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JRC Statistical Audit of the 2020 Global Attractiveness Index

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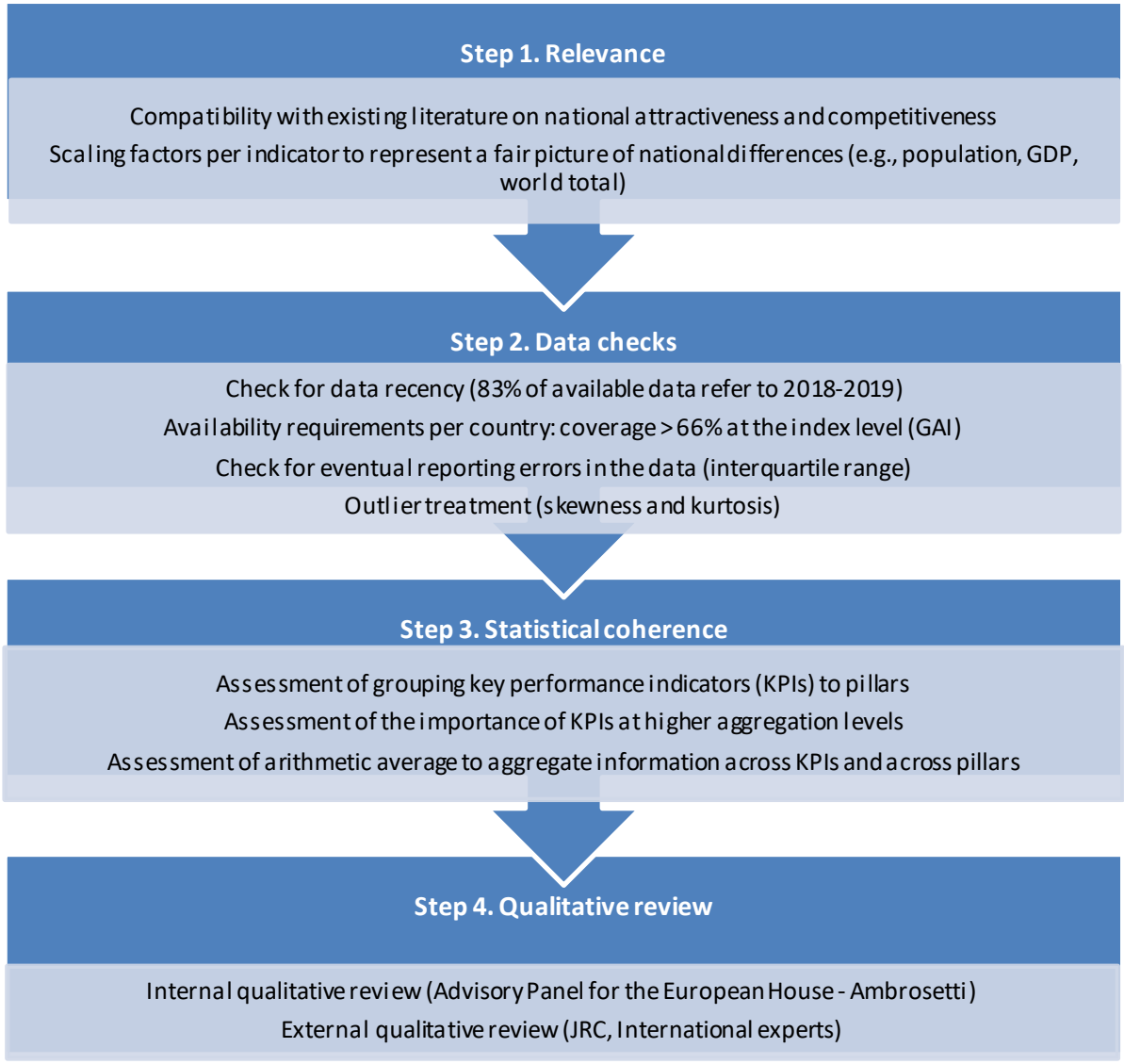
Abstract

Attractiveness is a crucial factor in the global scramble for talented people, investments and know-how. It is a prerequisite for competitiveness and it remains so also in the new challenging scenario depicted by the COVID-19 pandemic. The European House – Ambrosetti has developed the Global Attractiveness Index (GAI) to provide countries with a tool to measure and benchmark a country's attractiveness as determining element of its ability to be competitive and grow. The GAI – now at this fifth edition - builds on four attributes of attractiveness - Openness, Innovation, Efficiency, and Endowment - which are captured by 21 Key Performance Indicators (KPIs), then aggregated into a single summary measure of attractiveness. As in the previous editions, the GAI 2020 ranks 144 countries which cover approximately 93% of the world's population and 99%of Gross Domestic Product (in US$) worldwide. This framework inevitably entails both conceptual and practical challenges. Conducted by the European Commission's Joint Research Centre, the statistical audit of the 2020 version of the GAI aims at maximising the reliability and transparency of the index. The statistical quality check should enable policy analysts and researchers alike to draw more relevant and meaningful advice to improve or fully unleash countries' attractiveness potential.

1 Conceptual and statistical coherence in the GAI framework

Earlier versions of the Global Attractiveness Index were assessed by the JRC in May-June 2016, in May-June 2017, June-July 2018 and May-July 2019. Fine-tuning suggestions made by the JRC were taken into account by the European House – Ambrosetti in the final computation of the rankings, with a view to setting the foundation for a balanced indicator framework. The entire process followed four steps (Figure 1).

Figure 1. Conceptual and statistical coherence in the GAI 2020 Framework



Source: European Commission, Joint Research Centre, 2020.

Step 1: Relevance

Almost 200 variables were initially considered by The European House – Ambrosetti for their relevance to the four attractiveness attributes – Openness, Innovation, Efficiency, and Endowment - on the basis of a literature review and expert consultation in 2016. *Openness* captures a country's efforts to promoting the circulation of economic, human and business resources both internally and externally. *Innovation* synthesizes how a country's ecosystem (research network, public institutions, businesses, financial system) promote scientific and technological progress. *Efficiency* monitors the ability of organisational and function-related structures to guarantee proper functioning (and quality) of capital markets, the labour market, services and government. Finally, *Endowment* captures high-quality assets that are capable of being sources of competitive advantage.

After screening for data coverage and subsequently testing for statistical coherence, twenty-one key performance indicators (KPIs) were selected. To represent a fair picture of country differences, two types of denominators for the indicators were used. External factors: for those KPIs that express magnitudes related to the attractiveness of a country in relation to others, raw data values were divided by the world total (e.g., KPI 7 Exports of high-technology goods, compared with world total) ([1]). Internal factors: for those KPIs that capture aspects of internal attractiveness, raw data values were divided by relevant national factors (e.g., KPI 4 Foreign university students, compared with youth population).

