	[90, 93]
Paraguay	91	[87, 92]	94	[91, 98]	84	[80, 87]
Brunei Darussalam	92	[82, 121]	53	[46, 70]	129	[115, 129]
Azerbaijan	93	[90, 101]	79	[75, 83]	110	[109, 119]
Kyrgyzstan	94	[93, 103]	85	[79, 93]	108	[103, 114]
Ghana	95	[91, 102]	105	[101, 109]	88	[87, 93]
Namibia	96	[94, 105]	84	[81, 90]	113	[107, 114]
Cambodia	97	[93, 98]	92	[88, 98]	102	[94, 103]
Ecuador	98	[93, 101]	96	[92, 99]	98	[95, 99]
Senegal	99	[98, 103]	93	[91, 100]	105	[101, 106]
El Salvador	100	[87, 101]	101	[92, 102]	95	[84, 97]
Trinidad and Tobago	101	[88, 106]	95	[86, 103]	103	[92, 108]
Bangladesh	102	[93, 110]	112	[109, 125]	90	[89, 98]
United Republic of Tanzania	103	[99, 119]	100	[97, 118]	99	[98, 123]
Tajikistan	104	[103, 108]	104	[99, 113]	101	[98, 107]
Rwanda	105	[100, 120]	91	[87, 103]	123	[110, 124]
Madagascar	106	[96, 115]	125	[120, 128]	85	[85, 95]
Zimbabwe	107	[96, 126]	120	[110, 127]	93	[92, 121]
Nicaragua	108	[103, 109]	99	[94, 111]	112	[99, 114]
Côte d'Ivoire	109	[107, 121]	109	[101, 117]	106	[105, 126]
Guatemala	110	[100, 111]	117	[111, 120]	96	[89, 96]
Nepal	111	[106, 111]	106	[101, 114]	111	[101, 112]
Lao People's Democratic Republic	112	[105, 116]	98	[96, 108]	122	[108, 122]
Honduras	113	[103, 113]	108	[97, 109]	116	[107, 117]
Nigeria	114	[108, 125]	113	[105, 119]	107	[101, 128]
Algeria	115	[109, 117]	110	[100, 115]	118	[115, 123]
Myanmar	116	[108, 118]	122	[116, 126]	104	[100, 104]
Ethiopia	117	[112, 124]	126	[123, 128]	100	[99, 106]
Zambia	118	[113, 120]	118	[111, 121]	115	[110, 116]
Uganda	119	[110, 123]	116	[103, 126]	120	[112, 123]
Burkina Faso	120	[119, 126]	114	[112, 118]	124	[124, 126]
Cameroon	121	[119, 125]	124	[117, 131]	114	[111, 122]
Togo	122	[114, 123]	115	[111, 119]	125	[119, 126]
Mozambique	123	[117, 126]	123	[118, 128]	119	[112, 122]
Benin	124	[116, 130]	107	[102, 116]	131	[127, 131]
Niger	125	[118, 127]	119	[116, 126]	126	[114, 127]
Mali	126	[115, 127]	128	[120, 128]	121	[111, 122]
Angola	127	[122, 132]	129	[128, 132]	117	[114, 132]
Yemen	128	[117, 131]	132	[125, 132]	109	[101, 118]
Mauritania	129	[127, 132]	121	[117, 126]	132	[131, 132]
Burundi	130	[129, 131]	127	[124, 132]	130	[126, 130]
Iraq	131	[127, 132]	130	[113, 131]	127	[127, 130]
Guinea	132	[128, 132]	131	[129, 132]	128	[126, 130]