Joint Research Centre Statistical Audit of the 2017 Global Attractiveness Index

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The Global Attractiveness Index (GAI) aims to summarise complex and versatile concepts that relate to the 'attractiveness' of a country and its economic system as determining element of its ability to be competitive and to grow. In so doing, it raises some conceptual and practical challenges, which are discussed in the GAI 2017 report. This study focuses on the practical challenges related to data quality and methodological choices by grouping country level data over 144 countries that altogether cover approximately 93% of the world's population and 98% of Gross Domestic Product (in US$) worldwide.

The GAI is built on 53 key performance indicators (KPIs) grouped into 10 pillars, and finally into three indices: (a) a Positioning Index (PI) measuring a country's attractiveness in terms of four main pillars: Openness, Innovation, Efficiency and Resources; (b, c) a Dynamicity Index (DI) and a Sustainability Index (SI) that complement the Positioning Index by measuring, respectively, the short-term change of the attractiveness level (over the last 3 years) and the actual sustainability of a country's position in the overall classification given its performance in terms of resilience and vulnerability.

The Positioning Index in the GAI 2017 has a strong statistical reliability (it has a Cronbach-alpha value of 0.88) and its 21 individual variables are statistically well grouped into the four pillars in order to measure the attractiveness attributes that such pillars try to capture. Country ranks are also robust to methodological changes related to the weighting and aggregation rule at the pillar level (with a shift of less than $\pm$ 3 positions with respect to the simulated median in 70% of the countries).

This audit represents the second analysis performed by the European Commission's Competence Centre on Composite Indicators and Scoreboards at the Joint Research Centre (JRC). The analysis has been performed in order to ensure the transparency and reliability of the GAI model and thus to enable policymakers to derive more accurate and meaningful conclusions, and to potentially guide their choices on priority setting and policy formulation. The JRC assessment of GAI 2017 focuses on two main issues: the statistical coherence of the hierarchical structure of indicators and the impact of key modelling assumptions on the GAI ranking.[1] The JRC analysis complements the reported country rankings for GAI with confidence intervals in order to better appreciate the robustness of these ranks to the computation methodology (in particular weights and aggregation formula at the pillar level).

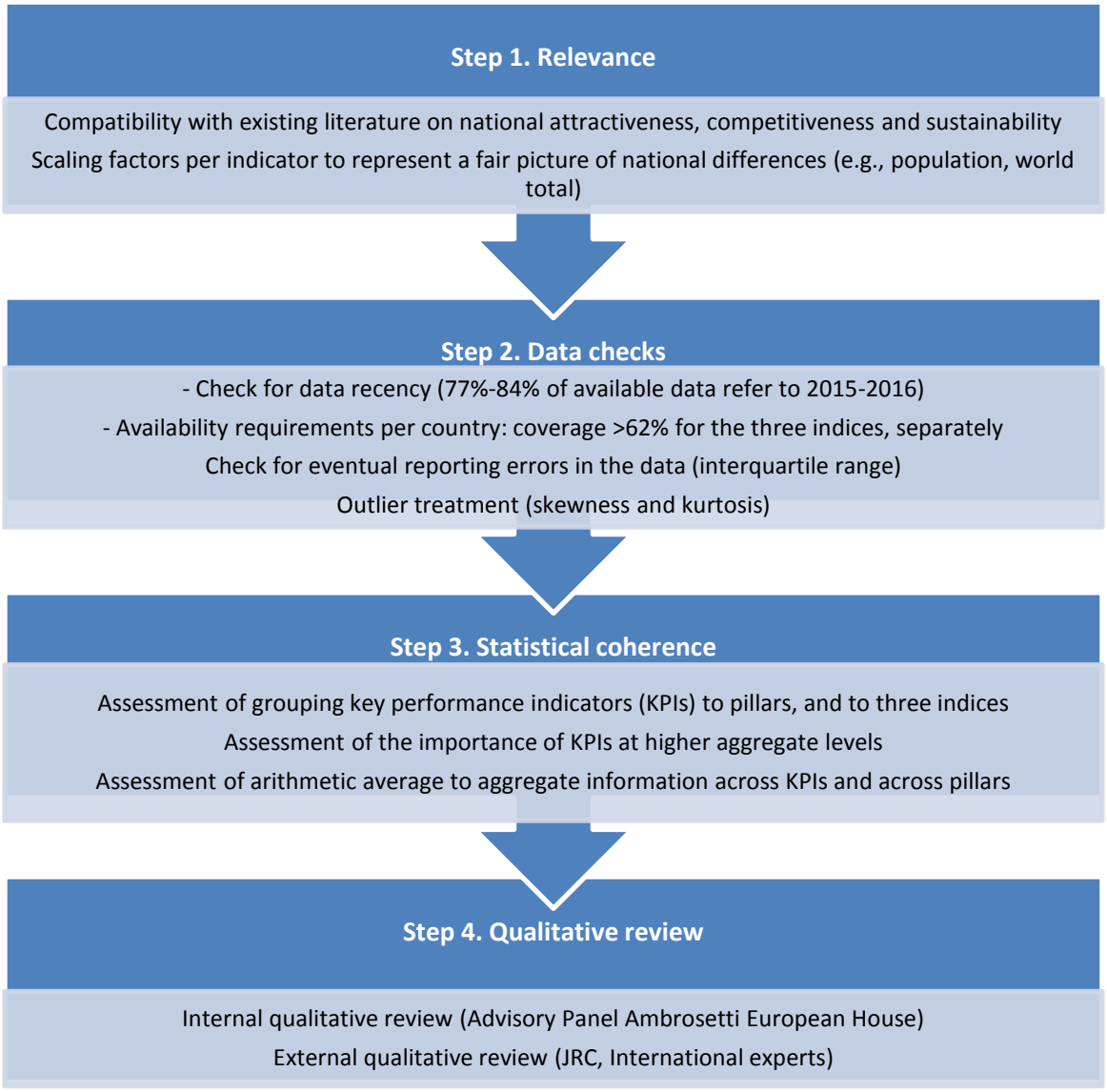
All in all, the 2017 GAI model is to a large extent coherent, balanced, and robust, displaying good to strong associations between most of the underlying variables and the GAI pillars, and between the pillars and the overall Positioning Index. Hence, the GAI offers a sound starting point for more informed discussions on national attractiveness and competitiveness issues. Nevertheless, four main recommendations are made herein in order to help the GAI reach its full potential as a monitoring and benchmarking tool that can guide policy formulation.