Step 2: Data checks

The most recently released data within the period 2015–19 were used for each country (total 144 countries): 83% of available data for the GAI refer to 2018 or 2019. Countries are included in the GAI if data availability is at least 66% (i.e., 14 out of 21 KPIs). Exceptionally, twelve countries with lower data coverage (compared to nine last year) have been included in the GAI: Syrian Arab Republic, Puerto Rico, Yemen, Venezuela, Libya and Timor-Leste (with 43% up to 57% data available) and Bhutan, Chad, Gabon, Haiti, Seychelles and Swaziland (with 62% data availability, i.e. 13/21 KPIs available). This means that data availability has slightly decreased, compared to the 2019 edition of the GAI, for the following countries: Bhutan, Seychelles and Timor-Leste.

Overall, data coverage in the GAI remains good: on average, 86% of the data are available for 126 (out of 144) countries (with at least 71% data coverage). At the same time, some countries have improved data coverage. For instance, Albania has now 100% data coverage on the Innovation pillar, compared to 80% last year. Cabo Verde and Myanmar now have values available for 4 innovation-related KPIs, passing from 60% to 80% data coverage on the Innovation pillar. Similarly, Jordan and Malaysia have data available for one KPI more on Endowment, compared to the 2019 edition, passing from 67% to 83% data coverage on this pillar. That said, for a few countries better data coverage is needed. For example, for both Syrian Arab Republic and Venezuela no KPI values are available under the Endowment pillar for the year 2019. The impact of missing values on the GAI results is further discussed in Section 2.

Potentially problematic indicators that could bias the overall results were identified on the basis of two measures related to the shape of the indicators' distribution: skewness and kurtosis. Values were treated if the indicators had absolute skewness greater than 3.0, approximately, and kurtosis greater than 3.5.[2] These criteria were proposed by the JRC back in 2016 for the specific dataset underpinning the GAI model. These indicators were

([1]) See Giampietro (2014) for a discussion on scaling factors for indicators (intensive versus extensive properties).
([2]) Groeneveld and Meeden (1984) set the criteria for absolute skewness above 1 and kurtosis above 3.5. The skewness criterion was relaxed in the GAI case after having conducted ad-hoc tests in the 2014-2018 timeseries.

treated by winsorization (four or less outliers per indicator) in order to avoid that few very high/low values result in polarised indicators and scores, and introduce distortion in the correlation coefficients that are subsequently used for the analysis of the statistical coherence in the GAI framework.

Step 3: Statistical Coherence

The reliability of the Global Attractiveness Index depends, *inter alia*, on the degree of coherence between the conceptual framework – 21 KPIs grouped into 4 pillars and finally into an index – and the statistical structure of the data. The more the statistical structure of the data is compatible with the GAI conceptual framework, the higher the reliability of the GAI will be. The coherence of the GAI framework was assessed by analysing whether the 21 KPIs explain a sufficient amount of variation in the aggregate scores (either in the four pillars or the overall index) by means of correlation, cross-correlation, and principal component analysis.

Given that the analysis of statistical coherence of the Global Attractiveness Index is based on correlations, the correspondence of the GAI to a real-world phenomenon needs to be critically addressed by experts in the field because 'correlations need not necessarily represent the real influence of the individual indicators on the phenomenon being measured' ([3]). The point made here is that the validity of the GAI framework relies on the combination of both statistical and conceptual soundness. In this respect, the GAI framework has been developed following an iterative process that went back and forth between the theoretical understandings of national competitiveness and attractiveness on the one hand, and data observations on the other.

Principal component analysis was used to assess the extent to which the conceptual framework underpinning the GAI – 21 indicators grouped in 4 pillars and finally into an index – is compatible with the data statistical properties. Results suggest that the expectation of a single statistical dimension (i.e., no more than one principal component with eigenvalue greater than 1.0) is confirmed for two of the four pillars, namely for the Openness and Innovation pillars. Instead there are two statistical dimensions within each of the other two pillars: Efficiency and Endowment. The presence of more than one statistical dimension in the Efficiency and Endowment pillars suggests that some of the information content of some KPIs does not arrive at the pillar level. This point is discussed in more detail in the concluding remarks in this section.

A more detailed analysis of the correlation structure within and across the four GAI pillars confirms the expectation that the indicators are generally more correlated to their own pillar than to any other (see Table 1). This result suggests that the allocation of the 21 KPIs to a specific attribute of a country's attractiveness is consistent both from conceptual and statistical perspectives. Furthermore, all associations between indicators and the respective pillar are statistically significant, and most correlation coefficients within a GAI pillar are close to or greater than 0.70, which suggests that at least half of the variance in the GAI pillar scores can be explained by an underlying indicator.

Finally, the four GAI pillars also share a single statistical dimension. The GAI captures 75% of the total variance in the four pillars, and the four correlation coefficients (between the index and each pillar) are high, 0.80 or greater. This result supports the aggregation of four GAI pillars into one number and suggests that all four pillars of a country's attractiveness can explain more than half of the variation of the GAI scores, as envisaged by the index developers. The reliability of the GAI, measured by the Cronbach-alpha value,

([3]) See (OECD-JRC, 2008).

is very good at 0.88—well above the 0.7 threshold for a reliable aggregate of the four pillars ([4]).

Concluding, the statistical coherence tests corroborate the two-level structure in the GAI framework, and confirm the desired unidimensionality of two out of the four pillars (Openness and Innovation), and the overall index. Furthermore, all 21 indicators are found to be influential at least at the first aggregation level (pillars) and for 17 out of the 21 indicators, this influence arrives up to the overall index. This is a highly desirable outcome as it suggests that the information content in the majority of the underlying indicators is maintained at all levels of aggregation in the GAI framework.

At the same time, the analysis (see Table 1) has also helped to evidence several issues that are worth of further reflection either because they indicate avenues for refining the index or for further policy analysis.

