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Joint Research Centre Statistical Audit of the 2018 Global Attractiveness Index

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Executive Summary

Attractiveness is a prerequisite and a symptom for competitiveness and it is valued both because it implies a nation's ability to attract talent, capital and assets (know-how, technologies, and other), and because more in general it stimulates the whole process of economic and social development. The European House - Ambrosetti has developed an international monitoring framework – the Global Attractiveness Index (GAI) – that measures a country's attractiveness as determining element of its ability to be competitive and to grow. The GAI builds on four attributes of attractiveness: Openness, Innovation, Efficiency, and Endowment. These pillars are used to organise and aggregate 21 Key Performance Indicators (KPIs) into a single summary measure for 144 countries that altogether 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[1]. The statistical audit discussed in this note was conducted by the European Commission's Joint Research Centre, and it aims at maximising the reliability and transparency of the Global Attractiveness Index[2]. It should enable policy analysts and researchers alike to draw more relevant, meaningful and useful conclusions on good practices and challenges that countries face in today's competitive game to business and job creation.

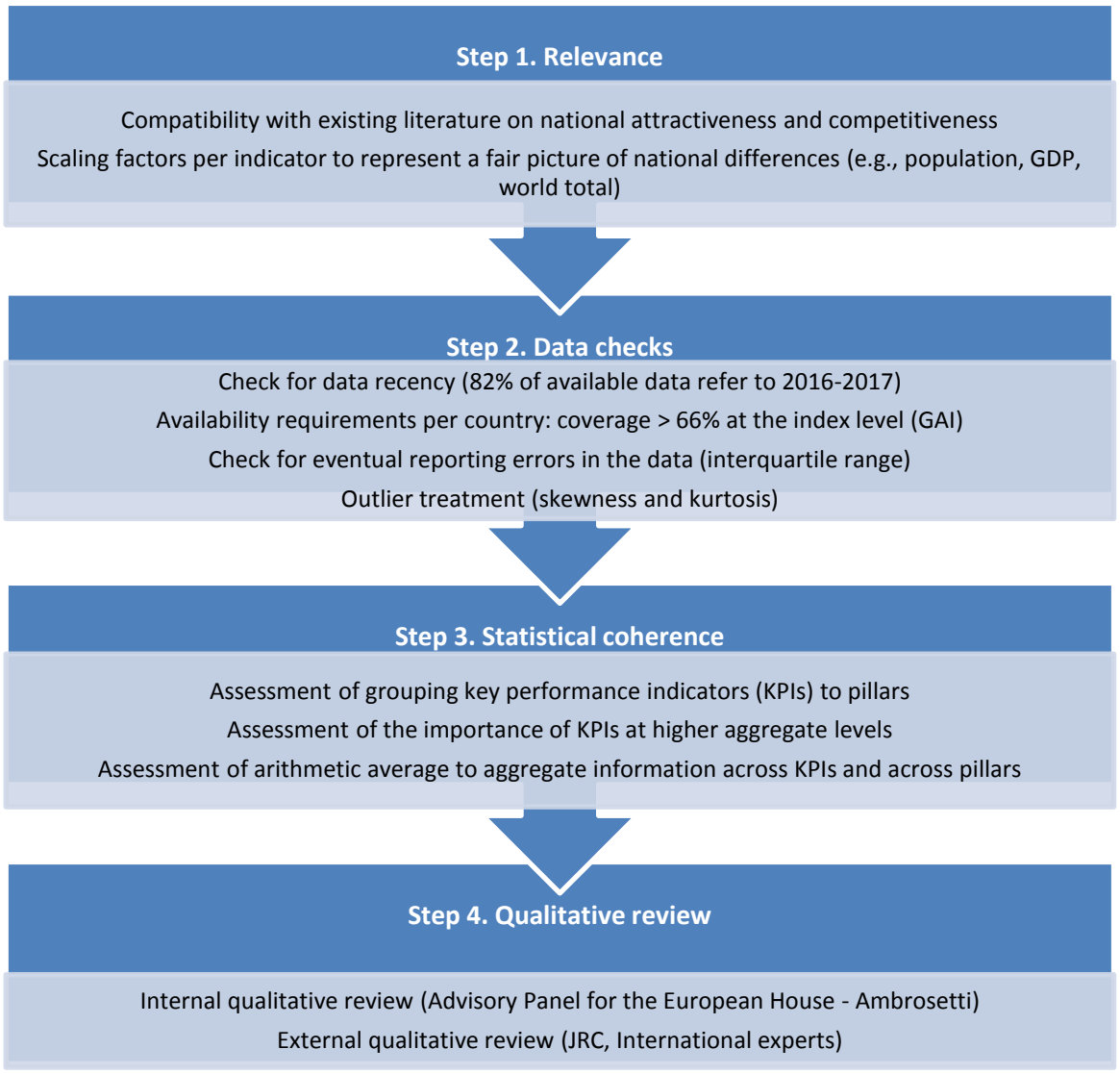
[1] The Positioning Index of the Global Attractiveness Index (GAI) measures the current level of a country's attractiveness in relation to other countries. Two more indices complement the conceptual framework of a country's attractiveness. A Dynamism Index that measures the short-to-medium term change in the preceding three-year period of the attractiveness level of the 21 KPIs. A Sustainability Index that attempts to show how the position achieved in the Positioning Index can be maintained over time. This latter builds on two pillars that are antithetic and complementary: resilience and vulnerability. The Dynamism index and Sustainability Index results are only communicated in qualitative terms (traffic light approach). The present JRC audit focuses on the GAI index (the Positioning Index). Upon request of the European House Ambrosetti, the Dynamism and Sustainability indices will be discussed in next year's audit.