1. Conceptual and statistical coherence in the GAI framework

Earlier versions of the GAI model were assessed by the JRC in May-June 2016 and in May-June 2017. Fine-tuning suggestions made by the JRC were taken into account by the Ambrosetti European House 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 (see Figure 1).

Figure 1: Conceptual and statistical coherence in the GAI 2017 Framework



Source: European Commission, Joint Research Centre, 2017.

Step 1: Relevance

Fifty-three indicators were selected for their relevance to a specific attractiveness or sustainability dimension on the basis of the literature review, expert opinion, country coverage, and timeliness. To represent a fair picture of country differences, two types of scaling factors 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., the "market share" based on the world total). Internal factors: for those KPIs that capture aspects of internal attractiveness, raw data values were divided by relevant national factors (e.g., population, GDP, etc.).

Step 2: Data checks

The most recently released data within the period 2012–16 were used for each country (total 144 countries): 77% of available data for the Positioning Index and for Dynamism Index, and 84% of available data for the Sustainability Index refer to 2015 or more recent years. Countries are included if data availability is at least 62% within each of the three indices (i.e., 13 out of 21 KPIs within the Positioning/Dynamism Index and 7 out of the 11 KPIs in the Sustainability Index). Exceptionally, four economies with lower data coverage have been included in the GAI: Libya, Puerto Rico, Syrian Arab, and Hong Kong. In practice, data availability in the GAI2017 is very good: 80% data available for 77% (=111/144) of the countries. That said, for some countries data coverage is not satisfactory at the pillar level. For example, for Syrian Arab Republic only one out of the five KPI values is available under the Openness pillar. The same holds for Seychelles under the Efficiency pillar. This is in general undesirable because the single KPI value available will dictate the pillar score for those countries.

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.[2] These criteria were proposed by the JRC back in 2016 for the specific dataset underpinning the GAI model. These indicators were treated by winsorization (less than eight outliers per indicator) in order to avoid that few very high/low values 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 practical items addressed in this step relate to the statistical coherence of the GAI model, which should be considered to be a necessary (though not necessarily sufficient) condition for a sound index. Given that the present statistical analysis of GAI will mostly, though not exclusively, be based on correlations, the correspondence of GAI to a real-world phenomenon needs to be critically addressed because 'correlations need not necessarily represent the real influence of

the individual indicators on the phenomenon being measured'.[3] The point is that the validity of GAI relies on the combination of both statistical and conceptual soundness. In this respect, GAI has been developed following an iterative process that went back and forth between the theoretical understanding of national attractiveness and competitiveness 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 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 only for the Resilience pillar under the Sustainability attribute (Sustainability Index). Instead, in all four pillars of the Attractiveness attribute (Positioning Index) and in the Vulnerability pillar of the Sustainability attribute there are two statistical dimensions. The presence of more than one statistical dimension in most GAI pillars suggests that the information content of some KPIs is lost in the aggregation at the pillar level.

