Chapter 7

JRC Statistical Audit of the Global Talent Competitiveness Index 2017

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The Global Talent Competitiveness Index (GTCI) aims to summarise complex and versatile concepts related to human capital and talent competitiveness at the national scale in 118 countries worldwide. In so doing, it raises some conceptual and practical challenges, which are discussed in the GTCI 2017 report. This chapter focuses on the practical challenges related to the data quality and the methodological choices made in the grouping of 65 variables into 14 sub-pillars, six pillars, two sub-indices, and an overall index.

GTCI 2017 has a very high statistical reliability (it has a Cronbach-alpha value of 0.95) and its 65 individual variables are statistically well grouped into the six pillars in order to measure the talent competitiveness dimensions that such pillars try to capture. Country ranks are also robust to methodological changes related to the treatment of missing values, weighting, and aggregation rule (with a shift of less than $\pm$ 2 positions with respect to the simulated median in 90% of the countries). The added value of the GTCI model lies in its ability to summarise different aspects of talent competitiveness in a more efficient and parsimonious manner than is possible with the variables and pillars taken separately. In fact, in more than 70% of the 118 countries included in this year's GTCI, the overall ranking differs from any of the six pillar rankings by 10 positions or more.

This audit represents the fourth analysis performed by the European Commission's Competence Centre on Composite Indicators and Scoreboards at the Joint Research Centre (JRC). The previous audit identified a few minor statistical issues concerning variables that had a low correlation with the talent dimension they were trying to capture, but these have largely been addressed in the 2017 index. Overall, the JRC concluded that the GTCI model is robust and

reliable, with a statistically coherent and balanced multi-level structure. The analysis was performed in order to ensure the transparency and reliability of the GTCI 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.

As in the previous audits, the present JRC assessment of GTCI 2017 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, aggregation formula, and normalisation). Furthermore, the JRC analysis includes an assessment of the added value of GTCI and a comparison with other global measures of competitiveness and innovation. Its main conclusions can be summarised as follows: the version of the GTCI model presented in 2017 is coherent, balanced, and robust, displaying strong associations between the underlying variables and the GTCI sub-pillars, pillars, and sub-indices, and hence offers a sound basis for policy interpretations. Some minor issues, which are outlined in this chapter, are also recommended for examination in the next version of index.

The practical items addressed in this chapter relate to the statistical soundness of the GTCI 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 GTCI will mostly, though not exclusively, be based on correlations, the correspondence of GTCI 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'.[2] The point is that the validity of GTCI relies on the combination of 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.

[a]Statistical Coherence in the GTCI Framework

An initial discussion of the properties of GTCI 2017 was given in June 2016. One of the main issues raised was that of the normalisation method, which does not scale all variables onto the same scale. Although it was agreed that the normalisation method could remain as it has been in previous versions of the index, it was decided to include, in the uncertainty analysis, the alternative assumption of using a full normalisation method (where all variables are mapped onto the same scale), in addition to the assumptions of previous audits.

Although the underlying concepts and framework used to describe global talent competitiveness in GTCI 2017 have remained essentially the same as those in GTCI 2015–16, several variables have been removed (mainly because of data availability issues) and several others have been added. As a result, there are a total of 65 variables used in GTCI 2017, in contrast to the 61 used in the 2015–16 version.

The main change in this regard is that the former sub-pillar 'Labour productivity' has been renamed 'Employability', and features four new variables. This is a significant improvement from the conceptual point of view because this sub-pillar measures the issues of skills gaps and skills matching. Not only is it important that countries develop talent and skills, it is also important that the economy actually uses such skills to their maximum potential. Additionally, two new variables—Regulatory quality and Corruption—have been included in the Regulatory Landscape sub-pillar. Finally, a new variable, Business opportunities for women, has been included in the Internal Openness sub-pillar, and Tertiary education expenditure has been added to the Formal Education sub-pillar. All of these modifications provide significant added value to the conceptual framework of GTCI 2017.

Two variables have also been re-allocated: Relationship of pay to productivity has become part of the Business and Labour Landscape sub-pillar because it complements well (as a measurement of meritocracy) the variable of professional management for measuring management practices as part of the business landscape. Additionally, this was flagged as a mismatch in the 2015–16 structure from a statistical point of view, a problem that seems to have been solved by its repositioning.

Overall, as will be shown in this chapter, the statistical properties of GTCI 2017 have improved notably with respect to the 2015–16 version. Following the iterative process during which the index has been fine-tuned, the current assessment of the statistical coherence in this final version of GTCI 2017 followed four steps:

[b]Step 1: Relevance

Candidate variables 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, variables were scaled either at the source or by the GTCI team as appropriate and where needed.

[b]Step 2: Data Checks

The most recently released data were used for each country. The cut-off year was changed from 2002 to 2005, thus affecting country coverage figures. Countries were included if data availability was at least 80% at the index level and at least 40% at the sub-pillar level. As a result, the GTCI 2017 data set comprises 118 countries and 65 variables. Consequently, data availability is at least 85% at the Input sub-index level and 63% at the Output sub-index level. Potentially problematic variables that could bias the overall results were identified by the GTCI development team as those having absolute skewness greater than 2 and kurtosis greater than 3.5,[3] and were treated either by Winsorisation or by taking the natural logarithm (in the case of five or more outliers). For variables with five outliers or more, a log transformation is used (see the Technical Notes of the GTCI report for details). These criteria follow the WIPO-INSEAD Global Innovation Index practice (formulated with the JRC in 2011).

[b]Step 3: Statistical Coherence

This section presents the JRC's analysis of the statistical coherence of GTCI 2017, which consists of a principal components analysis to analyse the structure of the data, a multi-level analysis of the correlations of variables, and a comparison of GTCI rankings with its pillars and with other similar composite indicators. This latter investigation demonstrates the added value of GTCI both against its component pillars and against other similar indexes.

