CHAPTER 6

JRC STATISTICAL AUDIT ON THE GLOBAL TALENT COMPETITIVENESS INDEX 2015–16

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The Global Talent Competitiveness Index (GTCI) attempts to summarise complex and interrelated concepts relevant to human capital and talent competitiveness at the national scale in 109 countries worldwide. In so doing, it raises some conceptual and practical challenges, which are discussed in the *GTCI 2015–16* report. Herein, the focus is on the practical challenges related to the data quality and the methodological choices on the grouping of 61 variables into 14 sub-pillars, six pillars, two sub-indices and an overall index. GTCI 2015–16 has a very high statistical reliability (Cronbach's alpha value at 0.94). Methodological changes related to the treatment of missing values, weighting and aggregation rule have a negligible impact on country ranks (less than ± 2 positions shift with respect to the simulated median in 90% of the countries). The added value of GTCI lies in its ability to summarise different aspects of talent competitiveness in a more efficient and parsimonious manner than is possible with the indicators and pillars taken separately.

Last year, the audit of the GTCI model conducted by the European Commission Joint Research Centre (JRC) concluded that the model was robust and reliable, with a statistically coherent and balanced multi-level structure. Indications were provided of areas in which the quality and relevance of the model could be enhanced. The Econometrics and Applied Statistics Unit at JRC in Ispra, Italy, has been invited for a third time by the GTCI development team to undertake an analysis of the statistical properties of the GTCI model, in order to ensure the transparency and reliability of the report and thus to enable policymakers to derive more accurate and meaningful conclusions, and potentially to guide choices on priority setting and policy formulation.

As in the previous audits, the present JRC assessment of GTCI 2015–16 focuses on two main issues: the statistical coherence of the structure, and the impact of key modelling assumptions on the GTCI scores and ranks.[1] The JRC analysis complements the reported country rankings for GTCI, and for the Input and Output sub-indices with confidence intervals, in order to better appreciate the robustness of these ranks to the computation methodology (in particular missing data estimation, weights and aggregation formula). Furthermore, the JRC analysis includes an assessment of the added value of the GTCI, and a comparison to other global measures of competitiveness and innovation. Its main conclusions can be summarised as follows: the version of the GTCI model presented in 2015 is coherent, balanced and robust, displaying strong associations between the underlying indicators and the GTCI sub-indices, pillars and sub-pillars, and hence offering a sound basis for policy interpretations. Further improvements can still be envisaged in order to enhance the model's ability to identify critical talent-related issues in a variety of economic contexts.

The practical items addressed in this chapter relate to the statistical soundness of the GTCI, which should be considered to be a necessary, though not necessarily sufficient, condition for a sound index. Given that the present statistical analysis of GTCI will mostly, though not exclusively, be based on correlations, the correspondence of the index with a real-world phenomenon needs to be critically addressed as "correlations need not necessarily represent the real influence of the individual indicators on the phenomenon being measured".[2] The point is that the validity of GTCI relies on the interplay between both statistical and conceptual soundness. In this respect, GTCI has been developed following an iterative process that went back and forth between the theoretical understanding of human capital and talent competitiveness on the one hand, and empirical observations on the other.

STATISTICAL COHERENCE IN THE GTCI FRAMEWORK

Earlier versions of the GTCI model were assessed by JRC in July 2015. Preliminary suggestions by JRC focused on dealing with variables with strong colinearity, reconsidering variables that behaved as noise in the overall framework and repositioning indicators on different (sub-) pillars. The JRC recommendations were taken into account in the final computation of the rankings by the GTCI development team through an iterative process, which aimed at setting the foundation for a balanced index.

The underlying concepts and framework used to describe global talent competitiveness in GTCI 2015–16 have remained essentially the same when compared to GTCI 2014. With regards to the changes experienced, they are related to the specific variables used to capture each underlying concept. Some of these modifications have been the result of the discussions held between JRC and the GTCI development team preceding the construction of the final version of GTCI 2015–16. Overall – and in spite of the addition of a new indicator (Tertiary education expenditure) – the number of variables used in the current model decreased from 65 variables in GTCI 2014 to 61 in GTCI 2015–16. With the aim of enhancing the statistical coherence of the index, those variables showing measurement problems, pointing in the opposite direction of the phenomenon being measured and adding noise to the framework, were excluded from this edition's model (e.g., FDI inflow and Pay level of executives, both present in GTCI 2014). Furthermore, some highly correlated variables were combined to prevent double counting of information (e.g., using overall Migrant stock instead of two separate variables measuring male and female adult migrants). Finally, some variables were moved from one pillar to another to improve the statistical coherence of the framework (e.g., International students was moved from Formal education to External openness). Note that the reasons for keeping, excluding or repositioning variables are both conceptual and empirical, as well as being related to data quality issues. As such, the GTCI 2015–16 development team chose to retain some variables for conceptual reasons despite their high correlation (e.g., Brain gain and Brain drain were both kept in the External openness sub-pillar) or very low impact on the variation of the GTCI scores (see Table 2 and relevant discussion below). Also, of the variables that could fit statistically better in another pillar, many of them have been kept in their current position, based on analytical and practical considerations.

Following on the iterative process during which the index has been fine-tuned, the current assessment of the statistical coherence in this final version of GTCI 2015–16 followed four steps:

Step 1: Relevance

Candidate indicators were selected for their relevance to a specific pillar, on the basis of the literature review, expert opinion, country coverage and timeliness. To represent a fair picture of country differences, indicators were scaled either at the source or by the GTCI development team as appropriate and where needed.

Step 2: Data checks

The most recently released data for each of the 61 variables were used for each country. The cut-off year for considering older data as valid was changed from 2002 to 2005, thus affecting country coverage figures. Countries were included in the GTCI final sample if two conditions were met: (i) data were available for at least 80% of the indicators at the index level (i.e., of all the 61 indicators); and (ii) data were available for at least 40% of indicators contained in each of the six sub-pillars. As a result, the GTCI 2015–16 data set comprises 109 countries. Also, data availability for any of the countries included in GTCI 2015–16 was found

to be at least 80% at the Input sub-index level and 59% at the Output sub-index level. Potentially problematic indicators with outliers that could bias the overall results were identified by the GTCI development team as those having absolute skewness greater than two and kurtosis greater than 3.5,[3] and were treated either by Winsorisation or by taking the natural logarithm (in case of more than five outliers). For variables with five outliers and above, log transformation is used (for more details, please refer to the Technical Notes section in the Appendices). These criteria follow the WIPO–INSEAD Global Innovation Index practice (formulated with JRC in 2011).

Step 3: Statistical coherence

i) Principal components analysis and reliability analysis

Principal component analysis (PCA) was used to assess the extent to which the conceptual framework is confirmed by statistical approaches. PCA confirms the presence of a single statistical dimension (i.e., a single principal component with eigenvalue greater than 1.0) in half of the sub-pillars, which captures 61% (Lifestyle) to 69% (Employable skills) of the total variance in the underlying indicators.[4] Nevertheless, a more detailed analysis of the correlation structure within and across the six pillars confirms the expectation that the sub-pillars are more correlated to their own pillar than to any other, and all correlations within a pillar are positive, strong and similar (see Table 1). These results suggest that the conceptual grouping of sub-pillars into pillars is statistically confirmed and that the six pillars are statistically well-balanced in the underlying sub-pillars.