A positive outcome comes from a more detailed analysis of the correlation structure within and across the four pillars of the Positioning Index (Table 1) and across the two pillars of the Sustainability Index (Table 2), which confirms the expectation that the KPIs are in general more correlated to their own pillar than to any other. Furthermore, correlations within a pillar are positive and sufficiently strong in most cases. These results suggest that the conceptual grouping of KPIs into pillars is statistically confirmed, and that the pillars are in general influenced by most underlying KPIs. Nevertheless, there are five (out of 21) variables that have a very low impact (less than 15%) on the variance of the respective pillar scores: Net number of migrants (Openness pillar), Total productivity of factors, and Total tax rate (Efficiency pillar), Gross fixed investment and PISA Test scores (Resources pillar). Although conceptually enriching the overall GAI framework, these KPIs are found not to co-vary with the respective pillars. This means that high pillar scores on Openness, Innovation or Resources can be associated with either high or low values in those KPIs and the same holds for low pillar scores.

Table 1. Statistical coherence in GAI, Attractiveness: Correlations between KPIs and pillars

DIMENSION	ATTRIBUTE	Key Performance Indicators (KPIs)	Attractiveness			
			Openess	Innovation	Efficiency	Resources
Attractiveness	D1. Openess	(Foreign Direct Investment flows into the country IN + the country's investment abroad OUT), % of world total	0.78	0.63	0.41	0.66
		(Export + Import), % of world total	0.78	0.80	0.56	0.79
		(No. foreign tourists IN + No. national tourists abroad OUT), compared with national population	0.66	0.45		
		Foreign university students, compared with youth population	0.72	0.55	0.46	0.39
		Net number of migrants, compared with population	0.35			
	D2.Innovation	Employed in high-technology sectors, compared with employed		0.54	0.32	
		Exports of high-technology goods, compared with world total	0.64	0.75	0.48	0.65
		ICT Development Index	0.75	0.88	0.52	0.55
		Number of scientific publications, compared with world total	0.63	0.74	0.47	0.80
		Internet users, % of population	0.72	0.86	0.50	0.51
	D3.Efficiency	Unemployment level (-1)			0.59	
		Logistics Performance Index	0.78	0.81	0.75	0.63
		Total productivity of factors			0.38	
		Rule of Law Index	0.71	0.73	0.78	0.50
		Total tax rate (% commercial profits)			0.33	
	D4. Resources	Gross Domestic Product (GDP), compared with world total	0.60	0.70	0.47	0.81
		Gross National Product, (GNP), per capita	0.74	0.70	0.47	0.50
		Gross Fixed Investment, compared with GDP				0.27
		Natural Resource Index				0.64
		College graduates, compared with world total	0.32	0.42	0.32	0.74
		PISA Test Score	0.50	0.59	0.54	0.43

Source: European Commission Joint Research Centre, 2017.

Notes: Numbers represent Pearson correlation coefficients (over 144 countries and across five years 2012-2016). 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. Correlation coefficients lower than 0.23 are not presented as they are not statistically significant (p-values >0.01). KPIs for which lower values are desirable are marked with (-1).

Table 2. Statistical coherence in the GAI, Sustainability: Correlations between KPIs and pillars

DIMENSION	ATTRIBUTE	Key Performance Indicators (KPIs)		Sustainability	
				Resilience	Vulnerability (lack of)
Sustainability	D9. Resilience	Human Development Index		0.93	-0.43
		Global Peace Index		0.65	
		World Giving Index		0.51	
		Life expectancy at birth		0.88	-0.35
		Avg. years of school attendance		0.90	-0.41
	D10. Vulnerability	Debt/GDP	(-1)	-0.39	0.59
		Inflation rate		-0.35	0.60
		Market concentration index		-0.57	0.59
		Number of suicides, % total national population	(-1)		0.57
		People at risk of poverty	(-1)	0.79	0.55
		People affected by natural disasters (last 3 years), per 1,000 people	(-1)		0.49

Source: European Commission Joint Research Centre, 2017.