[c]1. Principal components analysis and reliability analysis

Principal component analysis (PCA) was used to assess the extent to which the conceptual framework is compatible with statistical properties of the data. PCA confirms the presence of a single statistical dimension (i.e., no more than one principal component with eigenvalue greater than 1.0) in nine of the fourteen sub-pillars, which captures 58% (Formal Education) to 81% (Regulatory Landscape) of the total variance in the underlying variables.[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.

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

		Enable	Attract	Grow	Retain	Vocational and Technical Skills	Global Knowledge Skills
Input	1.1 Regulatory Landscape	0.96	0.85	0.83	0.82	0.74	0.76
	1.2 Market Landscape	0.92	0.72	0.88	0.86	0.81	0.85
	1.3 Business and Labour Landscape	0.83	0.66	0.54	0.58	0.51	0.49
	2.1 External Openness	0.74	0.92	0.57	0.61	0.52	0.54
	2.2 Internal Openness	0.77	0.89	0.74	0.66	0.57	0.58
	3.1 Formal Education	0.68	0.46	0.89	0.78	0.76	0.83
	3.2 Lifelong Learning	0.74	0.72	0.84	0.6	0.54	0.60
	3.3 Access to Growth Opportunities	0.82	0.76	0.90	0.77	0.69	0.80
	4.1 Sustainability	0.89	0.79	0.79	0.90	0.75	0.77
	4.2 Lifestyle	0.71	0.54	0.75	0.95	0.85	0.77
Output	5.1 Mid-Level Skills	0.64	0.48	0.68	0.82	0.92	0.67
	5.2 Employability	0.61	0.52	0.53	0.51	0.64	0.58
	6.1 High-Level Skills	0.75	0.57	0.82	0.82	0.80	0.93
	6.2 Talent Impact	0.70	0.56	0.76	0.71	0.64	0.92

Source: Becker, Saisana and Dominguez-Torriero European Commission Joint Research Centre (2016).

The six pillars also share a single statistical dimension that summarises 82% of the total variance, and the six loadings (correlation coefficients) are very similar to each other, ranging from 0.82 to 0.94. The latter suggests that the six pillars contribute in a similar way to the variation of the GTCI scores, as envisaged by the development team: all six pillars are assigned equal weights.

The reliability of GTCI, measured by the Cronbach-alpha value, is very high at 0.95—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, GTCI 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 0.99 and 0.95, respectively, which suggests that the sub-indices are effectively placed on equal footing. Overall, the tests so far show that the grouping of variables 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 variables in future versions of the index, so as to render it even sounder from both a conceptual and statistical point of view.

[c]2. 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' importance in the index. However, in practice, the correlation structure of the variables and their different variances do not always allow the weights assigned to the variables to be considered equivalent to their importance.

This section assesses the importance of all 65 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 (otherwise known as the *coefficient of determination* R^2). The importance of the selected variables is taken to be equivalent to the contribution of those 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 coefficients of determination ('importance' measures) of the

65 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 can capture 92% of the variance in the respective sub-pillar scores (Regulatory Landscape), 90% of the variance in the respective pillar (Enable), and 90% both in the Input sub-index and overall GTCI scores. Similarly, country variations in 2.1.1 Foreign direct investment (FDI) and technology transfer scores can capture 49%, 43%, 30%, and 37% of the variance in the External Openness, Attract, Input, and GTCI scores, respectively. In the 2017 data set, there seem to be only three variables that have a very low impact on the GTCI variance (less than 10%): 1.3.1 Ease of hiring, 4.1.2 Taxation, and 5.2.4 Skills gap as major constraint. Of these, only Taxation was flagged in the JRC's previous audit of GTCI 2015–16. 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 reconsider the inclusion of these variables (or replace them with other variables) in next year's release.

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

			Squared correlation of variable (expressed as percentage) with:			
Pillar	**Sub-pillar**	**Variable name**	**Sub-pillar**	**Pillar**	**Input/ Output sub-index**	**GTCI Index**
1. ENABLE	1.1 Regulatory Landscape	Government effectiveness	92%	90%	90%	90%
		Business-government relations	46%	42%	30%	23%
		Political stability	70%	58%	59%	54%
		Regulatory quality	87%	82%	81%	81%
		Corruption	91%	83%	84%	80%
	1.2 Market Landscape	Competition intensity	50%	48%	39%	36%
		Ease of doing business	70%	69%	66%	68%
		Cluster development	55%	54%	49%	46%
		R&D expenditure	57%	35%	33%	36%
		ICT infrastructure	74%	61%	77%	81%
		Technology utilisation	74%	72%	71%	69%
	1.3 Business and Labour Landscape	Ease of hiring	57%	21%	10%	8%
		Ease of redundancy	46%	23%	15%	12%
		Labour-employer cooperation	53%	54%	47%	40%
		Professional management	46%	71%	68%	64%

		Relationship of pay to productivity	52%	48%	40%	39%
2. ATTRACT	2.1 External Openness	FDI and technology transfer	49%	43%	40%	37%
		Prevalence of foreign ownership	48%	49%	38%	35%
		Migrant stock	62%	47%	33%	30%
		International students	73%	62%	36%	32%
		Brain gain	67%	60%	39%	32%
	2.2 Internal Openness	Tolerance of minorities	66%	44%	46%	41%
		Tolerance of immigrants	40%	33%	20%	15%
		Social mobility	58%	70%	64%	57%
		Female graduates	20%	11%	22%	24%
		Gender earnings gap	51%	38%	27%	24%
		Business opportunities for women	31%	30%	22%	19%
3. GROW	3.1 Formal Education	Vocational enrolment	42%	29%	17%	21%
		Tertiary enrolment	67%	52%	40%	47%
		Tertiary education expenditure	11%	12%	14%	12%
		Reading, maths, and science	52%	46%	46%	49%
		University ranking	61%	58%	46%	48%
	3.2 Lifelong Learning	Quality of management schools	61%	59%	58%	57%
		Prevalence of training in firms	65%	34%	20%	16%
		Employee development	64%	54%	65%	59%
	3.3 Access to Growth Opportunities	Use of virtual social networks	55%	48%	60%	61%
		Use of virtual professional networks	80%	66%	63%	63%
		Delegation of authority	55%	57%	63%	59%
		Personal rights	65%	46%	36%	36%
4. RETAIN	4.1 Sustainability	Pension system	60%	77%	61%	67%
		Taxation	13%	1%	4%	2%
		Brain retention	53%	24%	46%	39%
	4.2 Lifestyle	Environmental performance	77%	66%	53%	59%
		Personal safety	60%	63%	57%	59%
		Physician density	68%	58%	38%	42%
		Sanitation	77%	69%	43%	47%
5. VOCATIONAL AND TECHNICAL SKILLS	5.1 Mid-Level Skills	Workforce with secondary education	54%	40%	27%	18%
		Population with secondary education	66%	49%	34%	22%
		Technicians and associate professionals	60%	63%	65%	63%
		Labour productivity per employee	35%	39%	33%	48%

