CHAPTER 6

JRC Statistical Audit of the Global Talent Competitiveness Index 2020

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Individual skills and talents, more than capital, are the driving forces that guide human beings towards the future. Since 2013, the business school INSEAD has developed the Global Talent Competitiveness Index (GTCI), which aims to summarise complex and versatile concepts related to human capital and talent competitiveness at the national scale worldwide. In so doing, it raises conceptual and practical challenges, which are discussed in the GTCI 2020 report. This chapter focuses on the practical challenges related to the data quality and the methodological choices made in the grouping of 70 variables into 14 sub-pillars, six pillars, two sub-indices, and an overall index for 132 countries.

The GTCI 2020 has a very high statistical reliability (it has a Cronbach's alpha value of 0.97) and captures the single latent phenomenon underlying the six main dimensions of the GTCI conceptual framework. Country ranks are also robust to methodological choices related to the treatment of missing values, weighting, and aggregation rule (with a shift less than or equal to ±2 positions with respect to the simulated median in 90% of the countries). The added value of the GTCI 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, the overall ranking differs from any of the six pillar rankings by 10 positions or more in at least 30% of the countries included in this year's GTCI.

The European Commission's Competence Centre on Composite Indicators and Scoreboards at the Joint Research Centre (JRC) has been invited to assess the statistical properties of the GTCI each year since its first release in 2013. Thus this audit represents the seventh analysis of the GTCI performed by the JRC. Overall, the JRC concluded that the GTCI 2020 is robust and reliable, with a statistically coherent and balanced multi-level structure. The analysis has been performed in order to ensure the transparency and reliability of the GTCI and thus to enable policymakers to derive more accurate and meaningful conclusions about human capital and national competitiveness, and potentially to guide their choices on priority setting and policy formulation.

As in the previous audits, the present JRC assessment of the GTCI 2020 focuses on two main issues: (1) the statistical coherence of the structure and (2) the impact of key modelling assumptions on the GTCI scores and ranks.[1] The JRC analysis complements the reported country rankings for the 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, the missing data estimation, weights, and aggregation formula). Furthermore, the JRC analysis includes an assessment of the added value of the GTCI and a comparison with other global measures of human capital, competitiveness, and innovation. The version of the GTCI model presented in 2020 has many aspects in common with these other global measures. Nevertheless, compared with the other indices, the GTCI 2020 is proven to offer additional insights into nations' human capital and competitiveness.

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 the GTCI will mostly, though not exclusively, be based on correlations, the correspondence of the GTCI to a real-world phenomenon needs to be critically addressed because *'correlations do not necessarily represent the real influence of the individual indicators on the phenomenon being measured'*.[2] The point is that the validity of the GTCI relies on the combination of both statistical and conceptual soundness. In this respect, the 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

The JRC undertook an initial assessment of the GTCI 2020 data set in September 2019. The latest GTCI model provided by the development team largely incorporated the issues identified and discussed in previous editions—in particular, the substitution of variables previously determined to be not influential on the final values of the index. No critical issues were identified in the 2020 model during this preliminary phase of the audit.

The underlying concepts and framework used to describe global talent competitiveness in the GTCI 2020 have remained essentially the same as those in the GTCI 2019, although there are some minor adjustments in this year's edition. Three variables have been excluded from the framework in the 2020 edition: Ease of hiring and Ease of redundancy (1.3.1 and 1.3.2) and Gender earnings gap (2.2.5).

On the other hand, six new variables have been included: Urban population (1.2.6), Tertiary-educated unemployment (1.3.1), and the Gender development gap (2.2.5) are inserted as an update of the excluded variables, and Rule of law (1.1.2) is an external index included in the Regulatory Landscape sub-pillar. Furthermore, Investment in emerging technologies (1.3.7) and Robot density (1.3.8) are used to form a new component, called *Technology Adoption,* of sub-pillar Business and Labour Landscape (1.3), which also contains Technology utilisation (moved from 1.2.6 last year to 1.3.6).

Following the iterative process during which the index has been fine-tuned, the current assessment of the statistical coherence in this final version of the GTCI 2020 followed four steps:

Step 1: Relevance

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.

Step 2: Data Checks

The data used are the most recently released. The cut-off year was set to 2008. 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 2020 data set comprises 132 countries and 70 variables.[3] Consequently, data availability is at least 84% 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,[4] and were treated either by winsorisation or by taking the natural logarithm (in the case of five or more outliers). In total, six indicators were treated: 1.3.8 Robot density, 2.1.3 Migrant stock, 2.1.4 International students, 2.2.5 Gender development gap, 6.1.5 Senior officials and managers, and 6.2.2 High-value exports (see Appendix I, Technical Notes, for details). In the case of Robot density, a larger share of missing data is observed. This variable is one of this year's new ones, so an improvement in its coverage in the next edition can be expected. These criteria follow the WIPO-INSEAD Global Innovation Index practice (formulated with the JRC in 2011). The variable Rule of law (1.1.2) is highly correlated with three out of four of the other variables of the Regulatory Landscape sub-pillar; this is not a critical issue, but the elimination of one of these variables should not damage the structure of the sub-pillar.

Step 3: Statistical Coherence

This section presents the JRC's analysis of the statistical coherence of the GTCI 2020, which consists of a principal component analysis to study 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 indices. This latter investigation demonstrates the added value of the GTCI both against its component pillars and vis-à-vis other relevant indices on competitiveness, innovation, and human capital.

1. Principal Component Analysis and Reliability Item 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 an eigenvalue significantly greater than 1.0)

Table 1

Statistical coherence in the GTCI: Correlations between sub-pillars and pillars

	SUB-PILLAR	ENABLE	ATTRACT	GROW	RETAIN	VOCATIONAL AND TECHNICAL SKILLS	GLOBAL KNOWLEDGE SKILLS
INPUT	1.1 Regulatory Landscape	0.95	0.85	0.87	0.89	0.84	0.83
	1.2 Market Landscape	0.95	0.77	0.89	0.92	0.88	0.87
	1.3 Business and Labour Landscape	0.93	0.85	0.86	0.80	0.84	0.77
	2.1 External Openness	0.81	0.93	0.72	0.68	0.70	0.64
	2.2 Internal Openness	0.80	0.90	0.76	0.75	0.74	0.65
	3.1 Formal Education	0.77	0.55	0.88	0.82	0.74	0.84
	3.2 Lifelong Learning	0.86	0.81	0.94	0.78	0.81	0.76
	3.3 Access to Growth Opportunities	0.92	0.85	0.93	0.84	0.85	0.82
	4.1 Sustainability	0.94	0.83	0.91	0.95	0.88	0.86
	4.2 Lifestyle	0.81	0.65	0.77	0.95	0.83	0.82
OUTPUT	5.1 Mid-Level Skills	0.72	0.56	0.66	0.80	0.86	0.74
	5.2 Employability	0.81	0.77	0.82	0.71	0.81	0.69
	6.1 High-Level Skills	0.84	0.68	0.84	0.87	0.86	0.95
	6.2 Talent Impact	0.83	0.66	0.85	0.82	0.76	0.95

Source: European Commission Joint Research Centre (2019).