Notes: Numbers represent Pearson correlation coefficients (over 144 countries and across five years 2012-2016). 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. Correlation coefficients lower than 0.23 are not presented as they are not statistically significant (p-values >0.01). KPIs for which lower values are desirable are marked with (-1).

To gain further insights as to whether these five KPIs are influential for some of the countries in the GAI, we tested how the pillar rankings change when these KPIs are eliminated one-at-a-time. Twenty-five countries would shift 35 positions or more in some pillars if any of the five KPIs in question are excluded from the GAI framework (Table 3). For example Argentina would lose 52 positions in the Efficiency pillar ranking (from 24th down to 76th) if the Total tax rate is excluded from the GAI framework. On the other hand, Azerbaijan would gain 37 positions (from 105th up to the 68th) if the Total productivity of factors is excluded.

The recommendation to the GAI development team is to carefully reconsider the inclusion of these five KPIs – Net number of migrants, Total productivity of factors, Total tax rate, Gross fixed investment, and PISA Test scores– and eventually replace them with other variables in next year's release, in light also of the impact that these KPIs have on some countries ranks at higher aggregate levels (pillar and/or index). The Dynamism Index, which measures short-term changes

(over the last 3 years) of the 21 KPIs under the Positioning Index will have to be revised accordingly.

Table 3. Countries that are most affected when excluding one-at-a-time five KPIs that were found not to pass the statistical coherence tests

	Openness pillar without:	Efficiency pillar without:		Resources pillar without:	
	Net number of migrants	Total Productivity of Factors	Total tax rate	Gross Fixed Investment	PISA Test scores
Argentina	-2	7	-52	9	10
Azerbaijan	6	37	-2	-9	6
Bangladesh	-1	-41	4	-7	7
Bolivia	-8	2	-53	0	11
Cabo Verde	20	20	55	-48	5
Chad	-21	13	-34	-41	1
Colombia	9	1	-40	-3	5
Cyprus	0	-18	29	38	0
Estonia	3	0	-9	3	-36
Greece	2	-7	-19	9	-52
Guinea	0	9	-38	19	0
Haiti	-2	5	-2	-59	6
Kuwait	-37	10	35	8	11
Kyrgyz Republic	9	-11	2	-36	5
Lao PDR	18	12	36	-7	8
Latvia	9	-12	6	3	-38
Mauritania	-13	18	-25	-62	7
Mauritius	5	7	36	23	0
Oman	-36	-4	17	-7	11
Portugal	4	0	-5	6	-41
Puerto Rico	-3	11	-17	44	0
Slovenia	3	-3	3	4	-41
Tajikistan	4	-37	-24	17	0
Timor-Leste	8	12	111	-56	8
Yemen, Rep.	-37	8	0	8	0

Source: European Commission Joint Research Centre, 2017.

Notes: Numbers represent shifts in rank in the relevant GAI pillar when a KPI is excluded from the framework. Positive shifts imply improvement in a country's rank position; negative shifts imply deterioration in a country's rank position. Shifts greater than 30 positions are highlighted.

In the Positioning Index, the four pillars share a single statistical dimension that summarises 74% of the total variance, and the four loadings (correlation coefficients) are similar to each other, ranging from 0.65 to 0.85. The latter suggests that the four pillars contribute in a similar way to the variation of the country scores in the Positioning Index, as envisaged by the development team: all four pillars are assigned equal weights. The reliability of the Positioning Index as an aggregate of the four pillars, measured by the Cronbach-alpha value, is very good at 0.88—well above the 0.7 threshold for a reliable aggregate.[4]

In the Dynamism Index, the four pillars do not share a single but two statistical dimensions. In fact, the arithmetic average of the four pillars summarises merely 33% of the total variance, and the four correlation coefficients of the pillars with the Dynamism Index, albeit similar to each other, they are below the desired 0.7 threshold (coefficients range from 0.49 to 0.62). These findings suggest that calculating the Dynamism Index based on three year differences across the 21 KPIs included in the Positioning index may not be the most suitable approach. Instead, the recommendation is to calculate the Dynamism Index based on three year differences in countries rank in the Positioning Index. Countries with the highest shifts in rank between the Positioning Index 2017 and 2014 would be considered in the 'critical zone'.

In the Sustainability Index, the two pillars – Resilience and Vulnerability– have a negative association, albeit very low (-.36). This is in line with the arguments made in the 2016 GAI methodology report, which highlights that these two attributes of sustainability are antithetical, but work together conceptually. This statistical result suggests that the two pillars should not be aggregated further into one index but presented instead as two separate attributes of a country's sustainability.