	5.2 Employability	Ease of finding skilled employees	67%	26%	31%	37%
		Relevance of education system to the economy	70%	37%	41%	51%
		Availability of scientists and engineers	72%	42%	47%	46%
		Skills gap as major constraint	29%	6%	3%	0%
6. GLOBAL KNOWLEDGE SKILLS	**6.1 High-Level Skills**	Workforce with tertiary education	68%	56%	52%	45%
		Population with tertiary education	41%	32%	28%	23%
		Professionals	63%	52%	55%	56%
		Researchers	57%	46%	47%	48%
		Senior officials and managers	27%	24%	20%	17%
		Quality of scientific institutions	64%	65%	67%	72%
		Scientific journal articles	61%	56%	57%	46%
	6.2 Talent Impact	Innovation output	71%	82%	78%	77%
		High-value exports	52%	41%	35%	30%
		New product entrepreneurial activity	25%	16%	13%	12%
		New business density	33%	22%	14%	14%

Source: Becker, Saisana, and Domínguez-Torreiro, European Commission Joint Research Centre (2017).
Note: The values are the squared Pearson correlation coefficients, expressed as percentages.

[c]3. Added value of 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 70% (up to 80%) of the 118 countries included in GTCI 2017, the overall GTCI ranking differs from any of the six pillar rankings by 10 positions or more (see Table 3). This is a desired outcome, because it evidences the added value of the GTCI model, which helps 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 towards 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 3: Distribution of differences between pillars and GTCI rankings

	GTCI Input Sub-Index				GTCI Output Sub-Index	
Shifts with respect to the overall GTCI rank	Enable	Attract	Grow	Retain	Vocational and Technical Skills	Global Knowledge Skills
More than 30 positions	46%	48%	49%	44%	47%	45%
20 to 29 positions	14%	13%	11%	13%	15%	11%
10 to 19 positions	16%	19%	13%	14%	19%	20%
5 to 9 positions	13%	7%	18%	15%	14%	13%
Less than 5 positions	9%	12%	8%	13%	4%	9%
0 positions	3%	2%	1%	2%	1%	2%
Total	100%	100%	100%	100%	100%	100%
More than 10	75%	80%	73%	70%	81%	76%

Source: Becker, Saisana, and Domínguez-Torreiro, European Commission Joint Research Centre (2017).

In addition, we compared GTCI 2017 with both the World Economic Forum's 2015–2016 Global Competitiveness Index and Cornell University, INSEAD, and WIPO's 2016 Global Innovation Index. After having extracted data from both projects' websites, we find that GTCI 2017 correlates substantially with both indices (correlation ≈ 0.9). GTCI has most in common with the 2016 Global Innovation Index. Looking at the shifts in rankings (see Table 4), we nevertheless find that 46% and 39% out of the 114 countries (four of the countries included in GTCI 2017 do not feature in one or both of the other two indices) differ in ranking by more than 10 positions when comparing GTCI 2017 with, respectively, the 2015–2016 Global Competitiveness Index and the 2016 Global Innovation Index. This indicates that GTCI 2017 clearly differs from these other indices.

Table 4: Distribution of differences between GTCI 2017 and other international rankings

Shifts with respect to GTCI 2017	2016 Global Innovation Index (Cornell, INSEAD, and WIPO)	2015–2016 Global Competitiveness Index (World Economic Forum)
More than 30 positions	3%	10%
20 to 29 positions	11%	16%
10 to 19 positions	25%	20%
5 to 9 positions	27%	24%
Less than 5 positions	28%	25%

0 positions	6%	4%
Total	100%	100%
More than 10	39%	46%

Source: Becker, Saisana, and Domínguez-Torreiro, European Commission Joint Research Centre (2017).

[b]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 development team and external experts to verify that the overall results are consistent with current evidence, existing research, or prevailing theory.

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

[A]Impact of Modelling Assumptions on the GTCI Results

Every country score on the overall GTCI and its two sub-indices depends on modelling choices: the six-pillar structure, the selected variables, the imputation or not of missing data, the normalisation method, and the weights and aggregation method, among other elements. These choices are based on expert opinion (e.g., selection of variables), 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 any errors and typos were corrected during the computation phase.

The robustness assessment of GTCI was based on a combination of a Monte Carlo experiment and a multi-modelling approach that dealt with four issues, three of which have been included in previous assessments of GTCI: pillar weights, missing data, and the aggregation formula. An additional assumption that was tested in this year's analysis was that of the normalisation method. In GTCI 2017, some variables are normalised onto the [0,100] interval, whereas others

are not (they use a normalisation that does not result in the minimum and maximum values being 0 and 100, respectively). The uncertainty analysis therefore includes the alternative assumption where all variables are strictly normalised onto the same [0,100] scale. In general, the uncertainty analysis, to some extent, aims to respond to possible criticisms that the country scores 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 normalisation method, 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 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: to ensure a wide enough interval to have meaningful robustness checks, and to 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 so that they always sum to 1.