[2] The JRC statistical audit is based on the recommendations of the OECD & JRC (2008) Handbook on Composite Indicators, and on more recent research from the JRC. In principle, JRC audits of composite indicators and scoreboards are conducted upon request of their developers, see https://ec.europa.eu/jrc/en/coin and https://composite-indicators.jrc.ec.europa.eu/

1 Introduction

Earlier versions of the Global Attractiveness Index were assessed by the JRC in May-June 2016, in May-June 2017 and June-July 2018. 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 2018 Framework



Source: European Commission, Joint Research Centre, 2018.

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, 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 labor 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)[3]. 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 2013–17 were used for each country (total 144 countries): 82% of available data for the GAI refer to 2016 or 2017. Countries are included in the GAI if data availability is at least 66% (i.e., 14 out of 21 KPIs). Exceptionally, eleven countries with lower data coverage have been included in the GAI: Libya, Puerto Rico, Swaziland, Syrian Arab Republic, and Timor-Leste (with 48% up to 57% data available) and Chad, Gabon, Guinea, Liberia, Venezuela, and Yemen (with 62% data availability, i.e. 13/21 KPIs available). In practice, data availability in the GAI is overall very good: at least 80% data available for 100 (out of 144) countries. That said, for some countries data coverage is not satisfactory at the pillar level. For example, for Libya and Venezuela only one out of the six KPI values under the Endowment pillar is available. This is in general undesirable because the single KPI value available will dictate the pillar score for those countries. The impact of missing values on the GAI results is discussed in Section 2.

[3] See Giampietro, 2014 for a discussion on scaling factors for indicators (intensive versus extensive properties).

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 and kurtosis greater than 3.5.[4] These criteria were proposed by the JRC back in 2016 for the specific dataset underpinning the GAI model. These indicators were treated by winsorization (five 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 aggregated scores (either in the four pillars or the overall index) by means of correlation, cross-correlation, and principal component analysis.

Given that this type of analysis 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'.[5] 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 in the other two pillars: Efficiency and Endowment. The presence of more than one statistical

[4] 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 2013-2017 timeseries.

[5] OECD & EC JRC (2008).

dimension in the Efficiency and Endowment pillars suggests that some of the information content of some KPIs does not arrive at the pillar level.

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, close to 0.8 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 developing team. The reliability of the Global Attractiveness Index, measured by the Cronbach-alpha value, is very good at 0.89—well above the 0.7 threshold for a reliable aggregate of the four pillars.[6]

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 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.

First, there are four indicators that do not have statistically significant correlation to the overall index: Employed in high-technology sectors (KPI6) within Innovation, Total productivity of factors (KPI13) and Total tax rate (KPI16) within Efficiency, and Gross fixed investment (KPI18) 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 have achieve high GAI scores irrespective of high or low values in KPIs 6, 13, 16, 18, and the same holds for low GAI scores. The JRC recommendation to

[6] See Nunnally (1978).

the GAI development team is to carefully monitor how these four indicators 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. This refinement can be inspired by the positive impact to the coherence of the GAI of the new data source on migrants (next point).