Note: The values are the bivariate Pearson correlation coefficients (n = 132). Shaded values represent the coefficients between sub-pillars and the respective pillar based on the GTCI conceptual framework. Values greater than 0.70 within the shaded areas are desirable as they imply that the pillar captures at least 50% (≈ 0.70 × 0.70) of the variation in the underlying sub-pillars and vice-versa.

in the great majority (12) of the 14 sub-pillars, which captures 42% (Internal Openness) to 89% (Regulatory Landscape) of the total variance in the underlying variables. A more detailed analysis of the correlation structure within and across the six pillars confirms the expectation that the GTCI sub-pillars are more correlated with their own pillar than with any other. This result suggests that the allocation of sub-pillars to pillars in the GTCI is consistent both from conceptual and statistical perspectives. Furthermore, all correlations within a pillar are positive, strong, and similar and well above 0.7, which suggests that roughly 50% (or more) of the variance in the GTCI pillar scores can be explained by an underlying sub-pillar (see Table 1). These results suggest that the conceptual grouping of GTCI sub-pillars into pillars is statistically confirmed and that the six pillars are statistically well balanced.

The six pillars also share a single statistical dimension that summarises 88% of the total variance, and the six loadings (correlation coefficients) are quite high and very similar to each other ranging from 0.87 (Attract pillar) to 0.98 (Enable pillar). The latter suggests that the six pillars contribute in a balanced way to the variation of the GTCI scores, as envisaged by the development team: all six pillars are assigned equal weights. The reliability of the GTCI, measured by the Cronbach's alpha value, is very high at 0.97—well above the 0.70 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 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 twice as important as 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 0.96, respectively, which suggests that the sub-indices are effectively placed on an 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 the GTCI has a balanced structure, whereby all six pillars are equally important in determining the variation in the GTCI scores.

2. Importance of the Variables in the GTCI Framework

The 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.[6]

This section assesses the importance of all 70 variables at the various levels of aggregation in the GTCI structure. The squared Pearson correlation coefficient (otherwise known as the *coefficient of determination* R^2) is used as a statistical measure of the importance of variables in an index. 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.

Table 2

Importance measures for the variables at the various levels of the GTCI structure

PILLAR	SUB-PILLAR	VARIABLE NAME	SUB-PILLAR	PILLAR	INPUT/OUTPUT	GTCI INDEX
1. ENABLE	1.1 Regulatory Landscape	1.1.1 Government effectiveness	95%	93%	90%	90%
		1.1.2 Rule of law	96%	89%	85%	84%
		1.1.3. Political stability	70%	53%	52%	48%
		1.1.4 Regulatory quality	92%	88%	86%	85%
		1.1.5 Corruption	93%	84%	82%	80%
	1.2 Market Landscape	1.2.1 Competition intensity	54%	49%	43%	42%
		1.2.2 Ease of doing business	65%	65%	61%	63%
		1.2.3 Cluster development	63%	65%	61%	60%
		1.2.4 R&D expenditure	63%	59%	54%	57%
		1.2.5 ICT infrastructure	80%	70%	75%	77%
		1.2.6 Urban population	57%	41%	47%	46%
	1.3 Business Landscape	1.3.1 Tertiary-educated unemployment	31%	25%	26%	24%
		1.3.2 Active labour market policies	76%	76%	74%	75%
		1.3.3 Labour-employer cooperation	75%	59%	56%	54%
		1.3.4 Professional management	80%	75%	74%	72%
		1.3.5 Relationship of pay to productivity	79%	62%	58%	59%
		1.3.6 Technology utilisation	82%	83%	80%	79%
		1.3.7 Investment in emerging technologies	84%	73%	70%	70%
		1.3.8 Robot density	45%	49%	41%	42%
2. ATTRACT	2.1 External Openness	2.1.1 FDI and technology transfer	65%	63%	67%	64%
		2.1.2 Prevalence of foreign ownership	60%	52%	42%	38%
		2.1.3 Migrant stock	52%	46%	38%	37%
		2.1.4 International students	67%	56%	40%	39%
		2.1.5 Brain gain	69%	62%	45%	41%
	2.2 Internal Openness	2.2.1 Tolerance of minorities	56%	40%	29%	26%
		2.2.2 Tolerance of immigrants	26%	26%	13%	10%
		2.2.3 Social mobility	54%	70%	68%	66%
		2.2.4 Female graduates	27%	12%	16%	16%
		2.2.5 Gender development gap	43%	23%	25%	25%
		2.2.6 Leadership opportunities for women	46%	46%	39%	39%

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The results of this analysis appear in Table 2. Examining the importance measures of the 70 variables; almost all variables are important at the various levels of aggregation.

For example, country variations in 1.1.1 Government effectiveness scores can capture 95% of the variance in the respective sub-pillar score (Regulatory Landscape), 93% of the variance in the respective pillar (Enable), and 90% of the variance in both the Input sub-index and the overall GTCI scores. Similarly, country variations in 2.1.1 Foreign direct investment (FDI) and technology transfer scores can capture 65%, 63%, 67%, and 64% of the variance in the External Openness, Attract, Input, and GTCI scores, respectively.