The GTCI development team, for transparency and replicability, opted not to estimate the missing data (only 5.6% of data were missing in the data set of 118 countries for all 65 variables). The 'no imputation' choice, which is common in similar contexts, might encourage countries not to report low data values. To overcome this limitation, the JRC also estimated missing data using the Expectation Maximisation (EM) algorithm.

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

The effect of normalising all variables onto the same scale was tested because having variables on different scales may risk some distortion in the importance of each variable.

Table 5: Uncertainty analysis for GTCI 2017: Weights, missing data, aggregation, and normalisation

I. Uncertainty in the treatment of missing values			
Reference: No estimation of missing data		Alternative: Expectation Maximization (EM)	
II. Uncertainty in the aggregation formula at pillar level			
Reference*:* Arithmetic average		Alternative: Geometric average	
III. Uncertainty in the aggregation formula at pillar level			
Reference: Arithmetic average		Alternative: Geometric average	
IV. 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	Vocational and Technical Skills	0.5	U[0.40,0.60]
	Global Knowledge Skills	0.5	U[0.40,0.60]

Source: Becker, Saisana, and Domínguez-Torreiro, European Commission Joint Research Centre (2017).

Eight models were tested based on the combination of no imputation versus EM imputation, arithmetic versus geometric average, and full versus partial normalisation, combined with 1,000 simulations per model (random weights versus fixed weights), for a total of 8,000 simulations for GTCI and each of the two sub-indices (see Table 5 for a summary of the uncertainties considered in GTCI 2017).

[b]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 8,000 Monte Carlo simulations for GTCI and the 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

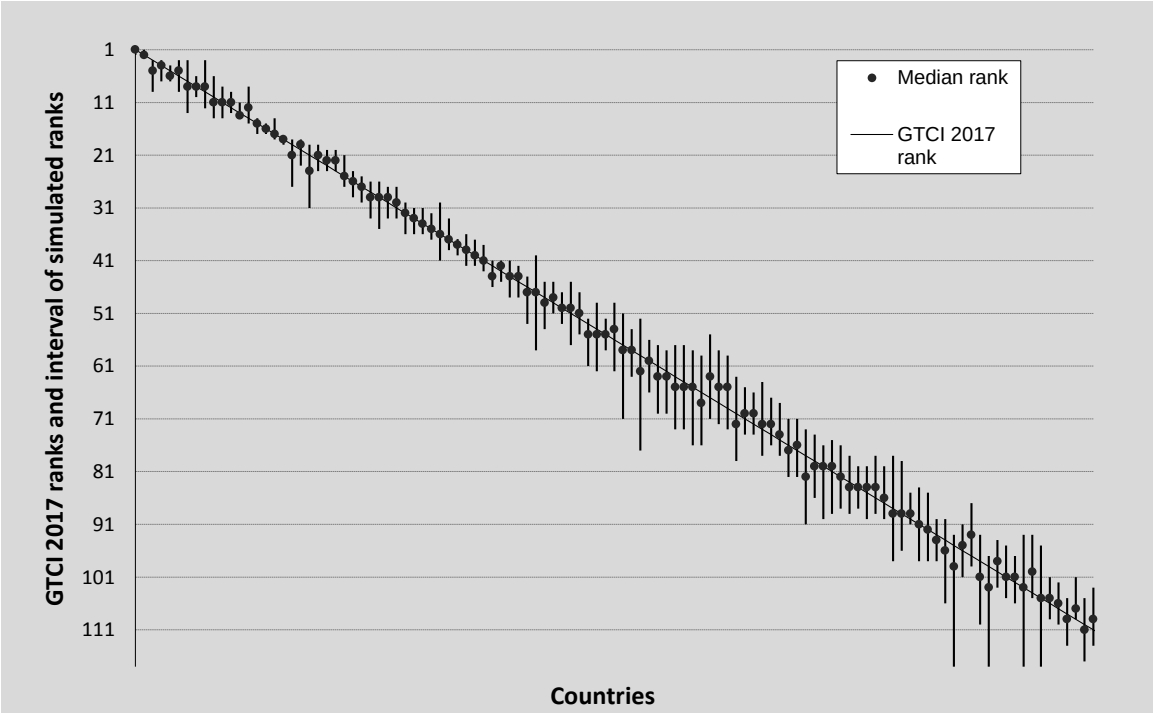
are narrow enough for most countries (less than 10 positions) to allow for meaningful inferences to be drawn.

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 reasonably narrow confidence intervals for the majority of the countries' ranks (less than ±4 positions for about 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 88% of the countries and the rank intervals are ±5 positions for 82% of the countries. Similarly, the Output rank is close to the median rank (less than two positions away) for 85% of the countries, and the rank intervals are ±5 positions for 79% of the countries.

Overall, country ranks in GTCI and its two sub-indices are fairly robust to changes in the pillar weights, the imputation method, full or partial normalisation, 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 8,000 scenarios) in order to better appreciate the robustness of these ranks to the computation methodology.