Table 1. Statistical coherence: correlations between GAI components

DIMENSION	ATTRIBUTE		Key Performance Indicators (KPIs)	Openness	Innovation	Efficiency	Endowment	GAI
Attractiveness	Openness	KPI1	(Foreign Direct Investment flows into the country IN + the country's investment abroad OUT), % of world total	0.75	0.72	0.45	0.68	0.75
		KPI2	(Export + Import), % of world total	0.77	0.81	0.49	0.78	0.83
		KPI3	(No. foreign tourists IN + No. national tourists abroad OUT), compared with national population	0.66	0.41	0.54		0.51
		KPI4	Foreign university students, compared with youth population	0.72	0.49	0.65	0.34	0.60
		KPI5	Net number of migrants, compared with population	0.66	0.39	0.47	0.31	0.52
	Innovation	KPI6	Employed in high-technology sectors, compared with employed		0.56			0.27
		KPI7	Exports of high-technology goods, compared with world total	0.64	0.75	0.43	0.59	0.70
		KPI8	ICT Development Index	0.75	0.86	0.67	0.56	0.83
		KPI9	Number of scientific publications, compared with world total	0.58	0.70	0.36	0.75	0.70
		KPI10	Internet users, % of population	0.69	0.84	0.61	0.52	0.78
	Efficiency	KPI11	Unemployment level			0.45		0.26
		KPI12	Logistics Performance Index	0.81	0.81	0.85	0.66	0.90
		KPI13	Total productivity of factors			0.29		0.14
		KPI14	Rule of Law Index	0.70	0.69	0.83	0.51	0.76
		KPI15	Total tax rate (% commercial profits)			0.42		0.02
	Endowment	KPI16	Gross Domestic Product (GDP), compared with world total	0.58	0.70	0.34	0.76	0.70
		KPI17	Gross National Product, (GNP), per capita	0.86	0.76	0.75	0.61	0.85
		KPI18	Gross Fixed Investment, compared with GDP				0.39	0.10
		KPI19	Natural Endowment Index				0.21	-0.11
		KPI20	College graduates, compared with world total	0.28	0.50		0.73	0.47
		KPI21	PISA Test Score	0.46	0.48	0.78	0.51	0.61

Attributes of Attractiveness	Openness	Innovation	Efficiency	Endowmen	GAI
Openness	1.00	0.81	0.69	0.64	0.91
Innovation	0.81	1.00	0.62	0.74	0.93
Efficiency	0.69	0.62	1.00	0.50	0.79
Endowment	0.64	0.74	0.50	1.00	0.83

Notes: Numbers represent the Pearson correlations coefficients between the GAI components (pillars or index) and the underlying indicators (for 144 countries) for last year only (2019). Values greater than 0.7 are desirable because they imply that the pillar captures at least 50% (≈ 0.7×0.7) of the variation in the underlying KPIs. Instead, values lower than 0.21 are not presented because they are not statistically significant. Grey boxes show the conceptual grouping of the indicators.

Source: European Commission, Joint Research Centre, 2020.

Overall, in this fifth edition, the correlation structure remains relatively stable with most KPIs behaving as expected, meaning that they help measure countries on the different complex constructs at stake (e.g. innovation, attractiveness). As regards other KPIs, one should be aware of the fact that some of them are not necessarily helping detect a country's attractiveness and should be subject to further analyses and improvements in future editions, as explained in more details in the following paragraphs.

As regards the relation between the 21 KPIs and the GAI, there are still four indicators that do not significantly correlate with the overall index: Total productivity of factors

([4]) See Nunnally (1978).

(KPI13) and Total tax rate (KPI15) within Efficiency, and Gross fixed investment (KPI18) and Natural Endowment Index (KPI19) within Endowment. Although conceptually enriching the overall GAI framework, these KPIs are found not to co-vary with the overall index. This means that countries may achieve high GAI scores in spite of the high or low values in KPIs 13, 15, 18 and 19, and the same holds for low GAI scores. In 2018, the Natural Endowment Index (KPI19) was updated at source: data now come from the World Bank thanks to the availability of data from more recent years and an expected yearly update of this composite indicator. However, this year the new KPI loses its statistically significant correlation with the Endowment pillar (yet much lower compared to last year: 0.21 vs. 0.29), and, again, it does not correlate with the overall Index. One option for the developers would be to check whether some of underlying components of the World Bank's Natural Endowment Index would better relate to the GAI. Overall, the JRC recommendation to the GAI development team is to carefully monitor how these four indicators (KPIs 13, 15, 18, 19) behave in the coming releases of the index and eventually to fine-tune the framework by considering a different formulation or different data source for these indicators.

As regards the KPIs' ability to measure the four founding pillars of the framework, the analysis confirms the positive impacts of changes implemented in the previous editions. At the same time, it highlights additional improvements that the GAI team could consider applying in the future.

First, the new data source selected in 2018 by the developing team for capturing the Net number of migrants (KPI5 within Openness, which is now based on United Nations Population Division data) maintains a high statistical coherence of 0.66 (compared to 0.65 last year) with the Openness pillar in this year's GAI.

Second, this year the indicator Employed in high-technology sectors (KPI6) maintains a statistically significant correlation with the GAI, which represents a preserved improvement from the 2018 edition. However, as it still deviates from the correlation coefficients of nearly all the other GAI's indicators (i.e. 0.27 vs. 0.6 or more in most cases), it is worth keeping an eye on this KPI in the future editions.

Third, unlike what one may expect, a country's unemployment level (KPI11) does not strongly contribute to the overall index (correlation remains stable, at merely 0.26). As also underlined in previous editions, this result calls for further analysis as it suggests that countries can achieve high levels of attractiveness irrespective of high unemployment levels. This is the case for Cabo Verde and Spain, for instance, which rank 19th and 26th, respectively, in the GAI 2020 despite having among highest unemployment levels worldwide.

Fourth, the Logistics Performance Index (KPI12) now correlates even more with its assigned pillar: Efficiency (0.85). Still, as also noticed in previous editions, it remains highly correlated with two other pillars of a country's attractiveness as well, namely with Openness and Innovation. Similarly, although Gross National Product (KPI17) belongs to the Endowment pillar, it is found to have much stronger statistical association to the Openness, Innovation and Efficiency pillars. Export + Import (KPI2) is also slightly more correlated to the Innovation and Endowment pillars than to its assigned Openness pillar. This transversal impact of KPI2, KPI12 and KPI17 across various pillars may be worth of further reflection and analysis.

Fifth, although the PISA Test score (KPI21) belongs to the Endowment pillar (correlation 0.51, much better than last year i.e. 0.29), it presents a similar correlation (0.46 and 0.48) to the Openness and Innovation pillars and a much stronger one (0.78) with the Efficiency pillar. It might be worth discussing whether the PISA test scores should be moved to another pillar, if both statistically and conceptually appropriate.

Last but not least, while most of the 21 KPIs are influential at the index level, three of them – Export + Import (KPI2), the Logistics Performance Index (KPI12) and this year also the Gross National Product (KPI17) – remain the best single predictors for a country's

attractiveness level (i.e. correlation coefficients with the GAI ranging from to 0.83 and 0.90).