Two variables in the 2020 data set have a very low impact on the GTCI variance (10% or less): 3.1.3 Tertiary education expenditure and 3.2.2 Prevalence of training in firms. Therefore these variables are not found to be important at the overall index level in the 2020 framework.[7] Five variables were flagged last year, including the two mentioned above; the other three have been removed from the framework this year (1.3.1 Ease of hiring, 1.3.2 Ease of redundancy, and 2.2.5 Gender earnings gap). That said, and given that these two variables (3.1.3 and 3.2.2) are influential at the first and second aggregation levels (sub-pillars and pillars), their inclusion in the GTCI framework is corroborated by the analysis. The JRC recommendation to the GTCI development

Table 2 *(continued)*

Importance measures for the variables at the various levels of the GTCI structure

PILLAR	SUB-PILLAR	VARIABLE NAME	SUB-PILLAR	PILLAR	INPUT/OUTPUT	GTCI INDEX
3. GROW	3.1 Formal Education	3.1.1 Vocational enrolment	45%	25%	17%	18%
		3.1.2 Tertiary enrolment	71%	47%	45%	49%
		3.1.3 Tertiary education expenditure	25%	17%	11%	10%
		3.1.4 Reading, maths, and science	70%	55%	53%	57%
		3.1.5 University ranking	66%	67%	55%	56%
	3.2 Lifelong Learning	3.2.1 Quality of management schools	78%	71%	66%	65%
		3.2.2 Prevalence of training in firms	43%	22%	7%	6%
		3.2.3 Employee development	80%	76%	77%	75%
	3.3 Access to Growth Opportunities	3.3.1 Delegation of authority	81%	72%	72%	70%
		3.3.2 Personal rights	40%	32%	33%	32%
		3.3.3 Use of virtual social networks	60%	47%	53%	53%
		3.3.4 Use of virtual professional networks	60%	60%	58%	57%
		3.3.5 Collaboration within organizations	74%	65%	63%	64%
		3.3.6 Collaboration across organizations	62%	56%	54%	54%
4. RETAIN	4.1 Sustainability	4.1.1 Pension system	65%	78%	60%	64%
		4.1.2 Social protection	85%	72%	77%	74%
		4.1.3 Brain retention	58%	36%	54%	51%
	4.2 Lifestyle	4.2.1 Environmental performance	83%	80%	69%	70%
		4.2.2 Personal safety	60%	61%	59%	58%
		4.2.3 Physician density	80%	66%	47%	51%
		4.2.4 Sanitation	76%	63%	46%	48%
5. VOCATIONAL AND TECHNICAL SKILLS	5.1 Mid-level Skills	5.1.1 Workforce with secondary education	72%	36%	29%	20%
		5.1.2 Population with secondary education	73%	40%	33%	24%
		5.1.3 Technicians and associate professionals	77%	71%	72%	67%
		5.1.4 Labour productivity per employee	52%	65%	67%	72%
	5.2 Employability	5.2.1 Ease of finding skilled employees	81%	42%	36%	40%
		5.2.2 Relevance of education system to the economy	89%	59%	53%	57%
		5.2.3 Skills matching with secondary education	89%	74%	69%	73%
		5.2.4 Skills matching with tertiary education	91%	58%	54%	62%
6. GLOBAL KNOWLEDGE SKILLS	6.1 Higher-Level Skills	6.1.1 Workforce with tertiary education	86%	77%	74%	66%
		6.1.2 Population with tertiary education	78%	64%	59%	52%
		6.1.3 Professionals	76%	76%	73%	68%
		6.1.4 Researchers	77%	77%	77%	73%
		6.1.5 Senior officials and managers	49%	43%	40%	34%
		6.1.6 Availability of scientists and engineers	52%	49%	57%	56%
	6.2 Talent Impact	6.2.1 Innovation output	81%	81%	76%	74%
		6.2.2 High-value exports	44%	36%	27%	23%
		6.2.3 New product entrepreneurial activity	40%	30%	28%	27%
		6.2.4 New business density	43%	34%	28%	27%
		6.2.5 Scientific journal articles	72%	77%	76%	75%

Source: European Commission Joint Research Centre (2019).

Note: The values are the squared Pearson correlation coefficients, expressed as percentages (n = 132 countries). The few cases where coefficients are 10% or less are in a lighter shade.

Table 3
Distribution of differences between pillar and GTCI rankings

	GTCI INPUT SUB-INDEX				GTCI OUTPUT SUB-INDEX	
Rank differences	Enable	Attract	Grow	Retain	Vocational and Technical Skills	Global Knowledge Skills
More than 30 positions	2%	14%	8%	2%	5%	10%
20 to 29 positions	9%	22%	8%	7%	8%	7%
10 to 19 positions	19%	20%	20%	25%	27%	32%
10 or more positions*	**29%**	**57%**	**36%**	**33%**	**41%**	**48%**
5 to 9 positions	22%	22%	20%	30%	26%	24%
Less than 5 positions	44%	19%	39%	32%	27%	24%
0 positions	5%	2%	5%	5%	7%	3%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Source: European Commission Joint Research Centre (2019).
Note: * This row is the rounded sum of the prior three rows.

team is to carefully monitor how these two variables behave in the coming releases of the index and eventually to fine-tune the framework in this respect.

3. 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 the GTCI. In fact, the overall GTCI 2020 ranking differs from any of the six pillar rankings by 10 positions or more in at least one-third of the 132 countries included in the 2020 edition, peaking at 57% of the countries in the case of the Attract pillar (see Table 3). 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 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.

In addition, the GTCI 2020 is compared with the World Economic Forum's 2018 Global Competitiveness Index; Cornell University, INSEAD, and WIPO's 2019 Global Innovation Index; and the World Bank's Human Capital Index, using the data extracted from these projects' websites. The rank correlation between GTCI 2020 with all three indices is substantially high (correlation ≈ 0.9), which suggests that the GTCI framework has many aspects in common with the frameworks on global competitiveness, global innovation, and human capital. Nevertheless, looking at the shifts in rankings (see Table 4), 33%, 43%, and 51% of the countries included in the GTCI 2020 that feature in the other three indices differ by 10 or more rank positions from those of the three selected international indices. This indicates that the GTCI 2020 offers additional insights into nations' human capital and competitiveness compared to the 2018 Global Competitiveness Index, the 2018 Human Capital Index, and the 2019 Global Innovation Index.

Step 4: Qualitative Review

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

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

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, 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) and driven by statistical analysis (e.g., treatment of outliers) or simplicity (e.g., no imputation of missing data). The robustness analysis aims 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.

As suggested in the relevant literature on composite indicators,[8] the robustness assessment of the GTCI was based on a combination of a Monte Carlo experiment and a multi-modelling approach that dealt with three issues: pillar weights, missing data, and the aggregation formula. In general, the uncertainty analysis aims to respond to some extent 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.

