CHAPTER 2

JRC Statistical Audit of the Global Talent Competitiveness Index 2022

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Individual skills and talents, more than capital, are the driving forces that guide human beings towards the future. From 2013 through 2020, the business school INSEAD advanced the Global Talent Competitiveness Index (GTCI); since 2021, it has been released by Portulans Institute. The index 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 that are discussed in the GTCI 2022 report. This chapter focuses on the practical challenges related to the data quality and the methodological choices made in the grouping of 69 variables into 14 sub-pillars, six pillars, two sub-indices, and an overall index for 133 countries.

The GTCI 2022 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 ± 3 positions with respect to the simulated median in 93% 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 32% (and up to 57%) of the countries included in this year's GTCI.

The European Commission's Competence Centre on Composite Indicators and Scoreboards (COIN) 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. This audit represents the ninth analysis of the GTCI performed by the JRC. Overall, the JRC concluded that the GTCI 2022 framework 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 2022 edition of the GTCI focuses on two main issues: (1) the statistical coherence of the GTCI 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 attractiveness, competitiveness, and innovation. The version of the GTCI model presented in 2022 is consistent with other international indicator frameworks measuring global innovation, global competitiveness, and global attractiveness at the national level. Furthermore, the GTCI 2022 is proven to offer additional insights into nations' human capital and competitiveness compared to the other indices.

The practical items addressed in this chapter relate to the statistical soundness of the GTCI, which should be considered 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 need 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 2022 data set in July–September 2022. The latest GTCI model provided by the development team largely incorporated the issues identified and discussed in previous editions of the audit, with particular attention to the substitution of variables that were previously proven to be not influential on the final values of the index. No critical issues were identified in the 2022 model during this preliminary phase of the audit.

The underlying concepts and indicator framework that are used to describe global talent competitiveness in the GTCI 2022 have remained largely the same as those in the previous edition, although there are some adjustments in this year's GTCI edition (see the Technical Notes for details). Following the iterative process during which the index was fine-tuned, the current assessment of the statistical coherence in this final version of the GTCI 2022 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 2011. 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 2022 data set comprises 133 countries and 69 variables and has 93.3% data coverage. Data availability is at least 80% 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). These criteria have been adopted since the first release of the GTCI, following the JRC-COIN recommendation.

Step 3: Statistical Coherence

This section presents the JRC's analysis of the statistical coherence of the GTCI 2022, 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 in comparison with its component pillars and vis-à-vis other relevant indices on attractiveness, competitiveness, and innovation.

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., one principal component with an eigenvalue significantly greater than 1.0) in all 14 sub-pillars, which captures 42% (Internal Openness) to 90% (Regulatory Landscape) of the total variance in the underlying variables. A more detailed analysis of the correlation structure within and across the six GTCI pillars confirms the expectation that the subpillars 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 from both conceptual and statistical perspectives. Furthermore, all correlations within a pillar are positive 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 GTCI conceptual grouping of 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 87% of the total variance, and the six loadings (correlation coefficients) are quite high and very similar to each other,

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

	SUB-PILLAR	ENABLE	ATTRACT	GROW	RETAIN	VOCATIONAL AND TECHNICAL SKILLS	GLOBAL KNOWLEDGE SKILLS
	1.1 Regulatory Landscape	0.95	0.88	0.84	0.90	0.78	0.86
	1.2 Market Landscape	0.92	0.73	0.89	0.80	0.77	0.82
	1.3 Business and Labour Landscape	0.94	0.84	0.85	0.83	0.76	0.84
	2.1 External Openness	0.77	0.93	0.71	0.72	0.66	0.72
Ŭ	2.2 Internal Openness	0.83	0.89	0.77	0.81	0.70	0.77
INF	3.1 Formal Education	0.84	0.69	0.94	0.84	0.80	0.86
	3.2 Lifelong Learning	0.83	0.72	0.93	0.72	0.67	0.79
	3.3 Access to Growth Opportunities	0.90	0.84	0.93	0.86	0.83	0.87
	4.1 Sustainability	0.90	0.83	0.86	0.95	0.80	0.86
	4.2 Lifestyle	0.83	0.76	0.78	0.95	0.82	0.81
	5.1 Mid-Level Skills	0.74	0.66	0.73	0.83	0.91	0.75
PUT	5.2 Employability	0.69	0.63	0.69	0.61	0.82	0.61
001	6.1 High-Level Skills	0.82	0.77	0.84	0.83	0.78	0.95
	6.2 Talent Impact	0.89	0.78	0.88	0.84	0.75	0.96

Source: European Commission, Joint Research Centre (2022).