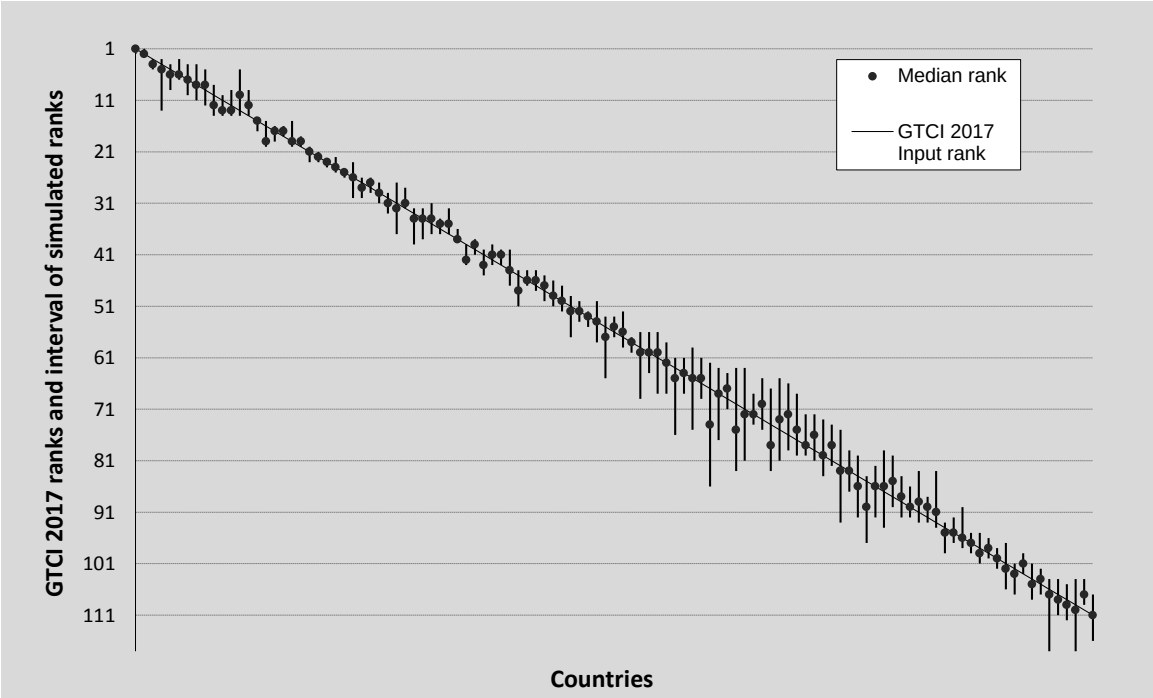
Figure 1a: Robustness analysis (GTCI rank vs. median rank, 90% confidence intervals)



Source: Becker, Saisana, and Domínguez-Torreiro, European Commission Joint Research Centre (2017).
Notes: The Spearman rank correlation between the median rank and the GTCI 2017 rank is 0.999. Median ranks and intervals are calculated over 8,000 simulated scenarios combining random weights, imputation versus no imputation of missing values, and geometric versus arithmetic average at the pillar level.

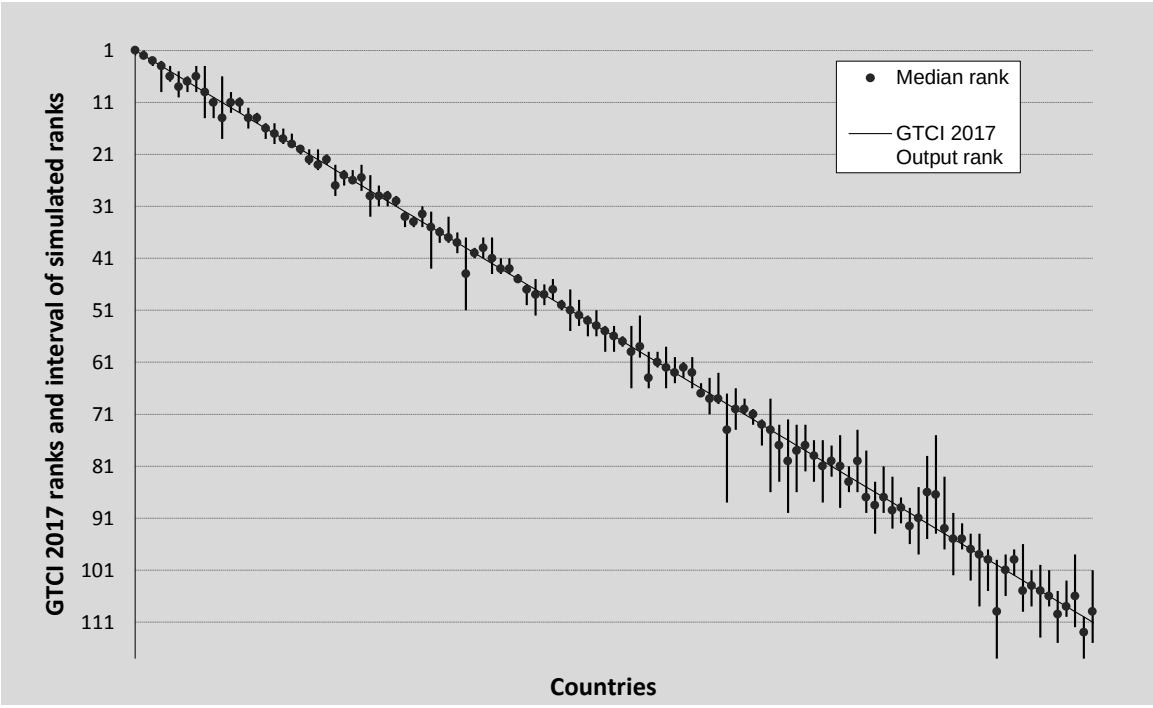
[[NEIL: vertical axis label – change "interval" to "intervals" for figures 1a, 1b, 1c]]

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



Source: Becker, Saisana, and Domínguez-Torreiro, European Commission Joint Research Centre (2017).
Notes: The Spearman rank correlation between the median rank and the GTCI 2017 Input rank is 0.999. Median ranks and intervals are calculated over 8,000 simulated scenarios combining random weights, imputation versus no imputation of missing values, and geometric versus arithmetic average at the pillar level

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



Source: Becker, Saisana, and Domínguez-Torreiro, European Commission Joint Research Centre (2017).
Notes: The Spearman rank correlation between the median rank and the GTCI 2017 Output rank is 0.998. Median ranks and intervals are calculated over 8,000 simulated scenarios combining random weights, imputation versus no imputation of missing values, and geometric versus arithmetic average at the pillar level.