Step 4: Qualitative Review

The GAI results were also evaluated by an ad-hoc Advisory Panel and by international experts invited by the European House – Ambrosetti to verify that they are, to a great extent, consistent with current evidence, existing research and prevailing theory.

To complement this qualitative evaluation, the GAI results are compared herein vis-à-vis other similar indices. The expectation is that the GAI correlates strongly to other international indices on competitiveness and innovation. Table 2 compares the GAI 2020 with the most recent versions of the World Economic Forum's Global Competitiveness Index (2018), with Cornell University, INSEAD, and WIPO's Global Innovation Index (2020) and with INSEAD's Global Talent Competitiveness Index (2020). The rank correlation between GAI 2020 with all three international indices remains substantially high (correlation ≈ 0.9), which suggests that the GAI framework has many elements in common with other international frameworks that monitor innovation and competitiveness at national level worldwide.

Table 2. Statistical consistency between the GAI and other relevant international indices

	Global Innovation Index (Cornell, INSEAD, WIPO)	Global Competitiveness Index (WEF)	Global Talent Competitiveness Index (INSEAD)
More than 30 positions	7%	2%	8%
20 to 29 positions	14%	8%	12%
10 to 19 positions	36%	31%	39%
More than 10 positions (*)	**56%**	**40%**	**59%**
5 to 9 positions	20%	23%	14%
Less than 5 positions	22%	33%	24%
0 positions	2%	4%	3%
Total	100%	100%	100%
Pearson correlation coefficient with the GAI	0.88	0.92	0.88
Spearman rank correlation coefficient with the GAI	0.89	0.95	0.90
Common countries with the GAI	121	127	124

Notes: The comparison between the GAI and the other indices was based on the common set of countries.
(*) This row is the sum of the prior three rows.

Source: European Commission, Joint Research Centre, 2020.

At the same time, looking at the shifts in rankings, 40% up to 59% of the countries differ in ranking by more than 10 positions when comparing the GAI 2020 with the recent releases of three international indices under analysis. This result suggests that the GAI 2020 receives validity when compared to other relevant international indices, and confirms that the GAI offers additional insights into nations' attractiveness and competitiveness that go beyond the findings of other international indices.

Notwithstanding these statistical tests and the positive outcomes on the statistical coherence together with the suggestions for refinement made above, the GAI model has been and should remain open for future improvements as better data, more comprehensive surveys and assessments, and new relevant research studies on national attractiveness and competitiveness become available.

2 Impact of modelling assumptions in the GAI

Assessing the effect of varying modelling assumptions in the GAI inside plausible ranges is an important part of the statistical audit. The rationale for the choices made by the GAI development team is manifold. For instance, literature review and expert opinion on national attractiveness and competitiveness, coupled with statistical analysis, is behind the selection of the 21 individual indicators and their grouping in four pillars and into an overall index; common practice and easy of interpretation suggests the use of a min-max normalization approach in the [0–100] range for the indicators; statistical analysis guides the choice on the treatment of outliers; and simplicity seems to advocate for not estimating missing data, assigning equal weights at all levels and adopting an arithmetic average formula.

Despite the well-substantiated rationale for the choices made during the GAI development, there is an unavoidable subjectivity (or uncertainty), which is accounted for in the robustness assessment carried out by the JRC. More precisely, the uncertainly analysis is conducted herein in order to allow for the joint analysis of the impact of the modelling choices on the GAI results, resulting in error estimates and confidence intervals calculated for the 144 countries included in the GAI.

As suggested in the relevant literature on composite indicators ([5]), the robustness assessment of the GAI model was based on Monte Carlo simulation and multi-modelling approaches, applied to 'error-free' data where eventual errors and typos have already been corrected in a preliminary stage. In particular, the three key modelling issues considered in the assessment of the GAI were the treatment of missing data, the aggregation formula at the pillar level and finally the pillar weights.

Missing data. The GAI developers, for transparency and replicability and following common practice on composite indicator development, opted not to estimate missing data. Technically, the 'no imputation' choice is equivalent to replacing an indicator's missing value for a given country with the respective pillar score. Hence, the available data (indicators) in the incomplete pillar may dominate the results, sometimes biasing the ranks up or down. Furthermore, the 'no imputation' choice might encourage countries not to report low data values. To test the impact of the 'no imputation' choice, the JRC estimated missing values in the GAI dataset using the Expectation Maximization (EM) algorithm that was applied in the entire set of 21 indicators. ([6])

Aggregation. Regarding the aggregation formula, decision-theory practitioners challenge the use of simple arithmetic averages because of their fully compensatory nature, in which a comparative high advantage on a few indicators can compensate a comparative disadvantage on many indicators.([7]) To assess the impact of this compensability issue, the strong perfect substitutability assumption inherent in the arithmetic average was relaxed in this analysis; instead the geometric average across the four GAI pillars was considered as an alternative. Nevertheless, the arithmetic average has been maintained at the KPIs level, where full compensability may be justifiable. The geometric average is a partially compensatory approach that rewards countries with balanced profiles and

([5]) Saisana et al., 2005; Saisana et al., 2011 ; Vértesy 2016; Vértesy and Deiss, 2016

([6]) The Expectation-Maximization (EM) algorithm (Little and Rubin, 2002; Schneider, 2001) is an iterative procedure that finds the maximum likelihood estimates of the parameter vector by repeating two steps. Step 1: The expectation E-step: Given a set of parameter estimates, such as a mean vector and covariance matrix for a multivariate normal distribution, the E-step calculates the conditional expectation of the complete-data log likelihood given the observed data and the parameter estimates. Step 2: The maximization M-step: Given a complete-data log likelihood, the M-step finds the parameter estimates to maximize the complete-data log likelihood from the E-step. The two steps are iterated until the iterations converge.

([7]) Munda, 2008.

motivates countries to improve in the GAI pillars in which they perform poorly, and not just in *any* GAI pillar.([8])

Weights. While the term *multi-modelling* refers to testing alternative assumptions—that is, an alternative aggregation method, and missing data estimation method—the Monte Carlo simulation explored the issue of weighting and comprised 1,000 runs, each corresponding to a different set of weights for the four pillars, randomly sampled from uniform continuous distributions centred in the reference values (equal weighting; pillar weights are 25%). The choice of the range for the weights' variation was driven by two opposite needs: to ensure a wide enough interval to have meaningful robustness checks, and to respect the rationale of GAI that places equal importance on all four pillars – Openness, Innovation, Efficiency, Endowment. Given these considerations, limit values of uncertainty intervals for the pillar weights are 15% to 35% for the four pillars (see Table 3). In all simulations, sampled weights are then rescaled so that they always sum to 1.