Second, the new data source selected by the developing team for capturing the Net number of migrants (KPI5 within Openness, which is now based on United Nations Population Division data) has contributed to increasing the statistical coherence in this year's GAI (correlation 0.65 with the Openness pillar compared to 0.35 in last year's version).

Third, although the PISA Test score (KPI21) belongs to the Endowment pillar, it presents a much stronger correlation to the other three pillars and in particular to the Efficiency pillar (Pearson correlation 0.74). The link between PISA test scores and a country's Efficiency calls for further reflection.

Forth, unlike what one may expect, a country's unemployment level is not strongly related to the overall index. This outcome merits further analysis as it suggests that countries can achieve high levels of attractiveness despite high unemployment levels (as it is the case for Spain, which ranks 25th in the GAI despite one of the highest unemployment level worldwide).

Fifth, although Gross National Product belongs to the Endowment pillar, it is found to have much stronger statistical association to the Openness pillar. Similarly, the Logistics Performance Index is found to be equally related to all four pillars of a country's attractiveness; this transversal impact of the Logistics Performance Index across all pillars may be worth of further analysis.

Finally, while most of the 21 KPIs are influential at the index level, two of them - Export + Import (KPI2) and the Logistics Performance Index (KPI 12) are the best single predictors for a country's attractiveness level.

Table 1. *Statistical coherence: correlations between GAI components*

ATTRIBUTE		Key Performance Indicators (KPIs)					
			Openness	Innovation	Efficiency	Endowment	**INDEX**
Openness	**KPI1**	(Foreign Direct Investment flows into the country IN + the country's investment abroad OUT), % of world total	0.75	0.66	0.47	0.66	0.74
	KPI2	(Export + Import), % of world total	0.80	0.81	0.57	0.77	0.85
	KPI3	(No. foreign tourists IN + No. national tourists abroad OUT), compared with national population	0.63	0.41	0.29		0.45
	KPI4	Foreign university students, compared with youth population	0.68	0.53	0.52	0.37	0.61
	KPI5	Net number of migrants, compared with population	0.65	0.38	0.27		0.43
Innovation	**KPI6**	Employed in high-technology sectors, compared with employed		0.50	0.26		0.20
	KPI7	Exports of high-technology goods, compared with world total	0.60	0.75	0.48	0.67	0.73
	KPI8	ICT Development Index	0.76	0.86	0.58	0.58	0.81
	KPI9	Number of scientific publications, compared with world total	0.61	0.76	0.50	0.77	0.77
	KPI10	Internet users, % of population	0.74	0.85	0.55	0.55	0.79
Efficiency	**KPI11**	Unemployment level (-1)			0.60		0.28
	KPI12	Logistics Performance Index	0.79	0.78	0.77	0.70	0.86
	KPI13	Total productivity of factors			0.38		0.15
	KPI14	Rule of Law Index	0.73	0.70	0.80	0.57	0.76
	KPI15	Total tax rate (% commercial profits)			0.28		0.07
Endowment	**KPI16**	Gross Domestic Product (GDP), compared with world total	0.59	0.71	0.46	0.75	0.73
	KPI17	Gross National Product, (GNP), per capita	0.85	0.76	0.58	0.67	0.82
	KPI18	Gross Fixed Investment, compared with GDP				0.28	0.04
	KPI19	Natural Resource Index				0.57	0.29
	KPI20	College graduates, compared with world total		0.39	0.29	0.78	0.48
	KPI21	PISA Test Score	0.58	0.51	0.74	0.27	0.59
		Attributes of Attractiveness					
			Openness	Innovation	Efficiency	Endowment	**INDEX**
		Openness	1.00	0.80	0.58	0.66	0.88
		Innovation	0.80	1.00	0.62	0.77	0.94
		Efficiency	0.58	0.62	1.00	0.59	0.78
		Endowment	0.66	0.77	0.59	1.00	0.87

Notes: Numbers represent the Pearson correlations coefficients between the GAI components (pillars or index) and the underlying indicators (for 144 countries). Values greater than 0.7 are desirable as they imply that the pillar captures at least 50% (≈ 0.7×0.7) of the variation in the underlying KPIs. Instead, values lower than 0.23 are not presented as they are not statistically significant (p-values >0.01). Grey boxes show the conceptual grouping of the indicators. KPIs for which lower values are desirable are marked with (-1).