Overall, the tests so far show that the grouping of KPIs into pillars, and into three indices are to some extent statistically coherent. Results for the Positioning Index are more reassuring: the index has a balanced structure, whereby all four pillars are roughly equally important in determining the variation in the Positioning Index scores.

Three main recommendations for next year's release, which would help to render the GAI framework even sounder from both a conceptual and statistical point of view, are the following. First, careful consideration is needed on the inclusion of five variables, all of them under the Positioning Index, that do not co-vary with the respective pillar scores: Net number of migrants

(Openness pillar), Total productivity of factors, and Total tax rate (Efficiency pillar), Gross fixed investment and PISA Test scores (Resources pillar). Yet, excluding these KPIs will notably affect the ranks of twenty-five countries (shifting more than 35 positions) and therefore any decision taken has to be seen in light of this impact. Second, in the Dynamism Index, the four pillars do not share a single statistical dimension and thereafter no single aggregate of them is statistically justifiable. The Dynamism Index could instead be calculated based on three year differences in countries rank in the Positioning Index and presented qualitatively ('high', 'medium', 'low', and 'critical' zones; countries with the highest shifts in rank between the Positioning Index 2017 and 2014 would be in the 'critical zone'). Third, the Resilience and Vulnerability pillar under the Sustainability Index are negatively associated to each other, which suggests that the two pillars should not be aggregated further into one index but presented instead as two separate (and antithetic) attributes of a country's sustainability.

Step 4: Qualitative Review

Finally, the GAI results were evaluated to verify that they are, to a great extent, consistent with current evidence, existing research, and prevailing theory. Notwithstanding these statistical tests and the positive outcomes on the statistical coherence together with the three main recommendations for revision made above, the GAI model, since its first release in 2016, 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, competitiveness and sustainability become available.

2. Impact of modelling assumptions on the Positioning Index

The Global Attractiveness Index ranking is presented only for the Positioning Index. The Dynamism and the Sustainability Indices are communicated qualitatively (high', 'medium', 'low', and 'critical' zones). Thereafter, this section focuses on the impact of modelling assumptions on the 144 country ranks in the Positioning Index. Modelling choices in the GAI relate to: (i) setting up an underlying hierarchical structure from twenty one KPIs grouped in four pillars, and finally aggregated in one index; (ii) choosing the individual variables to be used as KPIs; (c) deciding whether or not to impute missing data; (iii) deciding whether and how to treat outliers; (iv) selecting the normalization approach to be applied to the KPIs; (v) choosing the weights to be

assigned to the KPIs and the four pillars; (vi) deciding on the aggregation rule to be implemented.

The rationale for these choices is manifold. For instance, literature review and expert opinion on national attractiveness, competitiveness and sustainability, coupled with statistical analysis, is behind the selection of the individual indicators; common practice and easy of interpretation suggests the use of a min-max normalization approach in the [0–100] range; statistical analysis guides the choice on the treatment of outliers; and simplicity seems to advocate for not estimating missing data. The unavoidable uncertainty stemming from these modelling choices is accounted for in the robustness assessment discussed in this section.

As suggested in the relevant literature on composite indicators,[5] the robustness assessment of the Positioning Index ranking for the 144 countries included in the GAI was based on a combination of Monte Carlo simulation and multi-modelling approach, starting from 'error-free' data for the 21 KPIs where potential outliers and eventual errors and typos had been corrected in a preliminary stage. In particular, two key modelling issues have been considered in depth: the four pillar weights, and the aggregation formula from the pillars to an overall index. Later on, the impact of estimating missing data will be briefly touched upon. In general, this type of uncertainty analysis, to some extent, aims to respond to possible criticisms that rankings associated with aggregate measures are generally not calculated under conditions of certainty, even though they are frequently presented as such.

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, Resources. Given these considerations, limit values of uncertainty intervals for the pillar weights are 15% to 35% for the four pillars (see Table 4). In all simulations, sampled weights are then rescaled so that they always sum to 1.

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.[6] 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 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. [7]

Two models were tested based on the combination of arithmetic versus geometric average, combined with 1,000 simulations per model (random weights versus fixed weights), for a total of 2,000 simulations for the Positioning Index (see Table 4 for a summary of the uncertainties considered).