Table 6: Country ranks and 90% confidence intervals for GTCI 2017 and its Input/Output sub-indices

Country	*GTCI 2017*		*Input Sub-Index*		*Output Sub-Index*	
	Rank	*Interval*	*Rank*	*Interval*	*Rank*	*Interval*
Switzerland	1	[1, 2]	1	[1, 2]	2	[1, 2]
Singapore	2	[1, 2]	2	[1, 2]	1	[1, 2]
United Kingdom	3	[3, 9]	3	[3, 5]	9	[4, 14]
United States	4	[3, 7]	9	[5, 12]	3	[3, 4]
Sweden	5	[4, 7]	6	[3, 7]	7	[6, 9]
Australia	6	[3, 9]	5	[4, 9]	8	[4, 9]
Luxembourg	7	[3, 13]	4	[3, 13]	15	[13, 15]
Denmark	8	[6, 10]	7	[4, 10]	13	[10, 13]
Finland	9	[3, 12]	11	[10, 14]	4	[3, 9]
Norway	10	[6, 14]	8	[4, 11]	16	[15, 18]
Netherlands	11	[8, 14]	12	[9, 14]	12	[9, 13]
Ireland	12	[9, 13]	14	[9, 14]	14	[12, 16]
Canada	13	[11, 14]	10	[8, 14]	18	[16, 19]
New Zealand	14	[8, 15]	13	[5, 14]	17	[15, 19]
Iceland	15	[14, 17]	17	[16, 19]	10	[10, 14]
Belgium	16	[15, 17]	15	[15, 17]	23	[21, 23]
Germany	17	[14, 18]	20	[18, 20]	11	[6, 18]
Austria	18	[18, 19]	18	[16, 18]	25	[24, 27]
United Arab Emirates	19	[18, 27]	16	[15, 20]	35	[32, 43]
Estonia	20	[18, 23]	23	[23, 24]	6	[5, 10]
Qatar	21	[19, 31]	19	[15, 20]	39	[37, 51]
Japan	22	[19, 24]	21	[20, 23]	27	[23, 28]
Czech Republic	23	[20, 24]	22	[21, 23]	22	[20, 24]
France	24	[20, 24]	24	[22, 25]	19	[17, 19]
Israel	25	[21, 27]	34	[32, 38]	5	[4, 7]
Malta	26	[24, 29]	28	[26, 29]	24	[23, 29]
Slovenia	27	[25, 30]	37	[32, 37]	20	[20, 21]
Malaysia	28	[26, 33]	27	[26, 30]	31	[29, 31]
South Korea	29	[26, 35]	33	[32, 39]	26	[24, 26]
Cyprus	30	[27, 33]	38	[36, 38]	21	[20, 23]
Portugal	31	[27, 33]	25	[25, 26]	44	[41, 44]
Latvia	32	[30, 36]	36	[34, 37]	30	[28, 31]
Lithuania	33	[31, 36]	30	[29, 33]	37	[33, 38]

Country	*GTCI 2017*		*Input Sub-Index*		*Output Sub-Index*	
	Rank	*Interval*	*Rank*	*Interval*	*Rank*	*Interval*
Chile	34	[31, 36]	29	[27, 31]	41	[37, 41]
Spain	35	[32, 37]	32	[28, 32]	40	[39, 41]
Barbados	36	[30, 41]	26	[23, 30]	53	[52, 56]
Slovakia	37	[33, 39]	43	[40, 43]	29	[27, 31]
Poland	38	[37, 40]	42	[39, 43]	33	[33, 35]
Costa Rica	39	[36, 42]	35	[31, 37]	48	[46, 50]
Italy	40	[37, 42]	44	[40, 47]	34	[31, 35]
Hungary	41	[38, 43]	46	[44, 47]	32	[32, 35]
Saudi Arabia	42	[41, 46]	39	[39, 43]	52	[49, 54]
Greece	43	[41, 45]	47	[44, 48]	38	[36, 40]
Montenegro	44	[41, 48]	53	[52, 55]	28	[25, 33]
Croatia	45	[42, 48]	50	[47, 52]	36	[35, 38]
Mauritius	46	[44, 53]	41	[40, 45]	60	[59, 66]
Bahrain	47	[40, 58]	31	[27, 37]	84	[74, 86]
Panama	48	[45, 54]	51	[49, 57]	47	[45, 52]
Bulgaria	49	[45, 51]	52	[50, 54]	45	[44, 45]
Macedonia, FYR	50	[47, 53]	49	[46, 51]	54	[51, 56]
Uruguay	51	[45, 57]	40	[38, 41]	78	[73, 82]
Philippines	52	[47, 55]	58	[57, 60]	43	[41, 44]
Kazakhstan	53	[52, 61]	55	[53, 65]	55	[54, 59]
China	54	[49, 62]	60	[56, 64]	51	[47, 55]
Romania	55	[52, 58]	56	[53, 57]	57	[56, 58]
Russia	56	[49, 62]	68	[63, 77]	42	[37, 44]
Kuwait	57	[51, 71]	48	[45, 50]	82	[75, 89]
Jordan	58	[54, 63]	59	[56, 69]	56	[54, 59]
Oman	59	[52, 77]	45	[44, 51]	92	[79, 95]
Serbia	60	[56, 66]	79	[72, 81]	46	[46, 50]
Turkey	61	[57, 70]	63	[61, 76]	62	[58, 66]
Lebanon	62	[58, 70]	81	[74, 82]	50	[49, 51]
Botswana	63	[57, 73]	54	[50, 58]	77	[73, 86]
Argentina	64	[57, 73]	61	[56, 68]	67	[64, 71]
Armenia	65	[58, 76]	82	[75, 93]	49	[45, 49]
Azerbaijan	66	[59, 76]	70	[63, 83]	58	[54, 66]
South Africa	67	[55, 71]	65	[59, 75]	61	[59, 62]
Jamaica	68	[58, 72]	62	[58, 68]	68	[63, 69]
Ukraine	69	[59, 73]	75	[65, 81]	59	[52, 60]
Georgia	70	[63, 79]	67	[62, 86]	66	[65, 67]
Colombia	71	[65, 74]	64	[61, 68]	72	[70, 73]
Mongolia	72	[66, 74]	69	[64, 71]	70	[66, 74]
Thailand	73	[64, 78]	57	[52, 59]	85	[78, 90]