Source: European Commission Joint Research Centre, 2018.

Step 4: Qualitative Review

Finally, the GAI results were 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, innovation and human capital. Table 2 compares the GAI 2018 with both the World Economic Forum's 2017–2018 Global Competitiveness Index and the 2017 Global Human Capital Index, with Cornell University, INSEAD, and WIPO's 2018 Global Innovation Index and with INSEAD's 2018 Global Talent Competitiveness Index. The rank correlation between GAI 2018 with all four international indices is substantially high (correlation ≈ 0.9), which suggests that the GAI framework has many elements in common with other international frameworks that monitor innovation, competitiveness and human capital at national level worldwide.

Table 2. *Distribution of differences between the GAI 2018 and other international rankings*

	Global Innovation Index (Cornell, INSEAD, WIPO, 2018)	**Global Human Capital Index (WEF, 2017)**	**Global Competitiveness Index (WEF, 2017-2018)**	**Global Talent Competitiveness Index (INSEAD, 2018)**
More than 30 positions	4%	13%	8%	10%
20 to 29 positions	12%	16%	11%	11%
10 to 19 positions	32%	32%	35%	34%
More than 10 positions (*)	**48%**	**61%**	**54%**	**55%**
5 to 9 positions	22%	17%	26%	18%
Less than 5 positions	21%	19%	20%	24%
0 positions	9%	2%	1%	3%
Total	100%	100%	100%	100%
Pearson correlation coefficient with the GAI	0.89	0.78	0.89	0.86
Spearman rank correlation coefficient with the GAI	0.90	0.82	0.91	0.88
Common countries with the GAI	114	124	132	120

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, 2018.

At the same time, looking at the shifts in rankings, one finds that 48% up to 61% out of the countries included in the GAI 2018 that feature in the other four indices differ in ranking by more than 10 positions when comparing the GAI 2018 with the recent releases of the Global Competitiveness Index, the Global Human Capital Index, the Global Competitiveness Index and the Global Talent Competitiveness Index. This result suggests that the GAI 2018 receives validity when compared to other relevant international indices, and that the GAI offers additional insights into nations' human capital 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, in its third edition now, 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[7], 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, 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.[8]

[7] Saisana et al., 2005; Saisana et al., 2011 ; Vértesy 2016; Vértesy and Deiss, 2016

[8] 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

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.[9] 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 motivates countries to improve in the GAI pillars in which they perform poorly, and not just in *any* GAI pillar.[10]

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.

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.

[9] Munda, 2008.

[10] 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.

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, 2018.

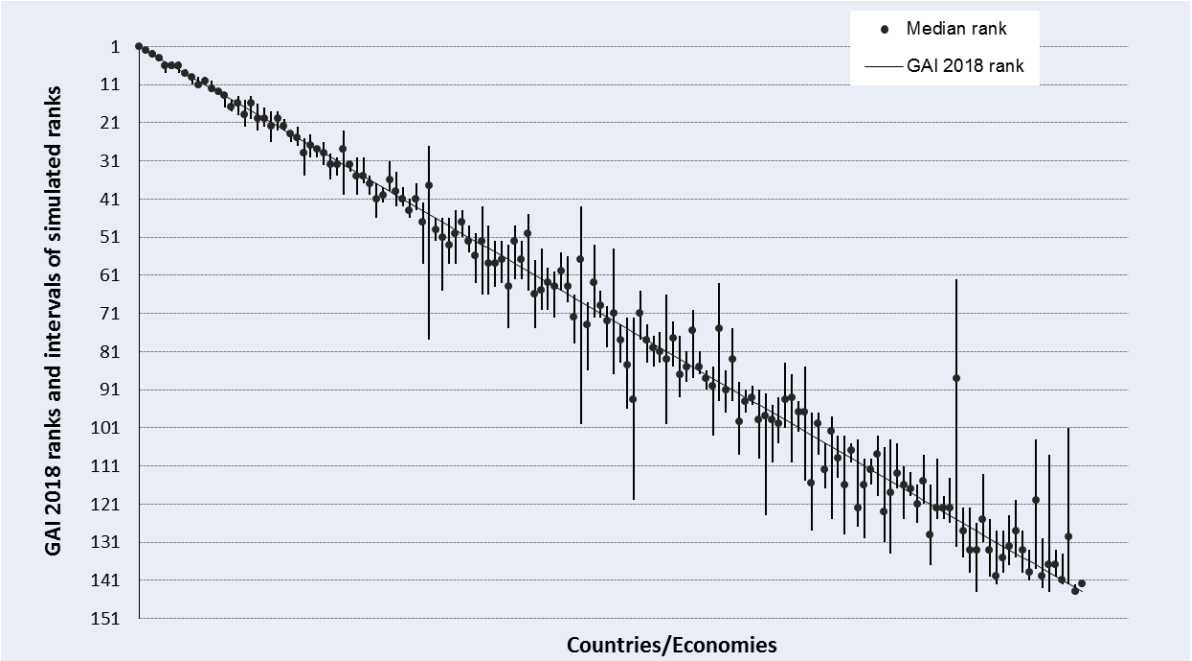
The main results of the robustness analysis are shown in Figure 2 with median ranks and the 90% confidence intervals computed across the 4,000 Monte Carlo simulations for the Global Attractiveness Index. Countries are ordered from high to low performance according to their reference GAI rank (black line),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