Four models were tested based on the combination of no imputation versus EM imputation at the indicator level, arithmetic versus geometric average at the pillar level. Combined with 1,000 simulations per model (random weights versus fixed weights), a total of 4,000 simulations for the Global Attractiveness Index were run.

Table 3. Uncertainty parameters in the GAI: missing values, weights, aggregation

	Reference	Alternative
I. **Uncertainty in the treatment of missing values**	No estimation of missing data	Expectation Maximization (EM)
II. **Uncertainty in the aggregation formula at pillar level**	Arithmetic average	Geometric average
III. **Uncertainty intervals for the weights of the four GAI pillars**	Reference value for the weight	Distribution assigned for robustness analysis
Openness	0.25	U[0.15,0.35]
Innovation	0.25	U[0.15,0.35]
Efficiency	0.25	U[0.15,0.35]
Endowment	0.25	U[0.15,0.35]

Source: European Commission, Joint Research Centre, 2020.

The main results of the robustness analysis are shown in Figure 2 with median ranks and the 90% confidence intervals computed across the 4,000 Monte Carlo simulations for the Global Attractiveness Index. Countries are ordered from high to low performance according to their reference GAI rank (black line), the dot being the median rank over the simulations.

All published GAI 2020 ranks lay within the simulated 90% confidence intervals, and for the vast majority of the countries these ranks can be considered as representative of the plurality of scenarios simulated herein. Taking the median rank as the yardstick for an economy's expected rank in the realm of the GAI's unavoidable methodological uncertainties, 75% of the economies are found to shift fewer than four positions with respect to the median rank in the GAI.

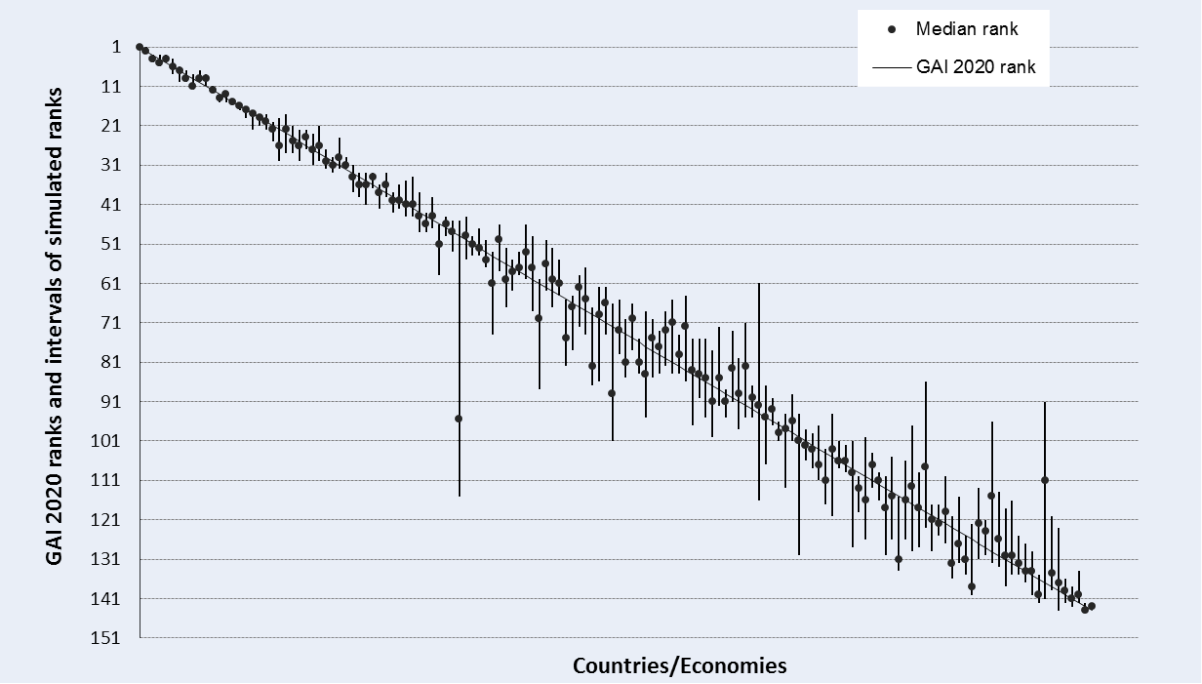
Furthermore, for most economies the simulated rank intervals are narrow enough for meaningful inferences to be drawn: there are fewer than 10 positions for 76 of the 144 economies, which is a noteworthy improvement compared to last year's edition (where for 64 of the 144 countries the simulated rank intervals were less than 10 positions wide).

([8]) In the geometric average, pillars are multiplied as opposed to summed in the arithmetic average. Pillar weights appear as exponents in the multiplication. A constant of 0.001 was added to the pillar scores to avoid zero values that would have led to zero geometric averages.

Nevertheless, several country ranks vary significantly with changes in the four pillar weights, the aggregation formula across the four pillars or the estimation of missing data (where applicable): confidence interval widths are 30 or greater for the following eight countries that are placed between the 49th (Timor-Leste) and the 137th (Venezuela) position: Timor-Leste, Algeria, Gabon, Cabo Verde, Libya, Syrian Arab Republic, Swaziland, and Venezuela. Furthermore, there are twenty more countries with confidence interval widths between 20 and 29: Azerbaijan, Suriname, Bhutan, Panama, Mongolia, Albania, Ecuador, Moldova, Guyana, Costa Rica, Argentina, Paraguay, Lao PDR, Nepal, Rwanda, Zambia, Mauritania, Bolivia, Myanmar, and Malawi. For these 28 countries the GAI ranks are highly sensitive to the modelling choices when building the GAI and should hence not be taken at face value.

For full transparency and information, Table 4 reports the GAI 2020 country ranks together with the simulated 90% confidence intervals in order to better appreciate the robustness of the results to the estimation of missing data, the choice of the four pillar weights and of the aggregation formula at pillar level.

Figure 2. Robustness analysis (GAI rank vs. median rank, 90% confidence intervals)



Notes: Median ranks and intervals are calculated over 4,000 simulated scenarios based on imputing (or not) missing values, random weights plus/minus 25% around the reference weights for the four pillars on Openness, Innovation, Efficiency, Endowment, and aggregation formula at pillar level (as shown in Table 3). The Spearman rank correlation between the median rank of the simulations and the GAI 2020 rank is 0.989.

Source: European Commission, Joint Research Centre, 2020.