Table 4. Uncertainty parameters in the Positioning Index: Pillar weights, aggregation across pillars

	Reference	Alternative
I. **Uncertainty in the aggregation formula at pillar level**	Arithmetic average	Geometric average
II. **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]
Resources	0.25	U[0.15,0.35]

Source: European Commission, Joint Research Centre, 2017.

Uncertainty analysis results

The main results of the robustness analysis are shown in Figure 2 with median ranks and the 90% confidence intervals computed across the 2,000 Monte Carlo simulations for the Positioning 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.

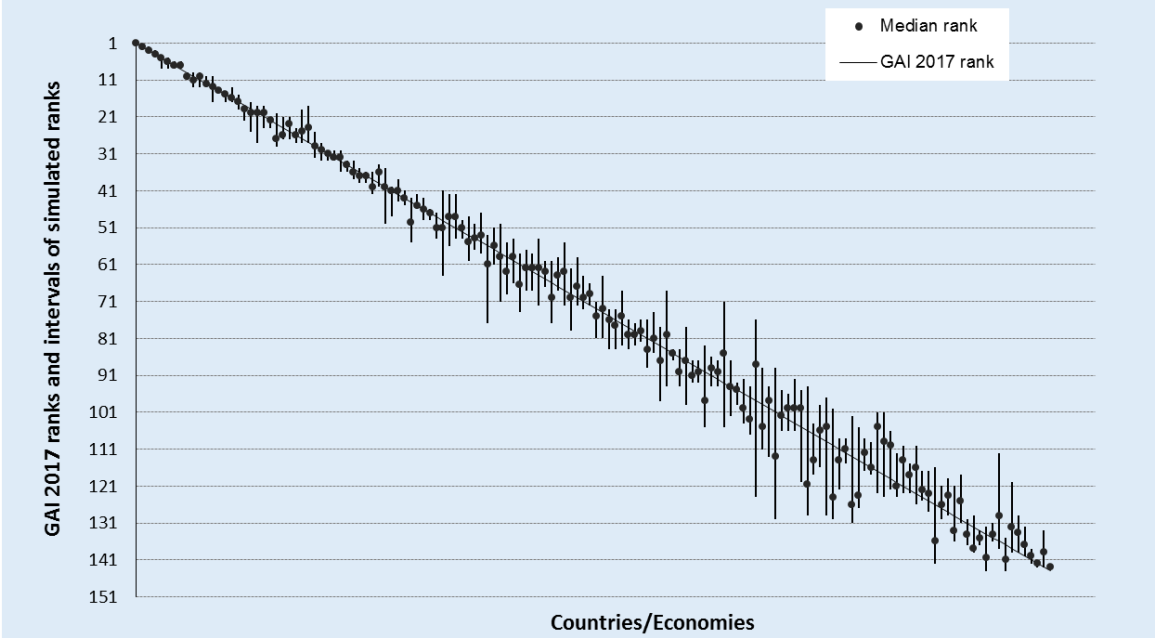
All published GAI 2017 ranks lay within the simulated 90% confidence intervals, and for the vast majority of the countries these ranks can be considered as representative of the plurality of

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 75 of the 144 economies. Nevertheless, several country ranks vary significantly with changes in the four pillar weights and the aggregation formula across the four pillars: confidence interval widths are 15 or greater for the following 11 countries: Bahrain, Suriname, Cyprus, Indonesia, Algeria, Bhutan, Montenegro, Guyana, Mauritius, Bosnia and Herzegovina, Lao PDR.

For full transparency and information, Table 5 reports the GAI 2017 country ranks together with the simulated 90% confidence intervals in order to better appreciate the robustness of the results to the choice of the four pillar weights and of the aggregation formula.

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



Source: European Commission Joint Research Centre, 2017.

Notes: Median ranks and intervals are calculated over 2,000 simulated scenarios combining simulated weights for the four pillars (Openness, Innovation, Efficiency, Resources) and geometric versus arithmetic average across the four pillars. The Spearman rank correlation between the median rank and the GAI 2017 rank is 0.995.

Table 5. GAI 2017: Positioning Index ranks and simulated 90% intervals

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

Source: European Commission Joint Research Centre, 2017.

Notes: Rank intervals (90%) are calculated over 2,000 simulated scenarios combining simulated weights for the four pillars (Openness, Innovation, Efficiency, Resources) and geometric versus arithmetic average across the four pillars.