All published GAI 2018 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, 70% of the economies are found to shift fewer than three 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 67 of the 144 economies. 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 14 countries that are placed between the 45th (Qatar) and the 142nd (Swaziland) position: Qatar, Oman, Jordan, Venezuela, Gabon, Montenegro, Cabo Verde, Armenia, Tanzania, Tajikistan, Seychelles, Namibia, Libya, and Swaziland. For these countries the GAI ranks should not be taken at face value.

For full transparency and information, Table 4 reports the GAI 2018 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 2018 rank is 0.991.

Source: European Commission Joint Research Centre, 2018.

Table 4. *GAI 2018: Index ranks and simulated 90% intervals*

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

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 reduced data coverage (less than 14/21 indicators) are highlighted in grey.

Source: European Commission Joint Research Centre, 2018.

Next, the impact of treating missing values in the GAI is analysed in more detail. Table 5 lists 27 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), together with the data availability per pillar. Most

countries' ranks are sensitive to the missing data estimation in one of the pillars, primarily the Efficiency or the Endowment pillar. Only four countries are sensitive to missing values in two pillars: Chad, Guinea, Lesotho and Venezuela. The JRC recommendation is to consider pillar ranks (and scores) for these countries with a grain of salt when drawing inferences on their performance.

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

	Country rank sensitive to the treatment of missing data				Data availability			
	Openness	Innovation	Efficiency	Endowment	Openness	Innovation	Efficiency	Endowment
Bahrain				YES	80%	80%	80%	67%
Benin			YES		100%	80%	60%	67%
Burundi			YES		80%	60%	60%	67%
Chad	YES		YES		60%	60%	60%	67%
El Salvador			YES		100%	80%	80%	83%
Estonia				YES	80%	100%	100%	83%
Greece				YES	80%	100%	100%	83%
Guinea			YES	YES	80%	60%	60%	50%
Haiti				YES	80%	60%	60%	67%
Hong Kong				YES	100%	80%	100%	67%
Iran	YES				80%	60%	100%	83%
Jordan				YES	100%	80%	100%	50%
Lesotho		YES		YES	80%	60%	60%	67%
Liberia			YES		60%	40%	80%	67%
Mali			YES		60%	80%	80%	67%
Mozambique				YES	100%	60%	80%	83%
Myanmar				YES	80%	80%	100%	50%
Nepal			YES		80%	60%	80%	67%
Nigeria				YES	80%	80%	100%	50%
Oman				YES	100%	80%	80%	50%
Qatar				YES	100%	80%	80%	50%
Seychelles				YES	80%	80%	40%	67%
Siria	YES				40%	60%	80%	33%
Tajikistan			YES		100%	40%	80%	67%
Timor-Leste				YES	80%	60%	40%	50%
Ukraine		YES			100%	60%	100%	83%
Venezuela		YES		YES	80%	60%	100%	17%

Source: European Commission Joint Research Centre, 2018.