Table 4

Distribution of differences between the GTCI 2020 and other international rankings

Rank differences with respect to the GTCI 2020	2018 Global Competitiveness Index (World Economic Forum)	2019 Global Innovation Index (Cornell, INSEAD, WIPO)	2018 Global Human Capital Index (World Bank)
More than 30 positions	2%	9%	7%
20 to 29 positions	9%	13%	16%
10 to 19 positions	22%	20%	29%
10 or more positions*	**33%**	**43%**	**51%**
5 to 9 positions	23%	21%	20%
Less than 5 positions	36%	31%	25%
0 positions	8%	6%	4%
Total	**100%**	**100%**	**100%**
Pearson correlation coefficient with the GTCI	0.96	0.93	0.88
Spearman rank correlation coefficient with the GTCI	0.96	0.90	0.90
Countries in common with the GTCI	129	120	122

Source: European Commission Joint Research Centre (2019).
Notes: The comparison between the GTCI and the other indices was based on the common set of countries. *This row is the rounded sum of the prior three rows.

Table 5

Uncertainty analysis for the GTCI 2020: Missing data, aggregation, and pillar weights

		REFERENCE	ALTERNATIVE
I. Uncertainty in the treatment of missing values		**No estimation of missing data**	**Expectation Maximisation (EM)**
II. Uncertainty in the aggregation formula at pillar level		**Arithmetic average**	**Geometric average**
III. Uncertainty in the weights			
GTCI sub-index	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	0.50	U[0.40,0.60]
	Global Knowledge Skills	0.50	U[0.40,0.60]

Source: European Commission Joint Research Centre (2019).

While the term *multi-modelling* refers to testing alternative assumptions—that is, alternative aggregation methods and missing data estimation methods—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 the GTCI that places equal importance on all six pillars. Given these considerations, the 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 the 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 5.3% of data were missing in the data set of 132 countries for all 70 variables). The 'no imputation' choice, which is common in similar contexts, might encourage countries not to report low data values. The consequence of the 'no imputation' choice in an arithmetic average is that it is equivalent to replacing an indicator's missing value for a given country with the respective mean of the other indicators that are being aggregated. Hence the available data (indicators) in the incomplete pillar may dominate, sometimes biasing the ranks up or down. To test the impact of this assumption, the JRC also estimated missing data using the Expectation Maximisation (EM) algorithm.[9]

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 for a few variables can compensate for a comparative disadvantage for many variables.[10] Despite the

arithmetic averaging formula receiving statistical support for the development of the GTCI, as discussed in the previous section, the geometric average was considered as a possible alternative. This alternative average 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.

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 the GTCI and each of the two sub-indices (see Table 5 for a summary of the uncertainties considered in the GTCI 2020).

Uncertainty Analysis Results

The main results of the robustness analysis are shown in Figures 1a–1c, with median ranks and 90% confidence intervals computed across the 4,000 Monte Carlo simulations for the GTCI and the two sub-indices. Countries are ordered from best to worst according to their reference rank, the blue dot being the simulated median rank. Error bars represent, for each country, the interval containing 90% of all simulations. For full transparency and information, Table 6 reports the published rankings and the simulated intervals (90% of the 4,000 scenarios) 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 or equal to 10 positions) to allow 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 (differing by two positions or less) for 90% of the countries suggests that the GTCI is a suitable summary measure. Furthermore, the narrow confidence intervals for the majority of the countries' ranks (less than or equal to 10 positions for 93% of the countries) imply that the GTCI ranks are also, for the vast majority of the countries, robust to changes in the pillar weights, the imputation method, and the aggregation formula.

Results for the Input and Output sub-indices are also robust and representative of the plurality of scenarios considered. The Input rank is close to the median rank (less than or equal to two positions away) for 93% of the countries, and the rank intervals are less than or equal to 10 positions for 89% of the countries. Similarly, the Output rank is close to the median rank (less than or equal to two positions away) for 80% of the countries, and the rank intervals are less than or equal to 10 positions for 79% of the countries.

Overall, country ranks in the GTCI and its two sub-indices are fairly 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.

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 the 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 the GTCI).

The most influential methodological assumption turns out to be the choice of geometric aggregation versus arithmetic aggregation, particularly in the case of the Output sub-index (given that a lower rank correlation indicates greater sensitivity). This choice has the largest impact on differences in ranking for the GTCI 2020 and the Output sub-index; it has less impact on differences for the Input sub-index. For example, in the most extreme case, Gambia and Oman fall by 14 positions in the Output ranking when geometric aggregation is applied, yet the two countries improve their position respectively by six and five positions if missing data are imputed with the EM algorithm. 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.[11]

Overall, the ranges of uncertainty in the final rankings are fairly modest. Consequently, the JRC recommendation is not to alter the GTCI methodology at this point, but to consider country ranks in the GTCI 2020 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 an overwhelming majority of the countries included in the GTCI, their ranks in the overall GTCI 2020 and the Input and Output sub-indices are the result of the underlying data and not of modelling choices.[12]

CONCLUSIONS

The European Institute of Business Administration INSEAD released the seventh edition of the Global Talent Competitiveness Index (GTCI) perpetuating a view to attracting attention to the growing challenges of talent attraction, development, and retention faced by countries worldwide. The JRC statistical audit has investigated the workings of the GTCI framework to assess the statistical properties of the data and the methodology used in the index construction. The JRC analysis suggests that the conceptualised structure on multiple levels of the GTCI 2020 is statistically coherent and balanced. It is 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. It shows that the GTCI is statistically reliable in its current form as the simple average of the

Figure 1a

Robustness analysis (GTCI rank vs. median rank, 90% confidence intervals)