The six pillars also share a single statistical dimension that summarises 77% of the total variance, and the six loadings (correlation coefficients) are very similar to each other. The latter suggests that the six pillars contribute in a similar way to the variation of the GTCI scores, as envisaged

Table 1: Statistical coherence in GTCI: correlations between sub-pillars and pillars

		Enable	Attract	Grow	Retain	LV	GK
INPUT	1.1 Regulatory landscape	0.93	0.81	0.81	0.77	0.70	0.78
	1.2 Market landscape	0.91	0.71	0.85	0.80	0.70	0.87
	1.3 Business–labour landscape	0.81	0.58	0.53	0.51	0.40	0.46
	2.1 External openness	0.73	0.85	0.62	0.57	0.35	0.57
	2.2 Internal openness	0.59	0.82	0.64	0.41	0.37	0.50
	3.1 Formal education	0.66	0.47	0.86	0.72	0.70	0.81
	3.2 Lifelong learning	0.73	0.74	0.86	0.54	0.43	0.59
	3.3 Access to growth opportunities	0.77	0.79	0.87	0.64	0.43	0.71
	4.1 Sustainability	0.78	0.59	0.72	0.94	0.72	0.78
	4.2 Lifestyle	0.72	0.53	0.69	0.95	0.75	0.76
OUTPUT	5.1 Employable skills	0.55	0.35	0.53	0.70	0.94	0.63
	5.2 Labour productivity	0.67	0.42	0.56	0.61	0.72	0.57
	6.1 Higher skills and competencies	0.78	0.61	0.81	0.82	0.70	0.94
	6.2 Talent impact	0.70	0.59	0.73	0.68	0.60	0.92

Source: Saisana and Domínguez-Torreiro, European Commission Joint Research Centre, 2015

by the GTCI development team, given that all six pillars are assigned equal weights. The reliability of the GTCI, measured by the Cronbach's alpha value, is very high at 0.94, which is well above the 0.7 threshold for a reliable aggregate.[5]

An important part of the analysis relates to clarifying the importance of the Input and Output sub-indices with respect to the variation of the GTCI scores. As mentioned above, the index is built as the simple arithmetic average of the four Input sub-pillars and the two Output sub-pillars, which implies that the Input sub-index has a weight of 4/6 versus a weight of 2/6 for the Output sub-index. Yet, this does not imply that the Input aspect is more important than the Output aspect in determining the variation of the GTCI scores. In fact, the correlation coefficient between the GTCI scores and the Input or Output sub-index is 0.98 and 0.94 respectively, which suggests that the sub-indices are effectively placed on equal footing. Overall, the tests so far show that the grouping of indicators into sub-pillars, pillars and an overall index is statistically coherent, and that GTCI has a balanced structure, whereby all six pillars are equally important in determining the variation in the GTCI scores. For some of the sub-pillars, recommendations have been made to modify the underlying indicators in future versions of the index, so as to render it even sounder from both a conceptual and statistical point of view.

ii) Importance of the variables in the GTCI framework

GTCI and its components are simple arithmetic averages of the underlying variables. Developers and users of composite indicators often consider that the weights assigned to the variables coincide with the variables' conceptual importance in the index. However, in practice, the correlation structure of the variables and the different variances do not always allow for the weights assigned to the variables to be considered as equivalent to the importance of the variables.

In this section we assess the importance of all 61 variables at the various levels of aggregation in the GTCI structure. As a statistical measure of the importance of variables in an index we use the squared Pearson correlation coefficient.[6] The importance of the selected variables is taken to be equivalent to the contribution of the variables to the variation of the aggregate scores, be those sub-pillars, pillars, sub-indices or the overall GTCI. The overarching consideration made by the GTCI development team was that all variables should be important at all levels of aggregation. The results of our analysis appear in Table 2. Examining the importance measures of the 61 variables, we see that almost all variables are important at the various levels of aggregation. For example, country variations in 1.1.1 Government effectiveness scores captures 87% of the variance in the respective sub-pillar scores (Regulatory landscape), 84% of the variance in the respective pillar scores (Enable) and 87% both in the Input sub-index and overall GTCI scores. Similarly, country variations in 2.1.1 FDI and technology transfer scores captures 43%, 28%, 26% and 22% of the variance in the scores of External openness, Attract, Input and GTCI overall index, respectively. In the 2015 data set, there seem to be only six variables that have a very low impact (less than 10%) on the GTCI variance. These are: 1.3.1 Ease of hiring, 2.2.5 Gender earnings gap, 3.1.3 Tertiary education expenditure, 3.2.2 Prevalence of training in firms, 4.1.2 Taxation and 5.2.3 Mid-value exports. Although conceptually enriching the overall GTCI framework, these variables are not found to be important at the overall index level. It is suggested that the GTCI development team reconsiders the inclusion of these variables (or their replacement by other variables) in next year's release.

iii) Added value of the GTCI

A very high statistical reliability among the main components of an index can be the result of redundancy of information. This is not the case in GTCI. In fact, for more than 39% (up to 59%) of the 109 countries included in GTCI 2015–16, the overall GTCI ranking differs by 10 positions or more from any of the six pillar rankings (see Table 3). For example, in the most extreme case, Senegal ranks 99th in the overall GTCI, but climbs up to the 32nd position when only the 'Attract' pillar is taken into account. This is a desired outcome, because it evidences the added value of the GTCI ranking, which helps to highlight other components of human capital and talent competitiveness that do not emerge directly by looking into the six pillars separately. At the same time, this result also points at the value of duly taking into account the individual pillars, sub-pillars and variables on their own merit. By doing so, country-specific strengths and bottlenecks in human capital and talent competitiveness can be identified and serve as an input for evidence-based policymaking.

Table 2: Importance measures for the variables at the various levels of the GTCI structure

			Sub-pillar	Pillar	Input/ Output	GTCI Index
1. ENABLE	1.1 Regulatory landscape	1.1.1 Government effectiveness	87%	84%	87%	87%
		1.1.2 Business–government relations	38%	41%	31%	22%
		1.1.3 Political stability	76%	60%	62%	59%
		1.1.4 Starting a foreign business	49%	27%	27%	36%
	1.2 Market landscape	1.2.1 Competition intensity	48%	42%	34%	33%
		1.2.2 Ease of doing business	71%	72%	67%	70%
		1.2.3 Cluster development	53%	44%	40%	36%
		1.2.4 R&D expenditure	73%	51%	48%	53%
		1.2.5 ICT Infrastructure	74%	61%	76%	82%
		1.2.6 Technology utilisation	75%	68%	70%	65%
	1.3 Business–labour landscape	1.3.1 Ease of hiring	56%	22%	10%	9%
		1.3.2 Ease of redundancy	56%	25%	15%	12%
		1.3.3 Labour–employer cooperation	39%	45%	40%	32%
		1.3.4 Professional management	36%	65%	65%	57%
2. ATTRACT	2.1 External openness	2.1.1 FDI and technology transfer	43%	28%	26%	22%
		2.1.2 Prevalence of foreign ownership	47%	49%	39%	36%
		2.1.3 Migrant stock	57%	32%	36%	32%
		2.1.4 International students	71%	52%	39%	33%
		2.1.5 Brain gain	76%	54%	39%	29%
		2.1.6 Brain drain	66%	51%	42%	32%
	2.2 Internal openness	2.2.1 Tolerance to minorities	64%	36%	13%	10%
		2.2.2 Tolerance to immigrants	58%	34%	17%	13%
		2.2.3 Social mobility	35%	68%	66%	56%
		2.2.4 Female graduates	17%	9%	12%	15%
		2.2.5 Gender earnings gap	34%	12%	6%	6%
3. GROW	3.1 Formal education	3.1.1 Vocational enrolment	49%	30%	21%	27%
		3.1.2 Tertiary enrolment	65%	44%	40%	47%
		3.1.3 Tertiary education expenditure	16%	16%	10%	9%
		3.1.4 Reading, maths and science	69%	35%	32%	43%
		3.1.5 University ranking	62%	56%	44%	45%