Sensitivity analysis results

Complementary to the uncertainty analysis, sensitivity analysis has been used to identify which of the modelling assumptions have the highest impact on certain country ranks. Table 6 summarizes the impact of changing the aggregation formula at the pillar level from arithmetic to geometric average and/or changing the equal pillar weights (25%; original GAI) to varying weights (15-35%). Small perturbations around the equal weights would have a negligible impact on the country ranks: no shift at all for 90% of the countries. Instead, when geometric averaging is used to aggregate the four pillars into one index, 22 countries (listed in Table 6) would change rank by 10 positions or more. These countries occupy positions between the 56th and 138th in the overall GAI ranking. For example when geometric averaging is used, Puerto Rico would lose 14 positions (from 56th down to 70th) due to its uneven performance across the four pillars (51st on Openness, 40th on Innovation, 57th on Efficiency, 131st on Resources). Two countries – Tanzania and Benin – would lose more than 20 positions when the geometric average is used. Instead, two countries – Botswana and Namibia – would gain 15 and 18 positions, respectively.

All in all, the published GAI 2017 ranks are reliable and for the vast majority of countries the simulated 90% confidence intervals are narrow enough for meaningful inferences to be drawn. Nevertheless, the readers of the GAI 2017 report should consider country ranks in the GAI 2017 not only at face value but also within the 90% confidence intervals in order to better appreciate to what degree a country's rank depends on the two modelling choices accounted for (weights and aggregation formula at the pillar level).

A final remark relates to the threshold adopted for a country's inclusion in the GAI. The GAI development team, for transparency and replicability, opted not to estimate missing data (14% missing values in the data set of 144 countries × 21 variables in the Positioning Index). The 'no imputation' choice, which is often adopted by index developers, might encourage economies not to report low data values. In fact, with arithmetic averages, the 'no imputation' choice is equivalent to replacing an indicator's missing value for a given country with the respective pillar score. For example, Syrian Arab Republic has only one out of the five KPI values available under the Openness pillar, namely the net number of migrants (which is the lowest in the dataset and hence achieves a zero score). Hence, for Syrian Arab Republic the Openness score is equal to zero. To test the impact of this assumption, the JRC estimated missing data using two different statistical methods: the Expectation Maximization (EM) algorithm[8] and the Nearest Neighbor

imputation algorithm.[9] Although results are not shown here, the impact of estimating missing data would have had a more pronounced impact on the country ranks compared to the two assumptions tested herein, namely the pillar weights and the aggregation formula.

The recommendation for a country's inclusion in next year's GAI release is to apply the 62% indicator coverage threshold at the pillar level. Practically, this means 3 indicators available in pillars with 5 KPIs and 4 indicators available in pillars with 6 KPIs. This more stringent criterion will lead to a net increase in the reliability of the GAI country ranks when accounting for all three assumptions–estimation of missing data, pillar weights, aggregation formula at the pillar level.

Table 6. Sensitivity analysis: Impact of modelling choices on countries with most sensitive ranks

	GAI rank	Shifts in rank under different assumptions		
	Arithmetic average across the four pillars & Equal pillar weights	Arithmetic average across the four pillars & Varying pillar weights (median of 1,000 simulations)	Geometric average across the four pillars & Equal pillar weights	Geometric average across the four pillars & Varying pillar weights (median of simulations)
Puerto Rico	56	-1	-14	-13
Lebanon	68	1	9	10
Moldova	83	0	-10	-11
Venezuela, RB	84	0	10	9
Sri Lanka	90	1	-12	-13
Gabon	93	0	11	11
Seychelles	98	-1	14	14
Bangladesh	99	1	-10	-10
Tanzania	101	1	-25	-26
Benin	106	1	-22	-23
Tajikistan	110	1	-18	-18
Mali	113	1	-17	-17
Rwanda	114	0	-12	-12
Botswana	117	0	15	15
Zambia	118	3	10	11
Mongolia	119	2	11	11
Timor-Leste	123	0	10	10
Chad	126	0	-15	-15
Honduras	130	1	10	11
Syrian Arab Republic	134	-1	-10	-10
Namibia	136	0	18	18
Swaziland	138	0	12	13
Average shift in rank (across 144 countries)		***0***	***5***	***5***
Shift in rank for the 10% most affected countries (across 144 countries)		***1***	***10***	***11***

Source: European Commission Joint Research Centre, 2017.

Notes: Numbers in the three columns on the right hand side represent shifts in rank in the Positioning Index under different modelling assumptions related to the pillar weights and the aggregation formula across the four pillars. Positive shifts imply improvement in a country's rank position; negative shifts imply deterioration in a country's rank position.