Table 4. GAI 2020: Index ranks and simulated 90% intervals

Germany	1 [1, 2]	Kazakhstan	51 [49, 54]	Ghana	101 [98, 106]
United States	2 [1, 2]	Latvia	52 [47, 54]	Bangladesh	102 [99, 108]
Singapore	3 [3, 5]	Vietnam	53 [50, 57]	Cote d'Ivoire	103 [97, 111]
Japan	4 [3, 6]	Azerbaijan	54 [53, 74]	Guatemala	104 [103, 117]
United Kingdom	5 [3, 5]	Croatia	55 [46, 58]	Lao PDR	105 [94, 120]
Hong Kong SAR, China	6 [4, 8]	Iran, Islamic Rep.	56 [52, 67]	Namibia	106 [101, 108]
China	7 [6, 10]	Slovak Republic	57 [55, 63]	Nigeria	107 [102, 109]
Canada	8 [7, 10]	Lithuania	58 [53, 59]	Nepal	108 [101, 128]
Korea, Rep.	9 [8, 12]	Turkey	59 [46, 60]	Sri Lanka	109 [110, 119]
Netherlands	10 [7, 10]	Seychelles	60 [49, 68]	Rwanda	110 [100, 126]
France	11 [8, 11]	Suriname	61 [60, 88]	Cambodia	111 [104, 113]
Australia	12 [11, 12]	Montenegro	62 [50, 63]	Senegal	112 [109, 116]
United Arab Emirates	13 [13, 15]	Greece	63 [52, 67]	Zambia	113 [110, 130]
Switzerland	14 [13, 15]	Bulgaria	64 [55, 64]	Mauritania	114 [105, 126]
Ireland	15 [14, 15]	Trinidad and Tobago	65 [65, 82]	Mozambique	115 [115, 134]
Austria	16 [16, 17]	Uruguay	66 [64, 78]	Bolivia	116 [106, 126]
Denmark	17 [16, 19]	Lebanon	67 [59, 72]	Libya	117 [97, 129]
Italy	18 [17, 22]	Jordan	68 [57, 74]	Kenya	118 [109, 128]
Belgium	19 [18, 21]	Bhutan	69 [67, 87]	Syrian Arab Republic	119 [86, 123]
Qatar	20 [18, 22]	Panama	70 [62, 86]	Honduras	120 [117, 129]
New Zealand	21 [20, 25]	Georgia	71 [62, 74]	Uganda	121 [117, 125]
Norway	22 [19, 30]	Algeria	72 [66, 101]	El Salvador	122 [110, 127]
Russian Federation	23 [18, 28]	Philippines	73 [65, 79]	Tanzania	123 [120, 136]
Sweden	24 [21, 28]	Dominican Republic	74 [70, 85]	Cameroon	124 [115, 132]
Luxembourg	25 [22, 30]	Ukraine	75 [66, 78]	Mali	125 [125, 135]
Spain	26 [22, 27]	Macedonia, FYR	76 [75, 84]	Chad	126 [122, 140]
Kuwait	27 [23, 31]	Mongolia	77 [68, 95]	Benin	127 [113, 131]
Bahrain	28 [21, 30]	Serbia	78 [70, 85]	Pakistan	128 [121, 130]
Finland	29 [27, 32]	Armenia	79 [73, 84]	Swaziland	129 [96, 132]
Iceland	30 [29, 33]	Mauritius	80 [68, 82]	Nicaragua	130 [114, 133]
India	31 [24, 32]	Kyrgyz Republic	81 [65, 84]	Myanmar	131 [118, 138]
Saudi Arabia	32 [29, 32]	Peru	82 [74, 84]	Zimbabwe	132 [116, 135]
Poland	33 [31, 38]	Albania	83 [64, 86]	Tajikistan	133 [125, 135]
Israel	34 [33, 39]	Ecuador	84 [75, 97]	Liberia	134 [127, 137]
Slovenia	35 [33, 41]	Puerto Rico	85 [75, 90]	Lesotho	135 [129, 140]
Estonia	36 [33, 37]	Moldova	86 [75, 95]	Madagascar	136 [135, 142]
Czech Republic	37 [36, 42]	Guyana	87 [78, 100]	Venezuela, RB	137 [91, 141]
Malaysia	38 [33, 39]	Costa Rica	88 [72, 92]	Gambia, The	138 [120, 139]
Hungary	39 [38, 43]	Jamaica	89 [88, 95]	Malawi	139 [123, 144]
Oman	40 [36, 42]	South Africa	90 [73, 91]	Yemen, Rep.	140 [136, 142]
Brazil	41 [35, 44]	Colombia	91 [80, 98]	Haiti	141 [138, 143]
Cyprus	42 [34, 44]	Argentina	92 [71, 95]	Guinea	142 [134, 142]
Mexico	43 [38, 48]	Egypt, Arab Rep.	93 [87, 95]	Burundi	143 [142, 144]
Portugal	44 [43, 48]	Gabon	94 [61, 116]	Sierra Leone	144 [140, 144]
Malta	45 [39, 47]	Paraguay	95 [87, 107]		
Chile	46 [46, 59]	Morocco	96 [90, 97]		
Thailand	47 [44, 49]	Botswana	97 [96, 101]		
Romania	48 [45, 53]	Tunisia	98 [94, 113]		
Timor-Leste	49 [45, 115]	Bosnia and Herzegovina	99 [89, 101]		
Indonesia	50 [44, 55]	Cabo Verde	100 [94, 130]		

Notes: Rank intervals are calculated over 4,000 simulated scenarios based on imputing (or not) missing values, random weights plus/minus 25% around the reference weights for the four pillars on Openness, Innovation, Efficiency, Endowment, and aggregation formula at pillar level. Countries with confidence interval widths that are 30 positions or greater are highlighted in grey.

Source: European Commission, Joint Research Centre, 2020.

Next, the impact of not estimating missing values in the GAI is analysed in more detail. The 2019 dataset has a very good coverage: 83% data available across 144 countries and 21 indicators. Out of the 517 missing values, only 41 data gaps in 37 countries are found to have a high impact on the results. Table 5 lists the 37 countries that are strongly affected (moving 20 positions or more in a given GAI pillar) when missing values are estimated via the EM algorithm as opposed to not being estimated at all (reference scenario). Data availability per pillar is reported as well. Most country ranks are particularly sensitive to the missing data estimation in two of the four pillars, namely the Efficiency or the Endowment pillar. Only ten countries are sensitive to missing values in the other two pillars, namely on Openness and on Innovation: Chad, Dominican Republic, Ecuador, Gabon, Iran, Islamic Rep, Paraguay, Trinidad and Tobago, Tunisia, and Venezuela. It is worth noting that the sensitivity of country ranks to the treatment of missing data is not necessarily directly related to the amount of missing data in a given country but rather the result of the missing values in the ensemble of countries. To give an example, in the Endowment pillar, countries with no data at all, namely Syrian Arab Republic, and Venezuela, or countries with 83% data availability, namely Cyprus, are equally affected by the estimation of missing data in the GAI dataset.