			Sub-pillar	Pillar	Input/ Output	GTCI Index
3. GROW	3.2 Lifelong learning	3.2.1 Quality of management schools	54%	56%	53%	47%
		3.2.2 Prevalence of training in firms	66%	26%	7%	4%
		3.2.3 Employee development	64%	56%	59%	52%
	3.3 Access to growth opportunities	3.3.1 Use of virtual social networks	46%	45%	57%	58%
		3.3.2 Use of virtual professional networks	75%	68%	66%	62%
		3.3.3 Delegation of authority	67%	63%	63%	56%
		3.3.4 Freedom of voice	51%	24%	15%	10%
4. RETAIN	4.1 Sustainability	4.1.1 Pension system	86%	82%	62%	70%
		4.1.2 Taxation	8%	3%	8%	5%
	4.2 Lifestyle	4.2.1 Environmental performance	81%	82%	71%	77%
		4.2.2 Safety at night	29%	28%	26%	24%
		4.2.3 Physician density	61%	52%	34%	38%
		4.2.4 Sanitation	79%	71%	47%	51%
		4.2.5 Flexible employment	35%	25%	22%	21%
5. LV SKILLS	5.1 Employable skills	5.1.1 Secondary-educated workforce	77%	56%	11%	19%
		5.1.2 Secondary-educated population	80%	67%	15%	26%
		5.1.3 Technicians and associate professionals	65%	71%	59%	70%
	5.2 Labour productivity	5.2.1 Labour productivity per employee	51%	39%	53%	71%
		5.2.2 Relationship of pay to productivity	23%	14%	14%	15%
		5.2.3 Mid-value exports	40%	15%	8%	2%
6. GK SKILLS	6.1 Higher skills and competencies	6.1.1 Tertiary-educated workforce	74%	66%	53%	52%
		6.1.2 Tertiary-educated population	64%	56%	49%	45%
		6.1.3 Professionals	74%	65%	69%	68%
		6.1.4 Researchers	82%	71%	65%	70%
		6.1.5 Senior officials and managers	37%	32%	25%	22%
		6.1.6 Quality of scientific institutions	66%	64%	55%	69%
		6.1.7 Scientific journal articles	75%	64%	57%	57%
	6.2 Talent impact	6.2.1 Innovation output	72%	85%	76%	78%
		6.2.2 High-value exports	41%	31%	28%	21%
		6.2.3 New product entrepreneurial activity	30%	15%	13%	11%
		6.2.4 New business density	46%	34%	23%	24%

Notes: The values are the squared Pearson correlation coefficients.
Source: Saisana and Domínguez-Torreiro, European Commission Joint Research Centre, 2015

Table 3: Distribution of differences between pillar and GTCI rankings

	GTCI Input sub-index				GTCI Output sub-index	
Shifts with respect to GTCI score	Enable	Attract	Grow	Retain	Labour and Vocational Skills	Global Knowledge Skills
More than 30 positions	4%	21%	6%	3%	11%	5%
20 to 29 positions	9%	20%	13%	9%	19%	11%
10 to 19 positions	27%	17%	25%	31%	28%	21%
5 to 9 positions	22%	18%	25%	24%	24%	29%
Less than 5 positions	31%	17%	30%	27%	17%	26%
0 positions	7%	6%	2%	6%	0%	8%
Total	100%	100%	100%	100%	100%	100%
More than 10	39%	58%	43%	43%	59%	37%

Source: Saisana and Domínguez-Torreiro, European Commission Joint Research Centre, 2015

In addition we compared GTCI 2015–16 with both the World Economic Forum's (WEF) 2014–15 Global Competitiveness Index[5] and the 2015 Global Innovation Index.[6] After having extracted data from both projects' websites, we find that GTCI 2015–16 correlates substantially with both indices (correlation ≈ 0.9). GTCI has most in common with the INSEAD 2015 Global Innovation Index. Looking at the shifts in rankings (see Table 4), we nevertheless find that 41% and 25% out of the 109 countries differ in ranking with more than 10 positions when comparing GTCI 2014 with respectively the WEF 2014–15 Global Competitiveness Index and the INSEAD 2015 Global Innovation Index. This indicates that GTCI 2015–16 clearly differs from these other indices.

Step 4: Qualitative review

Finally, the GTCI results, including overall country classifications and relative performances in terms of the Input or Output sub-indices were evaluated by the GTCI development team and external experts to verify that the overall results were, to a great extent, consistent with current evidence, existing research or prevailing theory.

Notwithstanding these statistical tests and the positive outcomes on the statistical soundness of GTCI, it is important to mention that the GTCI has to remain open for future improvements as better data, more comprehensive surveys and assessments, and new relevant research studies become available.

IMPACT OF MODELLING ASSUMPTIONS ON THE GTCI RESULTS

Every country score on GTCI and its two sub-indices depends on modelling choices: six-pillar structure, selected indicators, imputation (or not) of missing data, normalisation, weights and aggregation method, among other elements. These choices are based on expert opinion (e.g., selection of indicators) or common practice (e.g., min-max normalisation in the [0, 100] range), driven by statistical analysis (e.g., treatment of outliers) or simplicity (e.g., no imputation of missing data). The robustness analysis is aimed at assessing the simultaneous and joint impact of these modelling choices on the rankings. The data are assumed to be error-free since potential outliers and eventual errors and typos were corrected during the computation phase.

The robustness assessment of GTCI was based on a combination of a Monte Carlo experiment[7] and a multi-modelling approach that dealt with three issues: pillar weights, missing data and the aggregation formula. This

Table 4: Distribution of differences between GTCI and other international rankings

Shifts with respect to the GTCI	WEF 2014–15 Global Competitiveness Index	2015 Global Innovation Index
More than 30 positions	8%	1%
20 to 29 positions	11%	10%
10 to 19 positions	22%	14%
5 to 9 positions	27%	35%
Less than 5 positions	26%	37%
0 positions	7%	4%
Total	100%	100%
More than 10	41%	25%

Source: Saisana and Domínguez-Torreiro, European Commission Joint Research Centre, 2015

type of assessment aims to respond to eventual criticism that the country scores associated with aggregate measures are generally not calculated under conditions of certainty, even though they are frequently presented as such.[8]

The Monte Carlo simulation related to the issue of weighting, and comprised 1,000 runs, each corresponding to a different set of weights for the six pillars, randomly sampled from uniform continuous distributions centred in the reference values. The choice of the range for the weights' variation was driven by two opposite needs: ensure a wide enough interval to have meaningful robustness checks; and respect the rationale of GTCI that places equal importance on all six pillars. Given these considerations, limit values of uncertainty intervals for the pillar weights are: 15% to 35% for the four Input pillars for the calculation of the Input sub-index; and 40% to 60% for the two Output pillars for the calculation of the Output sub-index (see Table 5). For the calculation of GTCI, the limit values of uncertainty intervals for all six pillar weights are: 12% to 20%. In all simulations, sampled weights are rescaled to unity sum.