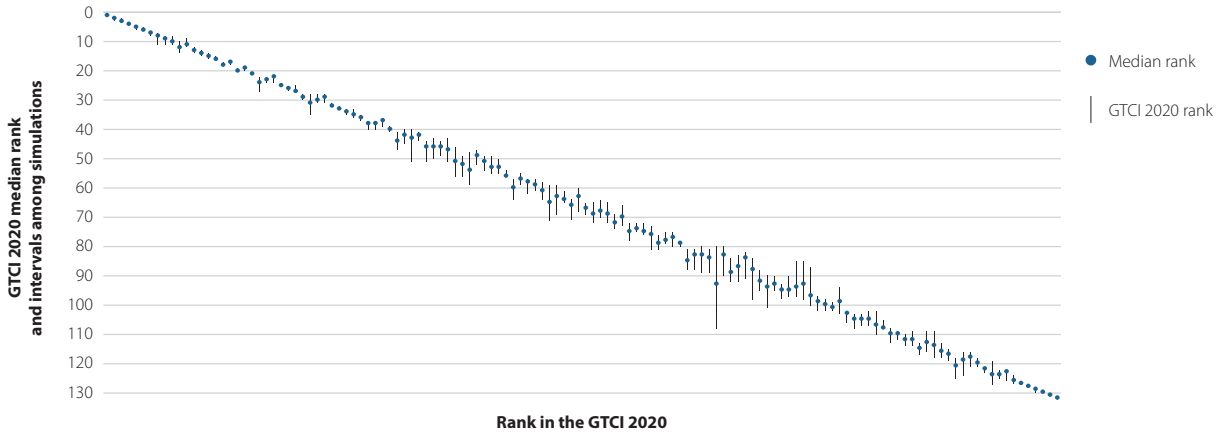


Figure 1b

Robustness analysis (Input rank vs. median rank, 90% confidence intervals)

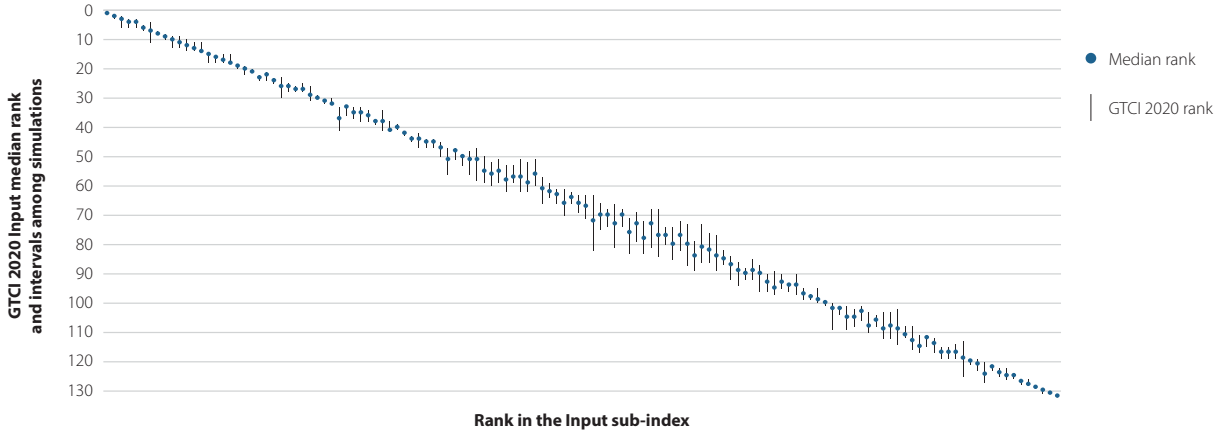
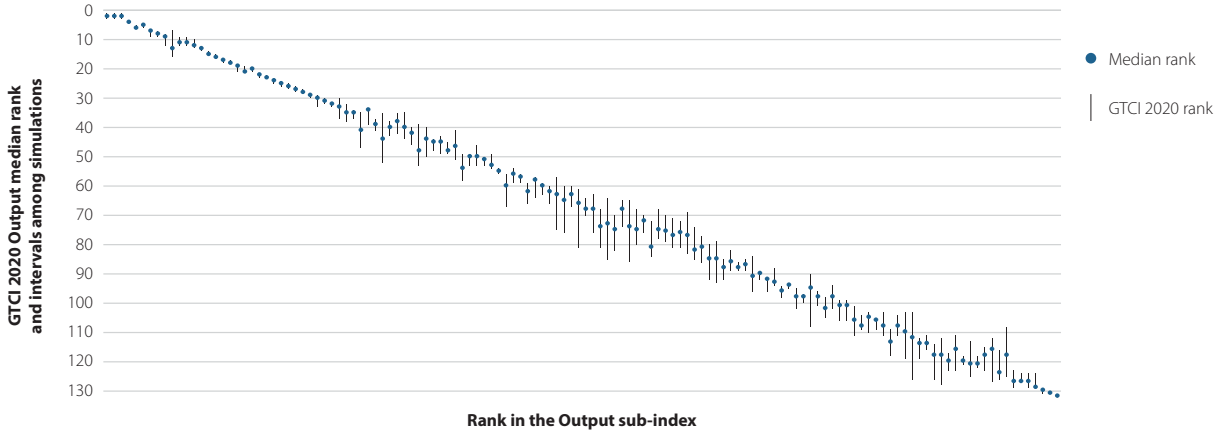


Figure 1c

Robustness analysis (Output rank vs. median rank, 90% confidence intervals)



Source: European Commission Joint Research Centre (2019).

Notes: The Spearman rank correlation between the median rank and the GTCI 2020 rank is 0.999 (n = 132); between the median rank and the GTCI 2020 Output rank it is 0.999; and between the median rank and the GTCI 2020 Input rank it 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.

Table 6

Country ranks and 90% confidence intervals for the GTCI 2020 and its Input/Output sub-indices