Country	*GTCI 2017*		*Input Sub-Index*		*Output Sub-Index*	
	Rank	*Interval*	*Rank*	*Interval*	*Rank*	*Interval*
Mexico	74	[67, 76]	73	[65, 75]	71	[68, 71]
Moldova	75	[68, 78]	83	[79, 87]	65	[60, 66]
Namibia	76	[71, 82]	71	[63, 81]	80	[76, 88]
Tunisia	77	[71, 82]	89	[84, 92]	63	[60, 65]
Bosnia and Herzegovina	78	[73, 91]	84	[80, 92]	69	[67, 88]
Ecuador	79	[74, 86]	76	[66, 79]	86	[84, 94]
Albania	80	[76, 90]	72	[68, 74]	91	[85, 98]
Brazil	81	[75, 89]	66	[61, 69]	95	[90, 102]
Sri Lanka	82	[76, 88]	86	[82, 92]	74	[68, 86]
Peru	83	[78, 89]	80	[73, 84]	88	[83, 93]
Dominican Republic	84	[80, 88]	78	[72, 80]	90	[89, 96]
Guatemala	85	[80, 90]	77	[68, 80]	96	[92, 97]
Vietnam	86	[78, 89]	90	[86, 92]	75	[73, 84]
Kyrgyzstan	87	[80, 90]	92	[88, 93]	76	[72, 90]
Egypt	88	[78, 98]	101	[97, 106]	64	[61, 64]
Zambia	89	[79, 96]	87	[79, 94]	94	[83, 97]
Indonesia	90	[85, 91]	95	[92, 97]	79	[76, 84]
Rwanda	91	[84, 98]	74	[67, 83]	113	[103, 113]
India	92	[85, 98]	103	[99, 103]	73	[72, 77]
Honduras	93	[90, 98]	93	[83, 94]	99	[97, 105]
Paraguay	94	[90, 106]	91	[83, 93]	105	[100, 114]
El Salvador	95	[93, 118]	88	[80, 90]	110	[110, 118]
Morocco	96	[91, 101]	94	[93, 99]	97	[94, 103]
Kenya	97	[87, 99]	98	[95, 101]	93	[75, 94]
Bhutan	98	[93, 110]	85	[84, 97]	114	[111, 118]
Nicaragua	99	[97, 118]	99	[96, 100]	100	[99, 118]
Senegal	100	[94, 103]	97	[95, 99]	102	[97, 102]
Lesotho	101	[95, 105]	100	[98, 102]	98	[94, 108]
Ghana	102	[97, 106]	96	[90, 98]	107	[105, 115]
Iran	103	[93, 118]	106	[104, 118]	81	[77, 83]
Bolivia	104	[93, 105]	105	[102, 107]	87	[81, 90]
Venezuela	105	[95, 118]	109	[104, 118]	83	[81, 86]
Uganda	106	[101, 109]	104	[101, 108]	104	[101, 108]
Algeria	107	[102, 110]	107	[104, 111]	101	[98, 106]
Cambodia	108	[105, 114]	102	[101, 107]	115	[112, 117]
Cameroon	109	[101, 109]	110	[104, 109]	103	[96, 109]
Ethiopia	110	[105, 117]	111	[107, 116]	108	[103, 110]
Pakistan	111	[103, 114]	116	[111, 117]	89	[87, 92]
Mali	112	[104, 113]	112	[107, 113]	109	[98, 112]
Bangladesh	113	[108, 114]	114	[110, 115]	106	[101, 108]

Country	*GTCI 2017*		*Input Sub-Index*		*Output Sub-Index*	
	Rank	*Interval*	*Rank*	*Interval*	*Rank*	*Interval*
Tanzania	114	[111, 118]	108	[105, 112]	118	[116, 118]
Mozambique	115	[111, 116]	113	[109, 114]	117	[111, 117]
Zimbabwe	116	[109, 117]	117	[113, 117]	112	[98, 112]
Burkina Faso	117	[115, 118]	115	[113, 118]	116	[113, 118]
Madagascar	118	[115, 118]	118	[118, 118]	111	[101, 115]

Source: Becker, Saisana, and Domínguez-Torreiro, European Commission Joint Research Centre (2017).