The GTCI development team, for transparency and replicability, opted not to estimate the missing data (only 6.9% missing data in the data set of 109 countries × 61 variables). The 'no imputation' choice, which is common in similar contexts, might encourage countries not to report low data values.[9] To overcome this limitation, JRC estimated missing data using the Expectation Maximisation (EM) algorithm.[10]

Regarding the aggregation formula, decision-theory practitioners have challenged the use of simple arithmetic averages because of their fully compensatory nature, in which a comparative high advantage on a few indicators can compensate for a comparative disadvantage on many indicators.[11] Despite the arithmetic averaging formula receiving statistical support for the development of GTCI, as already discussed in the previous section, the geometric average was considered instead,[12] which is a partially compensatory approach that rewards countries with similar performance in all pillars, and motivates those countries with uneven performance to improve in those pillars in which they perform poorly, and not just in *any* pillar.

Four models were tested based on the combination of no imputation versus EM imputation, and arithmetic versus geometric average, combined with 1,000 simulations per model (random weights versus fixed weights), for a total of 4,000 simulations for GTCI, and each of the two sub-indices (see Table 5 for a summary of the uncertainties considered in GTCI 2015–16).

Table 5: Uncertainty analysis for GTCI 2015–16: weights, missing data and aggregation

I. Uncertainty in the treatment of missing values			
Reference: no estimation of missing data		Alternative: Expectation Maximisation (EM)	
II. Uncertainty in the aggregation formula at pillar level			
Reference: arithmetic average		Alternative: geometric average	
III. Uncertainty in the weights			
	Pillar	Reference value for the weight (within the sub-index)	Distribution assigned for robustness analysis (within the sub-index)
INPUT	Enable	0.25	U[0.15,0.35]
	Attract	0.25	U[0.15,0.35]
	Grow	0.25	U[0.15,0.35]
	Retain	0.25	U[0.15,0.35]
OUTPUT	Labour and Vocational Skills	0.5	U[0.40,0.60]
	Global Knowledge Skills	0.5	U[0.40,0.60]

Source: Saisana and Domínguez-Torreiro, European Commission Joint Research Centre, 2015

UNCERTAINTY ANALYSIS RESULTS

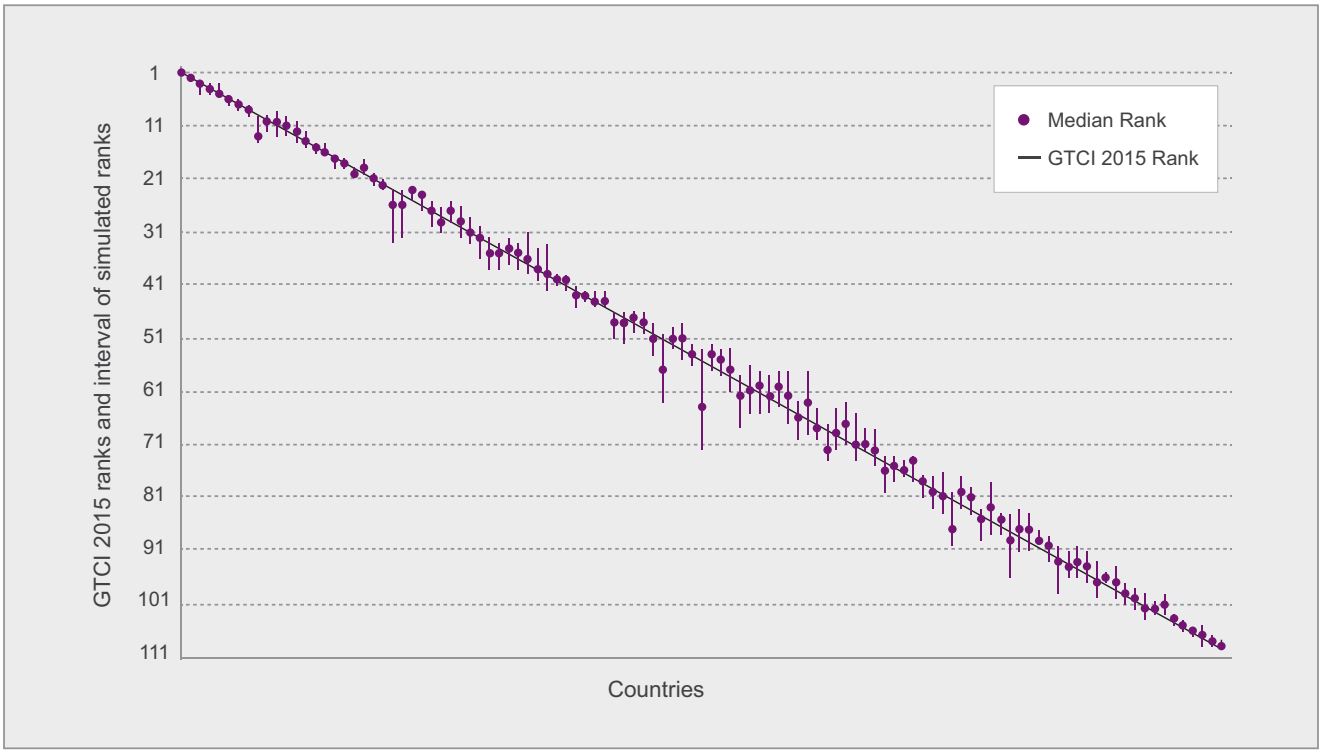
The main results of the robustness analysis are shown in Figure 1, with median ranks and 90% confidence intervals computed across the 4,000 Monte Carlo simulations for GTCI and its two sub-indices. Countries are ordered from best to worst according to their reference rank (black line), the dot being the median rank. Error bars represent, for each country, the 90% interval across all simulations. Table 6 reports the published rankings and the 90% confidence intervals that account for uncertainties in the missing data estimation, the pillar weights, and the aggregation formula. All published country ranks lay within the simulated intervals, and these are narrow enough for most countries (less than 10 positions) to allow for meaningful inferences to be drawn.

GTCI ranks are shown to be both representative of a plurality of scenarios and robust to changes in the imputation method, the pillar weights and the aggregation formula. If one considers the median rank across the simulated scenarios as being representative of these scenarios, then the fact that the GTCI rank is close to the median rank (less than two positions away) for 90% of the countries suggests that GTCI is a suitable summary measure. Furthermore, the narrow confidence intervals for the majority of the countries' ranks (less than ±3 positions for more than two-thirds of the countries) imply that the GTCI ranks are also, for most countries, robust to changes in the pillar weights, the imputation method and the aggregation formula.