	GTCI 2020		INPUT SUB-INDEX		OUTPUT SUB-INDEX	
COUNTRY	RANK	INTERVAL	RANK	INTERVAL	RANK	INTERVAL
Switzerland	1	[1,1]	1	[1,1]	2	[1,3]
United States of America	2	[2,3]	2	[2,3]	1	[1,3]
Singapore	3	[2,3]	3	[2,6]	3	[1,3]
Sweden	4	[4,4]	5	[3,6]	4	[4,4]
Denmark	5	[5,6]	6	[5,7]	6	[5,6]
Netherlands	6	[5,6]	4	[3,6]	11	[9,12]
Finland	7	[7,8]	8	[7,8]	5	[5,6]
Luxembourg	8	[7,11]	7	[4,11]	14	[13,14]
Norway	9	[8,11]	10	[9,13]	8	[7,9]
Australia	10	[8,11]	9	[8,10]	15	[14,15]
Germany	11	[10,14]	12	[10,14]	10	[7,16]
United Kingdom	12	[9,12]	11	[9,13]	13	[10,13]
Canada	13	[12,14]	13	[11,14]	16	[15,16]
Iceland	14	[13,15]	16	[16,18]	9	[8,12]
Ireland	15	[14,16]	18	[15,18]	12	[9,12]
New Zealand	16	[15,16]	14	[11,14]	19	[19,21]
Austria	17	[17,18]	15	[15,18]	20	[19,21]
Belgium	18	[17,18]	17	[15,18]	18	[17,18]
Japan	19	[19,20]	19	[19,20]	22	[22,23]
Israel	20	[19,20]	23	[21,24]	7	[7,9]
France	21	[21,21]	21	[20,21]	21	[20,21]
United Arab Emirates	22	[22,27]	20	[19,22]	31	[30,32]
Malta	23	[22,24]	22	[22,24]	26	[25,27]
Estonia	24	[22,24]	27	[26,28]	17	[17,18]
Czech Republic	25	[24,25]	24	[23,25]	27	[26,28]
Malaysia	26	[26,27]	28	[25,28]	25	[24,26]
Korea, Rep.	27	[25,27]	29	[26,31]	24	[24,25]
Portugal	28	[28,30]	26	[25,28]	32	[32,33]
Qatar	29	[28,35]	25	[23,30]	39	[35,52]
Cyprus	30	[28,31]	35	[33,37]	23	[22,23]
Slovenia	31	[28,31]	31	[31,32]	28	[27,28]
Spain	32	[31,32]	30	[29,30]	41	[35,42]
Latvia	33	[32,33]	38	[37,39]	29	[29,30]
Chile	34	[33,35]	34	[33,36]	35	[34,37]
Lithuania	35	[33,36]	37	[34,38]	33	[30,37]
Italy	36	[35,37]	39	[34,41]	34	[32,38]
Costa Rica	37	[37,40]	32	[30,32]	55	[54,56]
Brunei Darussalam	38	[37,40]	43	[43,45]	30	[29,33]
Slovakia	39	[37,39]	41	[39,41]	38	[37,41]
Saudi Arabia	40	[39,41]	42	[42,43]	36	[35,47]
Bahrain	41	[41,47]	33	[33,41]	63	[57,75]
China	42	[40,45]	44	[42,47]	45	[40,50]
Oman	43	[40,51]	36	[33,38]	66	[61,81]
Poland	44	[41,44]	46	[44,47]	40	[38,43]

(continued on next page)

Table 6 *(continued)*

Country ranks and 90% confidence intervals for the GTCI 2019 and its Input/Output sub-indices

	GTCI 2020		INPUT SUB-INDEX		OUTPUT SUB-INDEX	
COUNTRY	RANK	INTERVAL	RANK	INTERVAL	RANK	INTERVAL
Azerbaijan	45	[44,51]	47	[45,50]	44	[39,53]
Philippines	46	[43,50]	52	[47,58]	42	[35,44]
Greece	47	[44,49]	51	[48,56]	43	[40,46]
Russia	48	[43,51]	60	[51,60]	37	[34,39]
Mauritius	49	[46,56]	45	[44,47]	56	[56,67]
Trinidad and Tobago	50	[49,56]	50	[49,53]	50	[49,58]
Uruguay	51	[48,59]	40	[38,41]	89	[85,89]
Hungary	52	[47,52]	53	[50,59]	46	[44,48]
Montenegro	53	[49,54]	57	[53,59]	47	[43,49]
Kazakhstan	54	[49,55]	54	[52,60]	52	[46,53]
Bulgaria	55	[50,55]	55	[51,59]	54	[49,54]
Argentina	56	[54,56]	49	[47,51]	61	[59,63]
Jamaica	57	[57,64]	59	[52,62]	59	[59,66]
Serbia	58	[55,59]	65	[62,66]	51	[49,53]
Croatia	59	[57,62]	67	[63,71]	53	[50,53]
Armenia	60	[57,61]	69	[66,75]	48	[45,49]
Jordan	61	[58,64]	56	[53,62]	67	[64,70]
Panama	62	[59,71]	48	[47,56]	88	[86,89]
Kuwait	63	[59,69]	58	[51,62]	78	[70,79]
Romania	64	[61,65]	64	[61,70]	60	[57,64]
Indonesia	65	[64,71]	62	[59,64]	69	[68,81]
Ukraine	66	[60,68]	84	[76,86]	49	[41,51]
Thailand	67	[65,69]	63	[61,66]	77	[68,78]
Georgia	68	[65,72]	73	[71,83]	57	[54,59]
Mexico	69	[64,70]	66	[63,69]	72	[65,74]
South Africa	70	[65,72]	77	[68,84]	58	[56,59]
Botswana	71	[69,74]	61	[57,66]	87	[82,89]
India	72	[66,73]	76	[68,81]	62	[60,66]
Namibia	73	[72,78]	71	[66,81]	71	[70,82]
Colombia	74	[72,75]	74	[69,79]	75	[70,76]
Mongolia	75	[72,76]	80	[72,82]	70	[64,85]
Albania	76	[73,81]	72	[68,74]	85	[79,93]
Peru	77	[76,81]	86	[82,87]	74	[68,80]
Turkey	78	[75,79]	81	[73,87]	82	[74,85]
Tunisia	79	[75,80]	90	[85,92]	65	[60,67]
Brazil	80	[78,80]	70	[68,74]	93	[88,94]
Dominican Republic	81	[81,88]	79	[74,85]	95	[93,95]
Ecuador	82	[81,88]	83	[73,86]	92	[91,96]
Sri Lanka	83	[80,89]	94	[90,95]	73	[65,86]
Tajikistan	84	[81,89]	97	[95,99]	64	[60,76]
Gambia	85	[80,108]	68	[63,82]	112	[103,126]
Moldova	86	[80,90]	89	[88,92]	83	[77,86]
Ghana	87	[84,92]	85	[77,89]	94	[94,98]
Kenya	88	[83,92]	91	[87,96]	84	[80,92]

(continued on next page)

Table 6 *(continued)*

Country ranks and 90% confidence intervals for the GTCI 2019 and its Input/Output sub-indices