Concluding, the published GAI 2018 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 2018 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 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 2018 ranking and any of the four pillar rankings differ by 10 positions or more for at least 48% (up to 65%) 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	13%	5%	25%	17%
20 to 29 positions	17%	15%	13%	15%
10 to 19 positions	33%	28%	26%	26%
5 to 9 positions	15%	23%	17%	17%
Less than 5 positions	20%	25%	15%	20%
0 positions	2%	4%	3%	4%
Total	100%	100%	100%	100%
More than 10 positions	63%	48%	65%	58%

Source: European Commission Joint Research Centre, 2018.

4 Conclusions

The European House – Ambrosetti developed, in its third edition now, the Global Attractiveness Index (GAI) with a view to measure national attractiveness in 144 countries around the world. The JRC statistical audit has delved around in the workings of the GAI framework to assess the statistical properties of the data, and the methodology used in the index construction. Overall the GAI framework is well-constructed, into which a lot of thought has clearly been put and extensive original research into the multiple determinants of a county's attractiveness has been conducted by the developers. The key findings of the statistical assessment conducted herein are the following:

First, the coherence tests suggest that the **conceptual grouping** of the 21 indicators into four pillars and an overall index is corroborated by statistical analysis, and that the GAI scale is unidimensional and has high statistical reliability (Cronbach alpha 0.89) 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. Nevertheless, four indicators – Employed in high-technology sectors (KPI6), Total productivity of factors (KPI13), Total tax rate (KPI16) and Gross fixed investment (KPI18) – account for a small (almost negligible) amount of variation in the GAI scores. Although these indicators are conceptually enriching the GAI framework and their statistical impact arrives up to the pillar level, it is recommended to carefully monitor how these four indicators behave in the coming releases of the index and eventually to fine-tune the framework in this respect. The new data source used in this GAI edition for capturing the Net number of migrants (KPI5) has contributed to increasing the statistical coherence in this year's GAI.

Second, the GAI dataset has very good **data coverage** and 82% of the data refer to 2016 or 2017. Uncertainty and sensitivity analysis have shown that it is important to find reliable estimates for the missing values in 27 countries because of the impact on the country ranks along specific GAI pillars.

Third, the tests helped to single out 14 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, 70% of the economies are found to shift fewer than three 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.

Fourth, 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 48% up to 65% of the 144 countries.

Fifth, the external validity testing of the GAI confirms the high degree of association (correlation ≈ 0.9) to the latest releases of four international indices: the World Economic Forum's Global Competitiveness Index and Global Human Capital 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 48% up to 61% out of the countries included in the GAI 2018 that feature in the other four indices differ in ranking by more than 10 positions when comparing the GAI 2018 with the recent releases of these international indices. This latter result suggests that the GAI 2018 offers additional insights into nations' human capital and competitiveness that go beyond the findings of other international indices.

All things considered, the present JRC audit findings confirm that the Global Attractiveness Index 2018 meets, at large, international quality standards for statistical soundness. Consequently, the GAI framework offers a sound starting point for more informed discussions on what determines national attractiveness worldwide. Readers and policy analysts of the Global Attractiveness Index should hence go beyond the overall index scores (and ranks) and duly take into account the 21 individual indicators and four pillars on their own merit. The Global Attractiveness Index cannot possibly serve as the ultimate and definitive yardstick for monitoring national attractiveness. Instead, the GAI best represents an ongoing attempt by the European House Ambrosetti to stimulate public interest and help focus policy discussions on the multiple facets of a country's attractiveness, continuously adapting the Global Attractiveness Index framework to reflect the improved availability of statistics and the theoretical advances in the field.

References and related reading

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. 2018. The Global Innovation Index 2018: Energizing the World with Innovation. Ithaca, Fontainebleau, and Geneva.

Giampietro, M., 2014. 'Mono-dimensional accounting and multidimensional measures of sustainable growth'. Report produced by the European Commission-Joint Research Centre, Econometrics and Applied Statistics (DDG.01). EUR 26917 EN.

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

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

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

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

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

Saisana, M., A. Saltelli, and S. Tarantola. 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., M. Ratto, T. Andres, F. Campolongo, J. Cariboni, D. Gatelli, M., Saisana, and S. Tarantola. 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. 2017. The Global Competitiveness Report 2017–2018. Geneva

World Economic Forum. 2017. The Global Human Capital Report 2017 - Preparing people for the future of work. Geneva.

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