Results for the Input and Output sub-index are also robust and representative of the plurality of scenarios considered. The Input rank is close to the median rank (less than two positions away) for 90% of the countries and the rank intervals are ±3 positions for 52% of the countries. Similarly the Output rank is close to the median rank (less than two positions away) for 83% of the countries, and the rank intervals are ±3 positions for 72% of the countries.

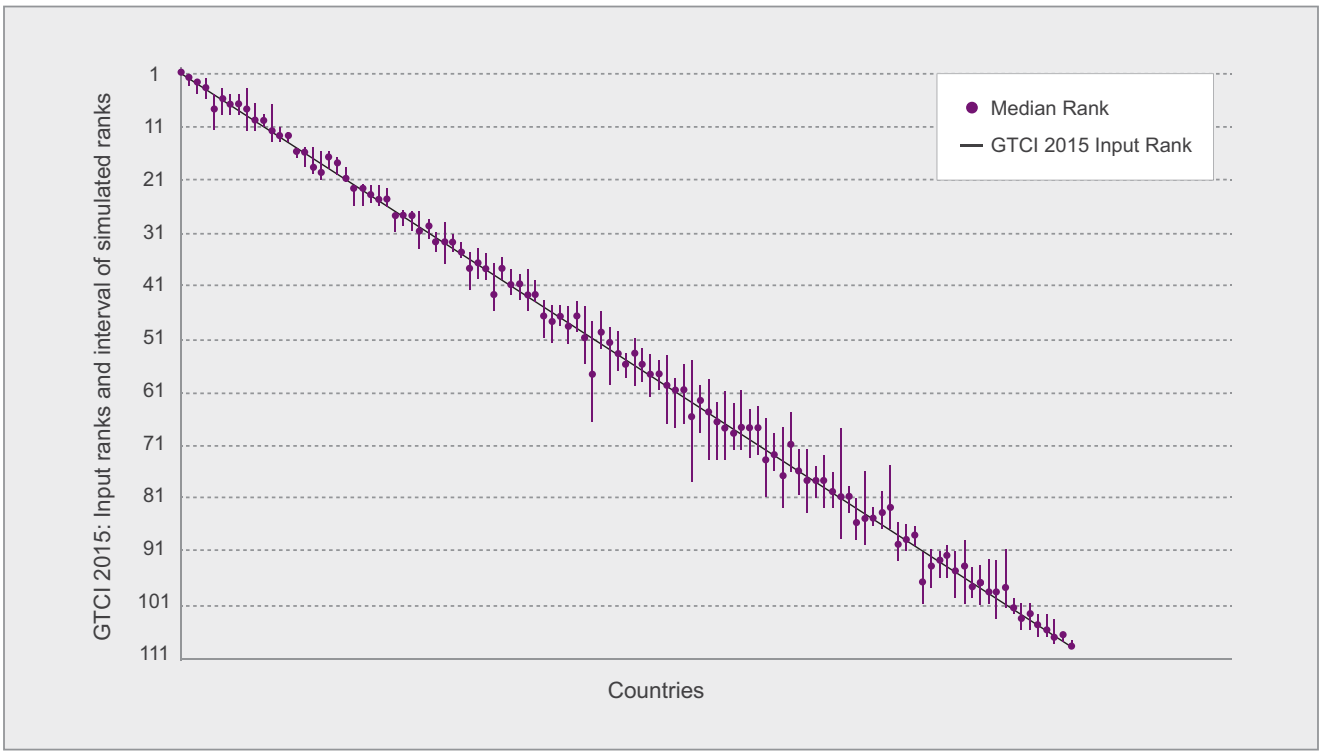
Overall, country ranks in GTCI and its two sub-indices are robust to changes in the pillar weights, the imputation method and the aggregation formula for the majority of the countries considered. For full transparency and information, Table 6 reports the GTCI country ranks (and those of the sub-indices) together with the simulated intervals (90% of the 4,000 scenarios) in order to better appreciate the robustness of these ranks to the computation methodology.

Figure 1a: Robustness analysis (GTCI rank vs. median rank, 90% confidence intervals)



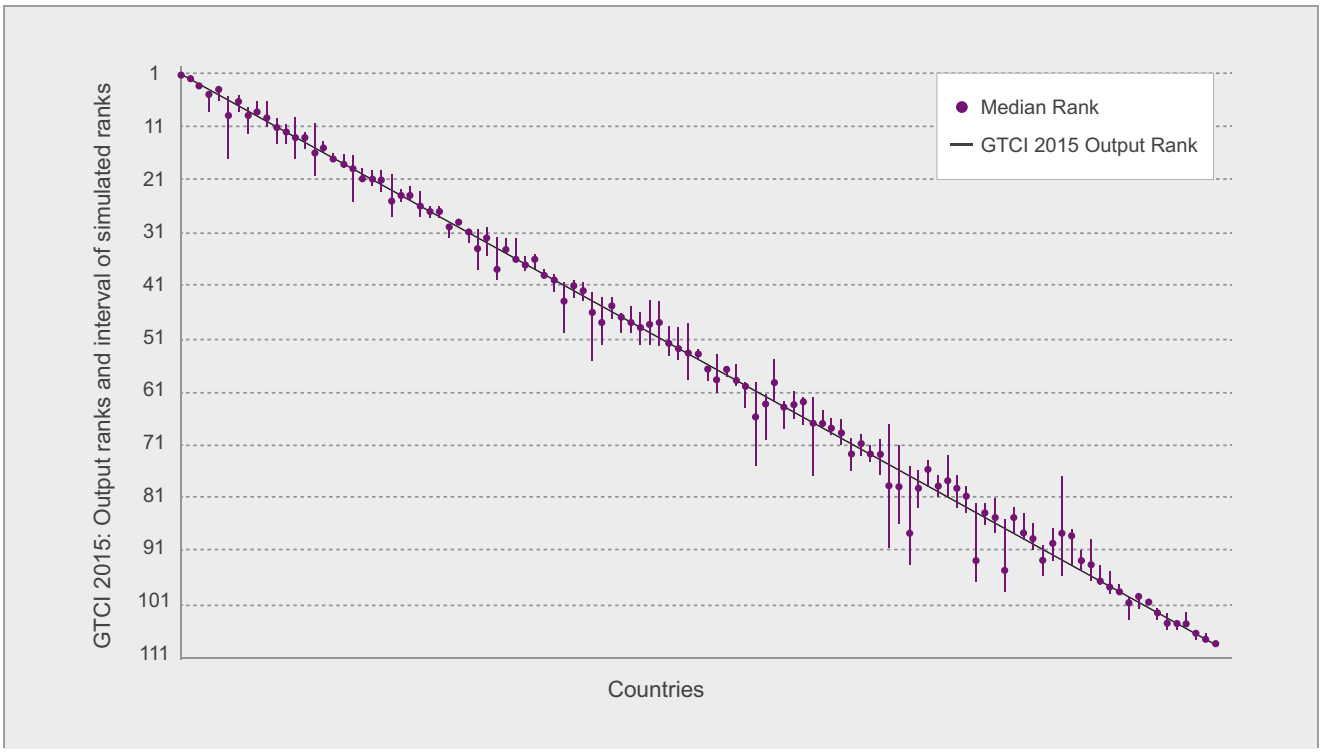
Notes: The Spearman rank correlation between the median rank and the GTCI 2015–16 rank is 0.999. Median ranks and intervals are calculated over 4,000 simulated scenarios combining random weights, imputation versus no imputation of missing values, and geometric versus arithmetic average at the pillar level.
Source: Saisana and Domínguez-Torreiro, European Commission Joint Research Centre, 2015