The JRC recommendation to readers and policy analysts is to consider the GAI pillar ranks (and scores) for these 37 countries with a grain of salt when drawing inferences on the countries performance when it comes to national Openness, Innovation, Efficiency or Endowment. The suggestion to the GAI developers is to find reliable estimates for those 41 missing values because of the high impact on the GAI pillar ranks.

Table 5. Impact of missing data estimation on countries with most sensitive pillar ranks

	Country ranks sensitive to the treatment of missing data				Data availability			
	Openness	Innovation	Efficiency	Endowment	Openness	Innovation	Efficiency	Endowment
Azerbaijan			YES		100%	80%	60%	83%
Bahrain				YES	100%	80%	80%	83%
Chad			YES		60%	60%	60%	67%
El Salvador			YES		100%	80%	80%	83%
Honduras			YES		80%	80%	80%	67%
Hong Kong SAR, China				YES	100%	80%	100%	67%
Iceland				YES	100%	100%	80%	83%
Iran, Islamic Rep.	YES				80%	80%	100%	83%
Lebanon			YES		100%	80%	80%	67%
Liberia			YES		80%	40%	80%	67%
Lithuania				YES	100%	100%	80%	50%
Malta				YES	100%	100%	80%	83%
Mauritius			YES		100%	80%	80%	67%
Mozambique			YES		100%	80%	80%	83%
Myanmar				YES	80%	80%	100%	50%
Nepal			YES		80%	80%	80%	67%
Seychelles			YES		80%	80%	20%	83%
Slovak Republic				YES	100%	80%	80%	83%
Swaziland		YES			80%	60%	40%	67%
Syrian Arab Republic	YES			YES	40%	60%	60%	17%
Tajikistan			YES		100%	40%	80%	83%
Tanzania			YES		80%	80%	80%	67%
Timor-Leste			YES		80%	80%	40%	67%
United Arab Emirates				YES	80%	80%	100%	83%
Venezuela, RB		YES		YES	80%	60%	100%	0%

Notes: Countries are listed here if they are strongly affected with shifts of 20 positions or more in a given GAI pillar when missing values are estimated via the EM algorithm as opposed to not being estimated at all (reference scenario).

Source: European Commission, Joint Research Centre, 2020.

Concluding, the published GAI 2020 ranks are reliable and for the vast majority of countries the simulated 90% confidence intervals are narrow enough for meaningful inferences to be drawn. Given the sensitivity of some countries' pillar ranks to the estimation of missing values, the JRC recommendation to the index developers is to find a suitable way for approximating missing values, where possible by contacting national statistical offices or finding additional data sources. For the readers and policy analysts of the GAI 2020 report, the recommendation is to consider country ranks within the 90% confidence intervals in order to better appreciate to what degree a country's rank depends on the three key modelling choices accounted for, namely estimation of missing data, weights and aggregation formula at the pillar level.

3 Added value of GAI - From four pillars to one single number of national attractiveness

This last section aims at touching upon the added value of the Global Attractiveness Index as a summary measure of the four pillars.

Table 6 shows that the GAI 2020 ranking and any of the four pillar rankings differ by 10 positions or more for at least 46% (up to 67%) of the 144 countries.

This finding suggests that there is an added value in referring to the GAI results in order to identify aspects of countries' attractiveness that do not directly emerge by looking into the four pillars separately. At the same time, this outcome points to the value of examining individual GAI pillars and indicators on their own merit in order to see which components are driving a country's attractiveness.

Table 6. Distribution of differences between pillars and GAI rankings

Shift with respect to the GAI	Openness	Innovation	Efficiency	Endowment
More than 30 positions	10%	6%	25%	26%
20 to 29 positions	11%	11%	9%	13%
10 to 19 positions	30%	29%	22%	27%
More than 10 positions (*)	51%	46%	56%	67%
5 to 9 positions	22%	26%	19%	16%
Less than 5 positions	25%	22%	21%	14%
0 positions	1%	6%	4%	3%
Total	100%	100%	100%	100%
Spearman rank correlation coefficient with the GAI	0.89	0.92	0.81	0.79

Notes: (*) This row is the sum of the prior three rows.

Source: European Commission, Joint Research Centre, 2020.

4 Conclusions

For the fifth consecutive year, The European House – Ambrosetti's Global Attractiveness Index (GAI) enables policy makers, investors and other interested stakeholders to measure and benchmark 144 countries around the world on a number of attractiveness parameters. With a view to maximise the reliability and transparency of the GAI, The European House – Ambrosetti has again asked the JRC to assess the impact of the methodological choices made in the development of the index. More specifically, in the present report, the JRC has analysed the statistical properties of the data and the methodology used in the index construction and provided advice for further improvements. Overall, the analysis herein confirms that GAI framework is accurately designed and built. This result signals the efforts that The European House – Ambrosetti's has put into the preparation of this work to identify the multiple determinants of a county's attractiveness and the best available data sources to measure them.

The key findings of the 2020 statistical assessment can be summarised as follows.

1

A conceptually coherent tool

On the one hand, the analysis of the correlation structure finds the **conceptual grouping** of the 21 indicators into four pillars and an overall index statistically appropriate. It also shows that the GAI scale –average of four key dimensions capturing Openness, Innovation, Efficiency and Endowment – is unidimensional and has high statistical reliability (Cronbach alpha 0.88) well above the recommended threshold (0.7) for a reliable aggregate. Seventeen out of the 21 indicators in the GAI framework are also found to be influential all the way up to the index level. The appropriateness of the new data source used since the GAI 2019 edition for capturing the Net number of migrants (KPI5) is confirmed as it has contributed to increasing KPI5's statistical coherence.