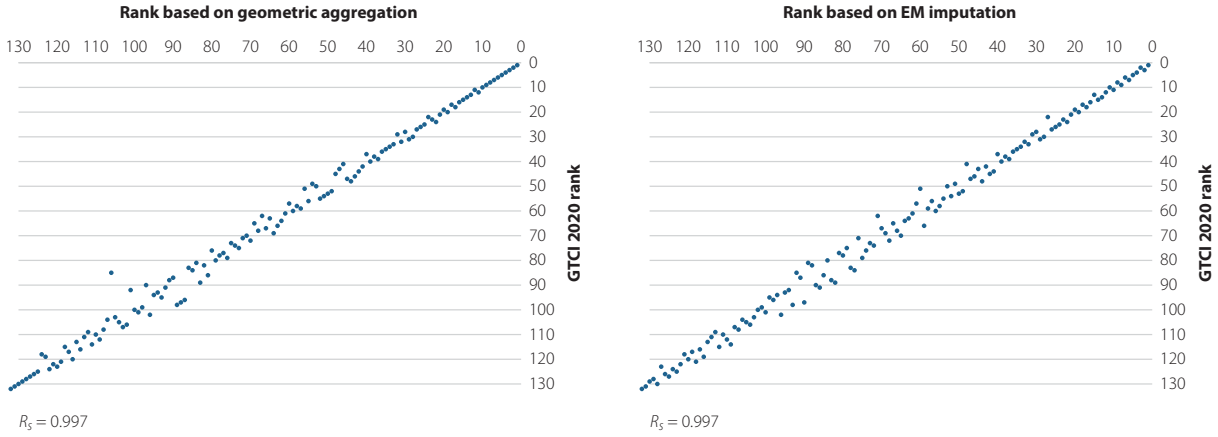
	GTCI 2020		INPUT SUB-INDEX		OUTPUT SUB-INDEX	
COUNTRY	RANK	INTERVAL	RANK	INTERVAL	RANK	INTERVAL
North Macedonia	89	[82,91]	93	[89,97]	80	[72,81]
Cabo Verde	90	[84,98]	82	[79,89]	98	[90,108]
Kyrgyzstan	91	[88,95]	98	[97,99]	76	[72,84]
Bhutan	92	[90,101]	75	[72,83]	111	[103,119]
Rwanda	93	[90,95]	78	[74,80]	110	[104,111]
Honduras	94	[93,98]	87	[84,92]	102	[99,106]
Guatemala	95	[90,97]	88	[86,94]	99	[96,101]
Viet Nam	96	[85,97]	95	[93,96]	90	[84,96]
Egypt	97	[85,98]	100	[99,101]	81	[69,83]
Lao PDR	98	[87,100]	104	[102,108]	68	[63,76]
Paraguay	99	[97,102]	92	[90,96]	106	[103,110]
Morocco	100	[98,102]	96	[90,97]	108	[103,111]
Bosnia and Herzegovina	101	[99,102]	105	[101,106]	86	[85,92]
Iran, Islamic Rep.	102	[94,103]	110	[102,114]	79	[71,81]
Zambia	103	[102,106]	101	[100,109]	100	[98,105]
Senegal	104	[103,108]	99	[95,100]	113	[112,119]
Algeria	105	[103,107]	109	[103,112]	97	[97,100]
Pakistan	106	[102,107]	114	[111,115]	91	[89,92]
Bolivia	107	[102,110]	108	[103,112]	103	[99,106]
Côte d'Ivoire	108	[105,108]	106	[103,110]	107	[105,109]
Nicaragua	109	[108,113]	102	[101,104]	117	[117,123]
El Salvador	110	[109,112]	107	[104,108]	109	[109,118]
Tanzania	111	[110,114]	103	[101,109]	119	[118,121]
Nigeria	112	[109,114]	116	[115,119]	96	[95,102]
Uganda	113	[113,117]	112	[108,116]	114	[111,116]
Venezuela, Bolivarian Rep.	114	[109,116]	119	[113,125]	101	[94,102]
Eswatini	115	[109,118]	111	[108,112]	125	[108,125]
Cameroon	116	[113,118]	120	[119,121]	104	[101,111]
Cambodia	117	[115,119]	115	[112,117]	122	[115,123]
Liberia	118	[118,125]	113	[111,117]	128	[124,129]
Lesotho	119	[116,124]	117	[115,119]	116	[112,128]
Malawi	120	[116,121]	118	[114,119]	118	[111,123]
Nepal	121	[118,121]	124	[122,125]	105	[104,109]
Burkina Faso	122	[121,123]	121	[119,123]	124	[116,126]
Ethiopia	123	[119,127]	122	[120,127]	120	[113,125]
Bangladesh	124	[122,125]	126	[124,126]	115	[114,126]
Mali	125	[123,126]	123	[121,123]	127	[124,127]
Madagascar	126	[124,127]	125	[122,126]	126	[123,129]
Zimbabwe	127	[126,127]	127	[126,128]	121	[118,122]
Mozambique	128	[128,128]	128	[126,128]	131	[130,131]
Burundi	129	[129,130]	129	[129,129]	130	[130,131]
Congo, Dem. Rep.	130	[129,130]	131	[130,131]	123	[112,127]
Angola	131	[131,131]	130	[130,131]	132	[132,132]
Yemen	132	[132,132]	132	[132,132]	129	[124,129]

Source: European Commission Joint Research Centre (2019).