Figure 1b: Robustness analysis (Input rank vs. median rank, 90% confidence intervals)



Notes: The Spearman rank correlation between the median rank and the GTCI 2015–16 Input rank is 0.999. Median ranks and intervals are calculated over 4,000 simulated scenarios combining random weights, imputation versus no imputation of missing values, and geometric versus arithmetic average at the pillar level.
Source: Saisana and Domínguez-Torreiro, European Commission Joint Research Centre, 2015

Figure 1c: Robustness analysis (Output rank vs. median rank, 90% confidence intervals)



Notes: The Spearman rank correlation between the median rank and the GTCI 2015–16 Output rank is 0.997. Median ranks and intervals are calculated over 4,000 simulated scenarios combining random weights, imputation versus no imputation of missing values, and geometric versus arithmetic average at the pillar level.
Source: Saisana and Domínguez-Torreiro, European Commission Joint Research Centre, 2015

Table 6: Country ranks and 90% intervals for GTCI 2015–16 and its Input/Output sub-indices

Country	GTCI 2015–16		Input Sub-index		Output Sub-index	
	Rank	Interval	Rank	Interval	Rank	Interval
Switzerland	1	[1, 1]	1	[1, 1]	3	[3, 3]
Singapore	2	[2, 2]	2	[2, 3]	2	[2, 2]
Luxembourg	3	[3, 5]	12	[7, 14]	1	[1, 1]
United States	4	[3, 5]	7	[5, 9]	5	[4, 6]
Denmark	5	[3, 5]	4	[2, 6]	9	[6, 9]
Sweden	6	[6, 7]	11	[9, 11]	7	[5, 8]
United Kingdom	7	[6, 8]	8	[5, 9]	13	[9, 17]
Norway	8	[7, 9]	3	[3, 5]	20	[19, 21]
Canada	9	[9, 14]	5	[5, 12]	24	[23, 25]
Finland	10	[9, 12]	13	[11, 14]	12	[11, 14]
New Zealand	11	[8, 13]	9	[4, 12]	19	[16, 25]
Netherlands	12	[9, 13]	10	[7, 12]	18	[16, 19]
Australia	13	[10, 14]	6	[4, 9]	26	[23, 28]
Germany	14	[12, 15]	19	[16, 19]	8	[7, 12]
Austria	15	[14, 16]	15	[15, 17]	15	[10, 20]
Ireland	16	[14, 16]	14	[12, 14]	28	[26, 28]
Iceland	17	[17, 19]	20	[17, 20]	22	[19, 23]
Belgium	18	[17, 19]	16	[15, 19]	27	[26, 28]
Japan	19	[19, 20]	21	[19, 21]	17	[16, 17]
Czech Republic	20	[17, 20]	22	[22, 26]	4	[4, 8]
Estonia	21	[20, 22]	23	[22, 26]	11	[9, 14]
France	22	[21, 22]	24	[22, 25]	16	[14, 16]
United Arab Emirates	23	[23, 33]	18	[16, 21]	47	[46, 50]
Qatar	24	[23, 32]	17	[15, 20]	53	[49, 55]
Israel	25	[23, 25]	33	[29, 37]	10	[6, 11]
Slovenia	26	[23, 27]	34	[32, 35]	14	[12, 15]
Slovakia	27	[25, 30]	42	[39, 42]	6	[5, 17]
Malta	28	[26, 31]	27	[27, 31]	32	[30, 38]
Latvia	29	[25, 29]	35	[33, 36]	21	[19, 22]
Malaysia	30	[26, 32]	29	[27, 31]	35	[32, 35]
Hungary	31	[28, 33]	40	[36, 40]	23	[20, 28]
Cyprus	32	[30, 36]	32	[31, 35]	33	[30, 35]
Portugal	33	[32, 38]	26	[23, 26]	51	[44, 52]
Chile	34	[33, 38]	31	[29, 32]	39	[38, 39]
Lithuania	35	[32, 37]	38	[35, 40]	30	[29, 30]
Spain	36	[33, 38]	28	[27, 30]	42	[40, 43]
South Korea	37	[31, 39]	43	[38, 46]	25	[22, 25]
Poland	38	[34, 40]	41	[38, 43]	29	[29, 32]
Barbados	39	[33, 42]	25	[22, 26]	63	[55, 63]
Costa Rica	40	[39, 41]	30	[27, 34]	48	[45, 50]
Italy	41	[39, 42]	44	[40, 44]	31	[31, 33]
Saudi Arabia	42	[41, 45]	36	[35, 42]	45	[43, 52]
Croatia	43	[42, 44]	47	[45, 49]	36	[32, 37]
Bulgaria	44	[42, 45]	46	[45, 52]	38	[35, 38]
Montenegro	45	[42, 45]	49	[44, 50]	37	[35, 38]
Macedonia	46	[46, 51]	48	[45, 52]	44	[42, 55]
Uruguay	47	[46, 52]	37	[34, 40]	70	[66, 71]
China	48	[46, 50]	52	[46, 53]	41	[40, 50]