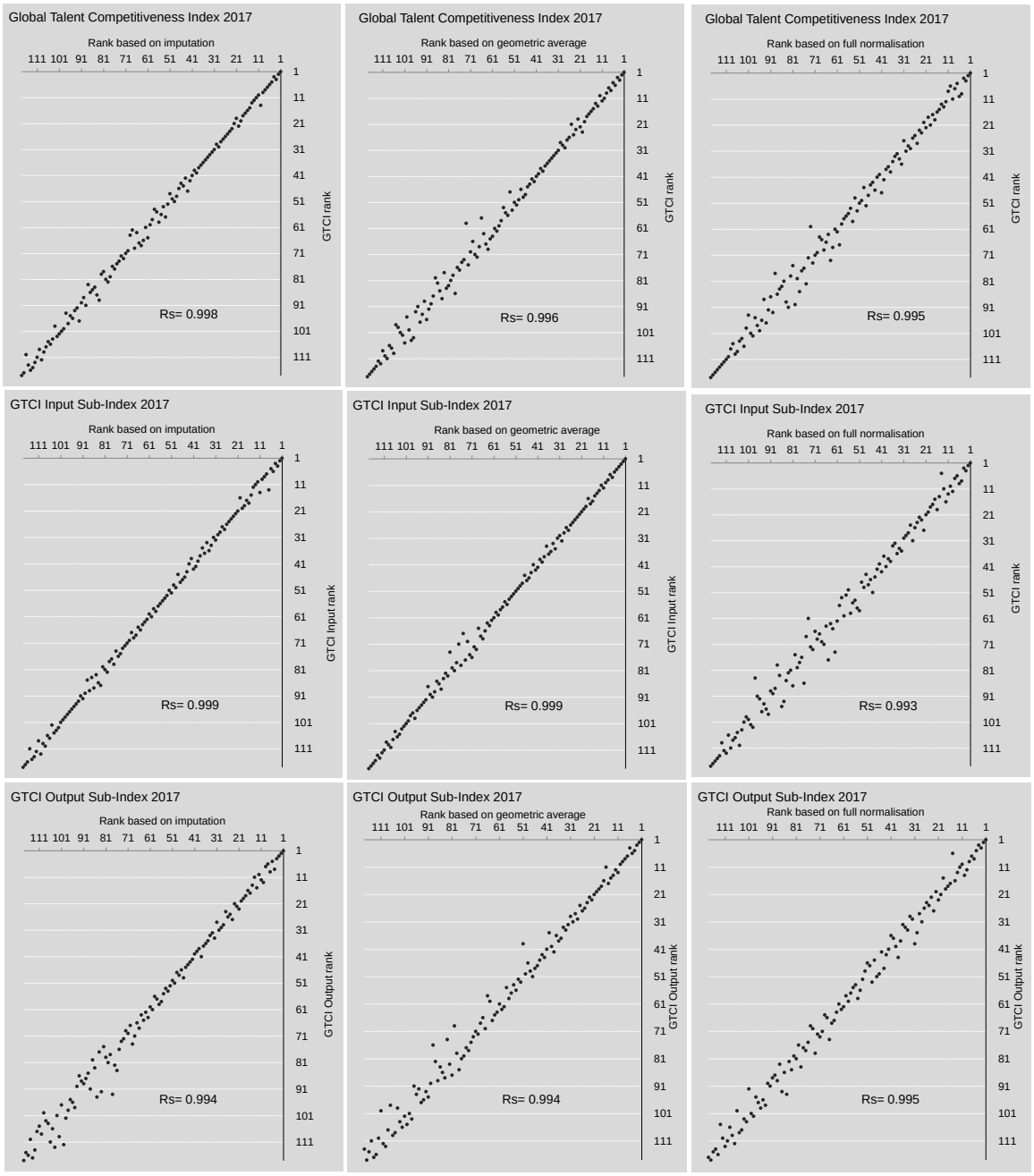
[b]Sensitivity Analysis Results

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 both sub-index 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 using partial versus full normalisation (given that a lower rank correlation indicates greater sensitivity). This choice has the largest impact on differences in ranking for the Input sub-index, and roughly equally for GTCI 2017 overall and the Output sub-index. For example, in the most extreme case, a country increased by three positions in the GTCI ranking when EM imputation is applied, falls by 14 positions if geometric aggregation (as opposed to arithmetic) is applied, and moves by zero places when full normalisation is used. 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.[6]

Overall, given the fairly modest ranges of uncertainty on the final rankings, the JRC recommendation is not to alter the GTCI methodology at this point, but to consider country ranks in GTCI 2017 and in the Input and Output sub-indices within the 90% confidence intervals, as 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 90% of the countries included in GTCI, their ranks in the overall GTCI 2017 and the Input and Output sub-indices are the result of the underlying data and not modelling choices.[7] It might be worthwhile, however, to consider the possibility of normalising all variables onto the same scale in future releases of the index, unless there is a strong conceptual justification for doing otherwise.

Figure 2: Sensitivity analysis: Impact of modelling choices



Source: Becker, Saisana, and Domínguez-Torreiro, European Commission Joint Research Centre (2017).
Notes: r_s represents the Spearman rank correlation coefficient.
[[NEIL: change Rs in all tables to r_s]]

[A]Conclusions

The JRC analysis suggests that the conceptualised multi-level structure of GTCI 2017 is statistically coherent and balanced (i.e., not dominated by any pillar or sub-pillar; all variables 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 the GTCI model is statistically reliable in its current form as the simple average of the six pillars (as measured by a very high Cronbach-alpha value of 0.95, 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 concern mainly three out of the 65 variables, namely 1.3.1 Ease of hiring, 4.1.2 Taxation, and 5.2.4 Skills gap as major constraint. Although present in the conceptual framework, these variables do not contribute significantly to the variation of the GTCI country scores and, consequently, do not have an impact on the GTCI rankings. A further possible change might be to consider normalising all variables to the same scale, given that this has been identified as the most sensitive of the assumptions. However, it should be noted that the overall uncertainty in rankings remains relatively low.

On the whole, the analysis of the correlations at the sub-pillar level reveals that the statistical structure of the GTCI model is coherent with its conceptual framework, given that sub-pillars correlate strongly with their respective pillars. Furthermore, all pillars correlate strongly and fairly evenly with GTCI itself, which indicates that the framework is well balanced.

GTCI and both the Input and Output sub-indices are relatively robust to methodological assumptions related to the estimation of missing data, weighting, and aggregation formula. It is reassuring that for over 90% of the countries included in the GTCI report, 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 the report, although some caution may be needed for a few countries. Note that perfect robustness would have been undesirable because this would have implied that the GTCI components are perfectly correlated and hence redundant, which is not the case for GTCI 2017. In fact, one way in which GTCI helps 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 around 70% 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 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 2017, subject to some minor hints for future releases, in reliably identifying weaknesses and best practices and ultimately monitoring national performance in human capital and competitiveness issues around the world.

[A]References

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[a]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 are available at http://composite-indicators.jrc.ec.europa.eu/ (all audits were carried upon request of the index developers).

[2] OECD & EC JRC (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 (118 countries).

[4] The sub-pillars that have more than one latent dimension are: 1.3 Business and Labour Landscape, 2.2 Internal Openness, 3.2 Lifelong Learning, 5.2 Employability, and 6.1 High-Level Skills. This indicates that a notable amount of information is lost when aggregating directly the variables into sub-pillars.

[5] See Nunnally (1978).

[6] Saltelli and Funtowicz (2014).

[7] As already mentioned in the uncertainty analysis, at least 85% of the simulated median ranks for the GTCI, Input, and Output (Sub-) Indices are less than two positions away from the reported 2017 rank.