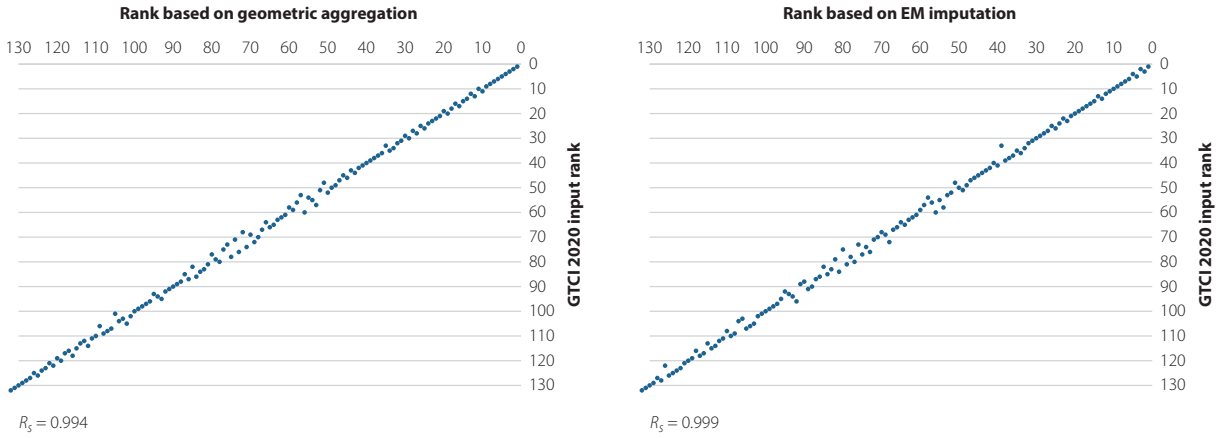
Figure 2

Sensitivity analysis: Impact of modelling choices

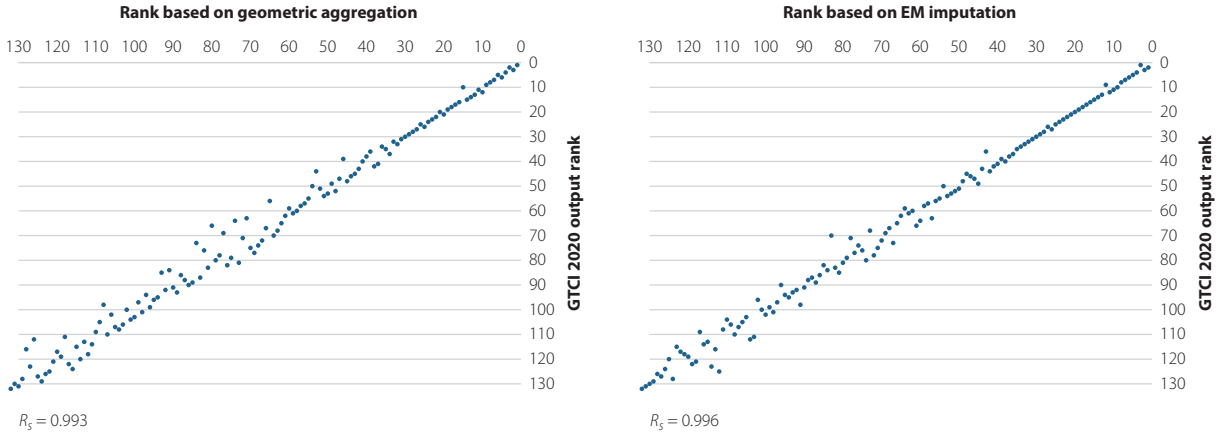
Global Talent Competitiveness 2020



GTCI 2020 Input sub-index



GTCI 2020 Output sub-index



Source: European Commission Joint Research Centre (2019).
Note: R_s represents the Spearman rank correlation coefficient (n = 132).

six pillars (as measured by a very high Cronbach's alpha value of 0.97, well above the recommended 0.70 threshold for a reliable aggregate).

Points that call for possible refinements of the GTCI framework were also identified. These refinements mainly concern two out of the 70 variables, namely 3.1.3 Tertiary education expenditure and 3.2.2 Prevalence of training in firms. Although conceptually enriching the GTCI framework—in most cases the statistical impact of these variables reaches the second aggregation level (the GTCI pillars)—their impact on the GTCI ranking is low and can explain only a small (negligible) amount of variation in the GTCI scores. It is recommended that the GTCI development team delves into the formulation of these two indicators and carefully monitor how they behave in the coming releases of the index, eventually fine-tuning the GTCI framework in this respect. Although the GTCI index shows reliable robustness to the imputation of missing data, it is suggested that particular attention be paid to the data coverage of three variables (i.e., 1.3.8 Robot density, 3.1.4 Reading, maths, and science, and 6.2.3 New product entrepreneurial activity).

On the whole, the analysis of the correlations at the sub-pillar level reveals that the statistical structure of the GTCI 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 the GTCI itself, which indicates that the framework is well balanced.

The GTCI and both sub-index country ranks are relatively robust to methodological assumptions related to the estimation of missing data, weighting, and aggregation formula. It is reassuring that for a large majority of the countries included in the 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 the GTCI, although some caution may be needed for a few countries.[13] 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 the GTCI 2020. In fact, one way in which the 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 the GTCI and each of the six pillars. In the analysis, the GTCI ranking differs from any of the six pillar rankings by 10 positions or more for at least 29% (up to almost 60%) of the countries. 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 2020, subject to some minor hints for future releases, for reliably identifying weaknesses and best practices and ultimately monitoring national performance in human capital and competitiveness issues around the world. Readers and policy analysts should also go beyond the overall GTCI scores and ranks and duly consider the individual indicators and pillars on their own merit. By doing so, country-specific strengths and challenges in attracting, developing, and retaining talent can be identified and serve as an input for data-informed policy analysis. The Global Talent Competitiveness Index cannot possibly serve as the ultimate and definitive yardstick of monitoring progress and performance on talent and competitiveness. Instead, the GTCI best represents an ongoing attempt by INSEAD to contribute to policy discussions on the very many challenges that national systems face in a world that is increasingly dependent on talent, continuously adapting the GTCI framework to reflect improved and new data sources and the theoretical advances on how to leverage talent as a tool for competitiveness.

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 out upon request of the index developers).

2 OECD & EC JRC (2008).

3 Compared to last year, eight new countries were added in the GTCI 2020: Angola, Bolivia, Burkina Faso, Cabo Verde, Côte d'Ivoire, Eswatini, Jamaica, and North Macedonia, while Lebanon is not included this year.

4 Groeneveld & Meeden (1984) set the criteria for absolute skewness above 1 and kurtosis above 3.5. The skewness criterion was relaxed herein to account for the small sample (132 countries).

5 See Nunnally (1978).

6 See Becker et al. (2017) and Paruolo et al. (2013) for discussions on why the weights assigned to the variables do not necessarily coincide with the variables' importance in an index.

7 3.2.2 Prevalence of training in firms is not found to be important at the Input sub-index.

8 Saisana et al. (2005), (2011); Saisana & Saltelli (2011); Saltelli et al. (2008); Vértesy (2016); Vértesy & Deiss (2016).

9 The Expectation-Maximization (EM) algorithm (Little & 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 maximization M-step: Given a complete-data log likelihood, the M-step finds the parameter estimates to maximize the complete-data log likelihood from the E-step. The two steps are iterated until the iterations converge.

10 Munda (2008).

11 Saltelli & Funtowicz (2014).

12 As already mentioned in the uncertainty analysis, about 89% of the simulated median ranks for the GTCI and 97% for the Input sub-index are less than two positions away from the reported 2019 rank—this percentage drops only to 84% in the Output sub-index.

13 Caution is needed when drawing inference on the relative standing of the following countries vis-a-vis other countries because of the very wide range of the confidence intervals, of almost 30 positions or more: Gambia's rank in the GTCI—with a rank confidence interval range of [80, 108], and in the Input and Output sub-indices with a confidence interval range of [63, 82] and [103, 126], respectively—and Mongolia's rank in the Output sub-index [64, 85].

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