Country	GTCI 2015–16		Input Sub-index		Output Sub-index	
	Rank	Interval	Rank	Interval	Rank	Interval
Greece	49	[46, 50]	45	[44, 51]	52	[49, 54]
Serbia	50	[48, 54]	70	[65, 74]	34	[32, 40]
Kuwait	51	[50, 63]	39	[37, 46]	82	[77, 83]
Romania	52	[49, 53]	59	[55, 60]	43	[40, 44]
Russia	53	[48, 55]	62	[56, 67]	40	[39, 42]
Panama	54	[52, 56]	50	[45, 56]	60	[59, 64]
Bosnia and Herzegovina	55	[53, 72]	51	[48, 67]	61	[59, 75]
Philippines	56	[52, 57]	55	[54, 59]	54	[48, 59]
South Africa	57	[53, 58]	58	[54, 62]	55	[53, 55]
Kazakhstan	58	[53, 61]	53	[49, 60]	65	[61, 66]
Georgia	59	[58, 68]	63	[55, 78]	57	[54, 61]
Mexico	60	[56, 65]	66	[63, 74]	56	[56, 59]
Armenia	61	[57, 65]	72	[66, 81]	49	[46, 52]
Colombia	62	[58, 65]	54	[50, 57]	72	[69, 73]
Turkey	63	[57, 64]	65	[59, 74]	59	[56, 60]
Moldova	64	[57, 67]	77	[72, 84]	46	[43, 47]
Argentina	65	[63, 70]	61	[59, 68]	68	[65, 68]
Ukraine	66	[57, 69]	79	[73, 83]	50	[44, 52]
Brazil	67	[64, 70]	57	[53, 59]	79	[74, 79]
Botswana	68	[67, 74]	60	[54, 67]	76	[71, 86]
Thailand	69	[64, 72]	56	[51, 60]	81	[73, 81]
Jordan	70	[63, 71]	69	[61, 72]	66	[62, 67]
Azerbaijan	71	[65, 74]	68	[63, 72]	67	[62, 77]
Mongolia	72	[68, 72]	75	[65, 76]	64	[63, 68]
Tunisia	73	[68, 75]	86	[80, 87]	58	[57, 58]
Peru	74	[73, 80]	74	[68, 83]	71	[70, 76]
Guatemala	75	[73, 78]	64	[60, 69]	88	[83, 88]
Dominican Republic	76	[74, 77]	76	[72, 81]	73	[71, 74]
Lebanon	77	[73, 78]	87	[75, 87]	62	[61, 70]
Ecuador	78	[77, 81]	71	[64, 73]	89	[84, 89]
Namibia	79	[77, 83]	81	[68, 89]	78	[76, 83]
Kyrgyzstan	80	[76, 84]	82	[79, 84]	75	[67, 91]
Nicaragua	81	[80, 90]	83	[81, 89]	77	[75, 94]
Vietnam	82	[77, 83]	85	[83, 86]	74	[70, 77]
Sri Lanka	83	[79, 84]	73	[69, 76]	94	[87, 94]
El Salvador	84	[83, 89]	80	[76, 83]	87	[85, 99]
Albania	85	[78, 88]	78	[75, 81]	93	[77, 96]
Kenya	86	[84, 88]	84	[76, 90]	90	[86, 91]
Rwanda	87	[84, 96]	67	[61, 74]	100	[100, 104]
Egypt	88	[83, 91]	101	[91, 102]	69	[66, 69]
India	89	[84, 91]	94	[90, 96]	80	[77, 81]
Indonesia	90	[87, 90]	90	[87, 90]	92	[87, 93]
Paraguay	91	[88, 93]	88	[86, 93]	95	[91, 95]
Lesotho	92	[90, 99]	96	[89, 101]	84	[82, 97]
Morocco	93	[91, 96]	89	[86, 91]	99	[98, 99]
Bolivia	94	[90, 96]	97	[94, 100]	86	[81, 88]
Venezuela	95	[91, 97]	100	[93, 104]	83	[79, 84]

Country	GTCI 2015–16		Input Sub-index		Output Sub-index	
	Rank	Interval	Rank	Interval	Rank	Interval
Cambodia	96	[93, 100]	91	[91, 101]	97	[94, 97]
Honduras	97	[95, 97]	93	[91, 96]	98	[95, 99]
Iran	98	[94, 100]	99	[93, 101]	96	[89, 97]
Senegal	99	[97, 101]	92	[91, 98]	101	[100, 102]
Bangladesh	100	[98, 102]	102	[100, 103]	91	[90, 96]
Uganda	101	[99, 104]	95	[91, 100]	106	[103, 106]
Ghana	102	[101, 103]	98	[94, 101]	103	[102, 104]
Pakistan	103	[99, 103]	108	[107, 108]	85	[82, 86]
Algeria	104	[103, 105]	104	[101, 106]	102	[101, 102]
Mali	105	[104, 106]	105	[103, 107]	104	[103, 106]
Tanzania	106	[106, 107]	103	[101, 106]	108	[107, 108]
Ethiopia	107	[105, 109]	107	[104, 109]	105	[105, 106]
Burkina Faso	108	[107, 109]	106	[103, 107]	109	[109, 109]
Madagascar	109	[108, 109]	109	[108, 109]	107	[107, 108]

Source: Saisana and Domínguez-Torreiro, European Commission Joint Research Centre, 2015

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. Figure 2 plots GTCI and its sub-indices rankings versus one-at-a-time changes of either the EM imputation method or the geometric aggregation formula (assuming equal weights for the six pillars as in GTCI).

The most influential methodological assumption is the choice of no imputation versus EM imputation. This choice has the largest impact on differences in ranking for the Output sub-index, less so for the Input sub-index, and least for the overall GTCI 2015–16. For example, in the most extreme case, a country declines by three positions in the Output ranking if a geometric aggregation is applied, yet the country improves by 16 positions if EM imputation is applied. If both assumptions are changed (namely EM imputation and geometric averaging – assuming equal pillar weights), this country with the most extreme shift improves by 12 positions. Note however that these assumptions concern methodological choices only and might overall be less influential than choices related to the background assumptions in the conceptual framework.[13]

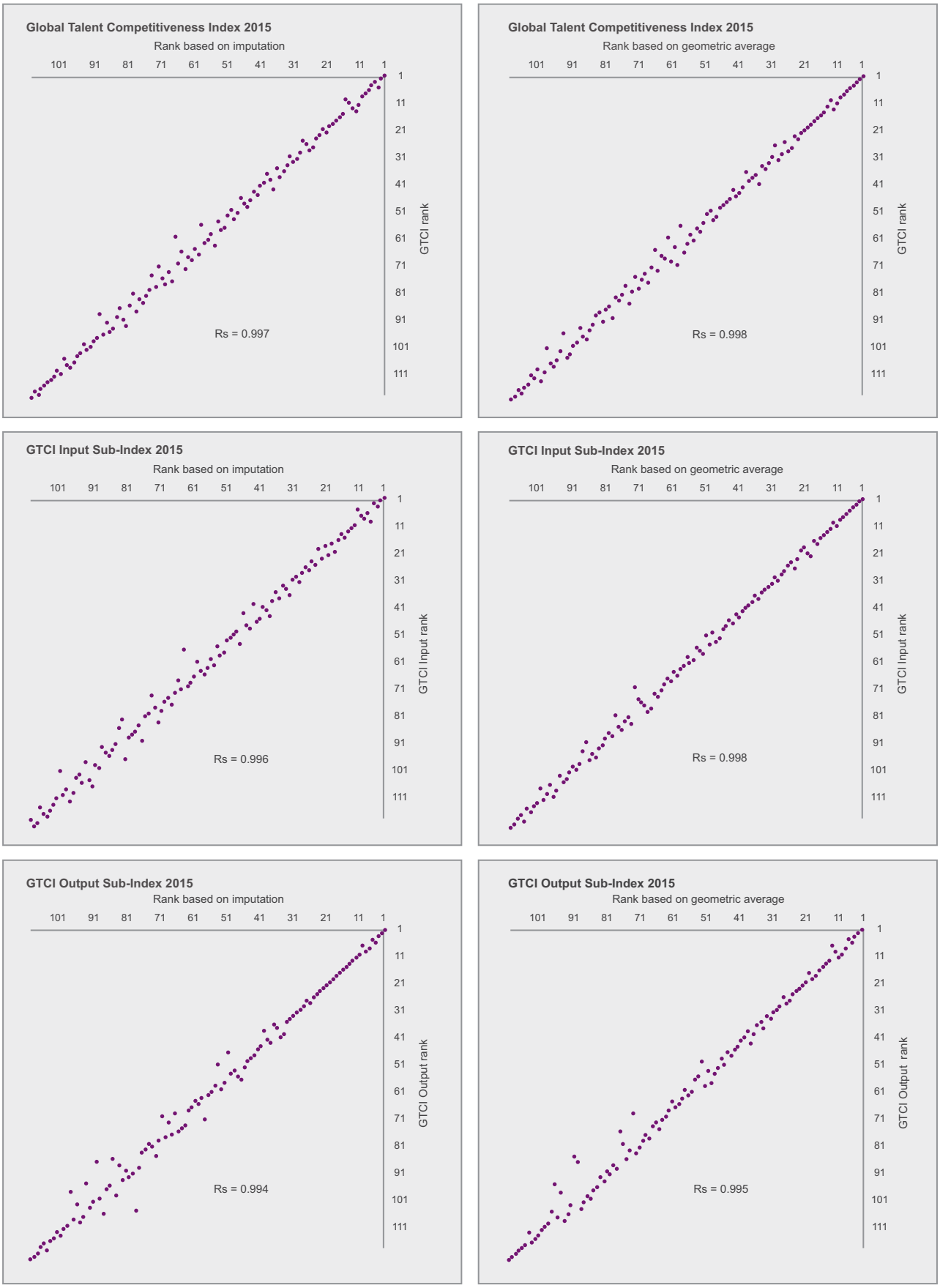
Overall, the JRC recommendation is not to alter the GTCI inclusion criteria on data availability, but to consider country ranks in GTCI 2015–16 and in the Input and Output sub-indices within the 90% confidence intervals, as those are reported in Table 6, in order to better appreciate to what degree a country's rank depends on the modelling choices. It is reassuring that for over 80% of the countries included in GTCI, their ranks in GTCI 2015–16, and Input and Output sub-indices are the result of the underlying data and not modelling choices.[14]