Conclusion

The JRC analysis suggests that the conceptualised multi-level structure of GAI 2017 is to a large extent statistically coherent and balanced (i.e., not dominated by any pillar or KPI and most KPIs contribute to the variation of the respective pillar scores in the Positioning Index). Furthermore, the analysis has offered statistical justification for the use of equal weights across the four pillars, showing that the GAI model is statistically reliable in its current form as the simple average of the four pillars on Openness, Innovation, Efficiency and Resources. The Positioning Index also has a good statistical reliability, Cronbach-alpha value of 0.88, well above the recommended 0.7 threshold for a reliable aggregate.

Points that call for possible refinements of the GAI framework were also identified. First, careful consideration is needed on the inclusion of five variables in the Positioning Index, which do not co-vary with the respective pillar scores: Net number of migrants (Openness pillar), Total productivity of factors, and Total tax rate (Efficiency pillar), Gross fixed investment and PISA Test scores (Resources pillar). Yet, excluding these KPIs will notably affect the ranks of twenty-five countries (shifting more than 35 positions) and therefore any decision has to be taken in light of this impact. Second, in the Dynamism Index, the four pillars do not share a single statistical dimension and thereafter no single aggregate of the four pillars is statistically justifiable. The Dynamism Index could instead be calculated based on three year differences in countries rank in the Positioning Index 2017-2014 and presented qualitatively ('high', 'medium', 'low', and 'critical' zones). Third, the Resilience and Vulnerability pillar under the Sustainability Index are negatively associated to each other, which suggests that the two pillars should not be aggregated further into one index but presented instead as two separate (and antithetic) attributes of a country's sustainability. Finally, a more stringent criterion for a country's inclusion in next year's GAI release has to be adopted. Currently, the 62% indicator data coverage at the index level has been applied, separately for each of the three indices. The recommendation is to apply the 62% indicator data coverage threshold at the pillar level. Practically, this would require that a country has at least 3 indicators available in pillars with 5 KPIs and 4 indicators available in pillars with 6 KPIs. This more stringent criterion will lead to a net increase in the reliability of the GAI country ranks when accounting for all three assumptions–estimation of missing data, pillar weights, aggregation formula at the pillar level.

The GAI ranking is relatively robust to methodological assumptions related to the weighting, and aggregation formula at the pillar level. It is reassuring that for over 70% of the countries included in the GAI report, the overall rank is the result of the underlying data and not of the modelling choices. Consequently, inferences can be drawn for most countries in the report, although some caution may be needed for a few countries that have been flagged herein. Note that perfect robustness would have been undesirable because this would have implied that the GAI components are perfectly correlated and hence redundant, which is not the case for GAI 2017. Readers of the GAI report should hence go beyond the overall ranking and duly take into account the individual KPIs and pillars on their own merit. By doing so, country-specific strengths and challenges in national attractiveness and competitiveness can be identified and serve as an input for data-informed policy analysis.

The GAI should not be seen as the ultimate and definitive ranking of countries with respect to national attractiveness. Instead, the GAI best represents an ongoing attempt by the Ambrosetti European House to propose key performance indicators that better capture the richness of national attractiveness, continuously adapting the GAI framework to reflect the improved availability of statistics and the theoretical advances in the field. The auditing conducted herein discussed the good statistical properties of the Global Attractiveness Index 2017, and highlighted the revisions needed in future releases, in order for the GAI to reach its full potential in reliably identifying challenges and best national practices and ultimately monitoring and benchmarking countries performance on attractiveness and competitiveness issues.

References and related reading

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Endnotes

[1] The JRC analysis was based on the recommendations of the OECD & EC JRC (2008) *Handbook on Constructing Composite Indicators* and on more recent research from the JRC. The JRC auditing studies of composite indicators, all audits conducted upon request of the index developers, are available at http://composite-indicators.jrc.ec.europa.eu/ .

[2] Groeneveld and Meeden (1984) set the criteria for absolute skewness above 1 and kurtosis above 3.5. The skewness criterion was relaxed to account for the small sample (144 economies).

[3] OECD & EC JRC (2008).

[4] See Nunnally (1978).

[5] Saisana et al., 2005; Saisana et al., 2011 ; Becker et al., 2017.

[6] Munda, 2008.

[7] 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 0.00001 was added to the pillar scores to avoid zero values that would have led to zero geometric averages.

[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: (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. (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.

[9] Nearest neighbor (NN) imputation algorithms are efficient methods to fill in missing data where each missing value on some records is replaced by a value obtained from related cases in the whole set of records (Andridge and Little, 2010).