2

KPIs to be kept under the spotlight

On the other, a number of following issues calls for **further reflection** and analysis. First, four indicators – **Total productivity of factors** (KPI13) and **Total tax rate** (KPI15) within Efficiency, and **Gross fixed investment** (KPI18) and **Natural Endowment Index** (KPI19) within Endowment – still account for a small (almost negligible) amount of variation in the GAI scores. Although these indicators are conceptually relevant to measure attractiveness and their statistical impact arrives up to the pillar level, we recommended the GAI's developers to keep monitor these four indicators in the coming releases of the index and consider fine-tuning the framework in this respect. One option would be to check whether some of underlying components of the World Bank's Natural Endowment Index would better relate to the GAI. Secondly, despite expectations, the indicator **Employed in high-technology sectors** (KPI6) has a statistically significant correlation with the GAI, but the correlation coefficient remains particularly low. Similarly, a country's **Unemployment level** (KPI11) is not strongly related to the overall index (correlation remains stable merely at 0.26), which suggests that countries can achieve high levels of attractiveness irrespective of high unemployment levels. Finally, the **PISA Test score** (KPI21) belongs to the Endowment pillar, but presents a much stronger correlation to the other three pillars on Openness, Innovation and Efficiency. The developers should explore why it is so and whether it would be relevant to move this indicator, if also conceptually relevant, under another pillar or find an alternative indicator.

3

An acceptable impact of missing data on shifts in the rankings

Overall, the GAI dataset has good **data coverage** and 83% of the data refer to 2018 or 2019. Uncertainty and sensitivity analysis have shown that it is important to find reliable estimates for 41 missing values in 37 countries (i.e. 8% of the missing data) because of the very high impact on the country ranks along specific GAI pillars.

Third, the tests helped to single out 28 countries with GAI ranks that are very **sensitive to the modelling choices** and hence these ranks should be interpreted cautiously. On the other hand and compared to the reference GAI rank, 75% of the economies are found to shift fewer than four positions with respect to the median rank over 4,000 simulations. Thereafter, the GAI framework allows to reliably benchmark national attractiveness in the vast majority of the countries analysed.

4

The GAI tells what others do not about a country's attractiveness

Last but not least, results show that there is an **added value in referring to the GAI results** in order to identify aspects of countries' attractiveness that do not directly emerge by looking into the four pillars separately. In fact, the GAI ranking and any of the four pillar rankings differ by 10 positions or more for at least 46% up to 67% of the 144 countries.

Also, the external validity testing of the GAI confirms the high degree of association (correlation ≈ 0.9) to the latest releases of three relevant international indices: the World Economic Forum's Global Competitiveness Index, the Cornell University, INSEAD, and WIPO's Global Innovation Index, and the INSEAD's Global Talent Competitiveness Index. At the same time, one finds that 40% up to 59% out of the countries included in the GAI 2020 that feature in these three indices differ in ranking by more than 10 positions when comparing the GAI 2020 with the recent releases of these international indices. This latter finding means that the GAI 2020 offers additional insights into nations' human capital and competitiveness that go beyond the findings of other international indices.

5

The JRC audit confirms that the Global Attractiveness Index 2020 meets, at large, international quality standards for statistical soundness

Overall, this year's JRC audit confirms that the Global Attractiveness Index 2020 meets, at large, international quality standards for statistical soundness. Consequently, the GAI framework offers a sound starting point for more informed discussions on a country's attractiveness. Stakeholders should also to check the GAI's results beyond the index scores (and ranks) as the 21 individual indicators and four pillars can offer more in-depth insights on the areas to be more carefully addressed by policy action. As from today, the GAI represents a well-designed but ongoing work by The European House - Ambrosetti to stimulate public interest and help focus policy discussions on the multiple aspects that shape a country's 'charm'. Still, the GAI, as any other tool aimed at capturing a complex and evolving reality, is subject to improvement. The GAI's developers intend to keep improving the tool in line with the theoretical advancement in the field and the availability of new (and relevant) data.

References

Becker, W., Saisana, M., Paruolo, P., Vandecasteele, I. 2017. Weights and importance in composite indicators: Closing the gap, Ecological Indicators 80: 12–22.

Cornell University, INSEAD, and WIPO. 2020. The Global Innovation Index 2020: : Who Will Finance Innovation? Ithaca, Fontainebleau, and Geneva.

Giampietro, M., 2014. 'Mono-dimensional accounting and multidimensional measures of sustainable growth'. European Commission, Joint Research Centre, EUR 26917 EN.

Groeneveld, R. A. and Meeden, G. 1984. 'Measuring Skewness and Kurtosis'. *The Statistician* 33: 391–99.

INSEAD. 2018. The Global Talent Competitiveness Index 2020, Fontainebleau, France.

Little, R. J. A. and Rubin, D. B. 2002. *Statistical Analysis with Missing Data*. 2nd edition. Hoboken, NJ: John Wiley & Sons, Inc.

Montalto, V., Tacao Moura, C. J., Langedijk, S., Saisana, M. (2020). Culture counts: An empirical approach to measure the cultural and creative vitality of European cities. *Cities*, 89, 167–185. https://doi.org/10.1016/J.CITIES.2020.01.014

Munda, G. 2008. *Social Multi-Criteria Evaluation for a Sustainable Economy.* Berlin Heidelberg: Springer-Verlag.

Nunally, J. 1978. *Psychometric Theory.* New York: McGraw-Hill.

OECD/EC JRC (Organisation for Economic Co-operation and Development/European Commission, Joint Research Centre). 2008. *Handbook on Constructing Composite Indicators: Methodology and User Guide.* Paris: OECD.

Paruolo, P., Saisana, M., Saltelli, A. 2013. 'Ratings and Rankings: Voodoo or Science?' *Journal of the Royal Statistical Society* A 176 (3): 609–34.

Saisana, M., D'Hombres, B., Saltelli, A. 2011. 'Rickety Numbers: Volatility of University Rankings and Policy Implications'. *Research Policy* 40: 165–77.

Saisana, M., Saltelli, A., Tarantola, S. 2005. 'Uncertainty and Sensitivity Analysis Techniques as Tools for the Analysis And Validation Of Composite Indicators'. *Journal of the Royal Statistical Society* A 168 (2): 307–23.

Saltelli, A., Ratto, M., Andres, T., Campolongo, F., Cariboni, J., Gatelli, D., Saisana, M., Tarantola, S. 2008. *Global Sensitivity Analysis: The Primer*. Chichester, England: John Wiley & Sons.

Schneider, T. 2001. 'Analysis of incomplete climate data: Estimation of mean values and covariance matrices and imputation of missing values. *Journal of Climate*, 14, 853–871.

Vertesy, D., Deiss, R. 2016. The Innovation Output Indicator 2016. Methodology Update. EUR 27880. European Commission, Joint Research Centre.

Vértesy, D. (2016, July). A Critical Assessment of Quality and Validity of Composite Indicators of Innovation. Paper presented at the OECD Blue Sky III Forum on Science and Innovation Indicators. Ghent, 19-21 Sept 2016.

World Economic Forum. 2018. The Global Competitiveness Report 2018. Geneva

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