CONCLUSION

The JRC analysis suggests that the conceptualised multilevel structure of GTCI 2015–16 is statistically coherent and balanced (i.e., not dominated by any pillar or sub-pillar; all indicators contribute to the variation of the respective Input/Output sub-indices and to the overall GTCI). Furthermore, the analysis has offered statistical justification for the use of equal weights and arithmetic averaging at the various levels of aggregation, showing that GTCI is statistically reliable in its current form as the simple average of the six pillars (as measured by a very high Cronbach's alpha value at 0.94, well above the recommended 0.7 threshold for a reliable aggregate).

Points that call for possible refinements of the GTCI framework were also identified. These refinements regard mainly six out of the 61 variables, namely 1.3.1 Ease of hiring, 2.2.5 Gender earnings gap, 3.1.3 Tertiary education expenditure, 3.2.2 Prevalence of training in firms, 4.1.2 Taxation and 5.2.3 Mid-value exports. Although present in the conceptual framework, these variables do not contribute significantly to the variation of the GTCI country scores

Figure 2: Sensitivity analysis: impact of modelling choices



Source: Saisana and Domínguez-Torreiro, European Commission Joint Research Centre, 2015

and consequently, do not have an impact on the GTCI ranking. The GTCI development team has opted to keep these variables in the current framework because of their conceptual relevance to the phenomenon, but it is suggested that next year's release should be refined on these issues. Furthermore, two highly-correlated variables (2.1.5 Brain gain and 2.1.6 Brain drain) have also been retained by the development team, arguing that having a clear distinction between the countries that are good at attracting talent and those that are good at retaining talent would add value to GTCI. As an alternative for keeping both variables while at the same time avoiding double counting, we proposed to assign 0.5 weights to these variables in the sub-pillar calculations. The development team preferred to keep both variables without assigning them a specific weight. They will revisit the issue in the context of the next GTCI. Also, in light of the statistical insights provided this year, for the next GTCI the development team will work on reconsidering the allocation of some of the variables that could fit in a different sub-pillar (e.g., 5.2.1 Labour productivity per employee and 5.2.2 Relationship of pay to productivity). Moreover, the development team has manifested its intention of revising and fine-tuning the output side of the model. Accordingly, this will allow them to tackle the point of whether the pillar 'Retain' (strongly correlated to both the Input and Output sub-indices, 0.89 and 0.86 respectively) should belong to the Input or Output sub-indices, or whether a model of Input-Process-Output (where 'Retain' could be considered as part of the 'Process' side) would be more suitable to characterise the phenomenon being measured.

GTCI and sub-indices country ranks are robust to methodological assumptions related to the estimation of missing data, weighting and aggregation formula. It is reassuring that for over 80% of the countries included in GTCI, the overall rank and those in the Input and Output sub-indices are the result of the underlying data and not of the modelling choices. Consequently, inferences can be drawn for most countries in GTCI, whilst some caution may be needed for a few countries. Note that perfect robustness would have been undesirable, as this would have implied that the GTCI components are perfectly correlated and hence redundant, which is not the case for GTCI 2015–16. In fact, one way in which GTCI helps to highlight other components of human capital and talent competitiveness is by pinpointing the differences in rankings that emerge from a comparison between GTCI and each of the six pillars: for more than 39% (up to 59%) of the countries, the GTCI ranking and any of the six pillar rankings differ by 10 positions or more. This outcome both evidences the added value of the GTCI ranking and points to the importance of taking into account the individual pillars, sub-pillars, and variables on their own merit. By doing so, country-specific strengths and bottlenecks in human capital and talent competitiveness can, as noted earlier, be identified and serve as an input for evidence-based policymaking.

The auditing conducted herein has shown the potential of the Global Talent Competitiveness Index 2015–16, upon some further refinements, in reliably identifying weaknesses and best practices and ultimately monitoring national performance in human capital and competitiveness issues around the world.

ENDNOTES

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

[2] OECD (2008)

[3] Groeneveld and Meeden (1984) set the criteria for absolute skewness above one and kurtosis above 3.5. The skewness criterion was relaxed to account for the small sample (109 countries).

[4] The sub-pillars that have a single latent dimension are: 1.2 Market landscape, 2.1 External openness, 3.3 Access to growth opportunities, 4.1 Sustainability, 4.2 Lifestyle, 5.1 Employable skills and 6.1 Higher skills and competencies. Hence, in the remaining sub-pillars there is more than one single latent dimension, and as a result a notable amount of information is lost when aggregating directly the variables into sub-pillars.

[5] World Economic Forum (2014)

[6] Cornell University, INSEAD and WIPO (2014); Saisana and Saltelli (2011); Saltelli et al. (2008)

[7] Monte Carlo experiments are a broad class of computational algorithms that rely on repeated random sampling to obtain numerical results. Monte Carlo methods are mainly used in three distinct problem classes: optimisation, numerical integration, and generating draws from a probability distribution.

[8] Saisana, Saltelli and Tarantola (2005); Saisana, D'Hombres and Saltelli (2011)

[9] With arithmetic average, the 'no imputation' choice is equivalent to replacing missing values with the average of the available (normalised) data within each sub-pillar.

[10] The Expectation-Maximisation (EM) algorithm (Little and Rubin, 2002) 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 maximisation M-step: Given a complete-data log likelihood, the M-step finds the parameter estimates to maximise the complete-data log likelihood from the E-step. The two steps are iterated until the iterations converge.

[11] Munda (2008)

[12] In the geometric average, pillars are multiplied as opposed to summed in the arithmetic average. Pillar weights appear as exponents in the multiplication. All pillar scores were greater than 1.0, hence there was no reason to rescale them (so as to avoid zero values that would have led to zero geometric averages).

[13] Saltelli and Funtowicz (2014)

[14] As already mentioned in the uncertainty analysis, at least 80% of the simulated median ranks for the GTCI, Input and Output (sub-) indices are less than two positions away from the reported 2015 rank.

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