Note: The values are the bivariate Pearson correlation coefficients (*n* = 133). 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% (\approx 0.70 × 0.70) of the variation in the underlying sub-pillars and vice-versa.

ranging from 0.89 (Vocational and Technical Skills pillar) to 0.97 (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.⁴

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 six pillars (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 translate into the Input sub-index being twice as important as the Output subpillar 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 0.97, respectively, which suggests that the sub-indices are effectively placed on an equal footing, as envisaged by the developers. 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 GTCl and its components are built as the 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 69 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, whether those are 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 this analysis appear in Table 2. Examining the importance measures of the 69 variables, all variables are important at all levels of aggregation.

For example, country variations in 1.1.1 Government effectiveness scores can capture 94% of the variance in the respective sub-pillar score (Regulatory Landscape), 91% of the variance in the respective pillar (Enable), 88% of the variance in the Input sub-index, and 87% of the variance in the overall GTCI scores. Similarly, country variations in 2.1.2 Financial globalisation scores can capture 73%, 71%, 58%, and 56% of the variance in the External Openness sub-pillar, Attract pillar, Input sub-index, and GTCI scores, respectively.

It is reassuring that all 69 variables in this 2022 edition are found to have a noteworthy impact on the GTCI variance (i.e., at least 10%). The only exception is the 5.2.1 Ease of finding skilled employees indicator: while influential at the sub-pillar pillar where it explains 34% of the variation of the Employability scores, it can explain only 5% of the variation of the GTCI scores.

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

	PILLAR	SUB-PILLAR	VARIABLE	SUB-PILLAR	PILLAR	INPUT/OUTPUT	GTCI
			1.1.1 Government effectiveness	94%	91%	88%	87%
			1.1.2 Rule of law	96%	89%	86%	84%
		1.1 Regulatory	1.1.3. Political stability	75%	58%	59%	56%
			1.1.4 Regulatory quality	93%	87%	87%	86%
			1.1.5 Corruption	93%	88%	84%	81%
			1.2.1 Extent of market dominance	66%	54%	44%	43%
			1.2.2 Domestic credit to private sector	61%	53%	47%	46%
		1.2 Market	1.2.3 Cluster development	71%	58%	48%	47%
	able	Landscape	1.2.4 R&D expenditure	62%	59%	51%	54%
INPUT	1. En		1.2.5 ICT infrastructure	80%	73%	74%	76%
			1.2.6 Urbanisation	55%	46%	50%	49%
			1.3.1 Labour rights	31%	27%	24%	23%
			1.3.2 Labour-employer cooperation	57%	56%	49%	47%
		1.3 Business Landscape	1.3.3 Professional management	69%	67%	59%	59%
			1.3.4 Relationship of pay to productivity	50%	54%	48%	49%
		Lanascope	1.3.5 Enterprise software	41%	28%	25%	25%
			1.3.6 Cloud computing	66%	58%	54%	54%
			1.3.7 Firms with website	62%	64%	70%	70%
		2.1.1 FDI regulatory restrictiveness 2.1.2 Financial globalisation 2.1 External 2.1.3 Migrant stock	2.1.1 FDI regulatory restrictiveness	24%	18%	11%	11%
			2.1.2 Financial globalisation	73%	71%	58%	56%
			2.1.3 Migrant stock	67%	52%	39%	37%
			2.1.4 International students	69%	55%	40%	39%
	ţ		2.1.5 Brain gain	36%	35%	25%	23%
	Attra		2.2.1 Tolerance of minorities	51%	39%	31%	28%
	·,		2.2.2 Tolerance of immigrants	26%	23%	15%	12%
		2.2 Internal	2.2.3 Social Mobility	54%	60%	63%	62%
		Openness	2.2.4 Economic empowerment of women	45%	27%	27%	27%
			2.2.5 Gender parity in high-skilled jobs	40%	20%	27%	28%
			2.2.6 Leadership opportunities for women	39%	42%	37%	38%

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The impact of the pandemic may partially explain this outcome. Overall, the fact that practically all variables are found to be influential at levels of aggregation in the GTCI 2022 is the direct result of the careful revision of the GTCI framework undertaken by the developers.

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 2022 ranking differs from any of the six pillar rankings by 10 positions or more in at least 32% of the 133 countries included in the 2022 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 evidencebased policymaking.

In addition, the GTCI 2022 is compared with three relevant international indices⁵—the World Intellectual Property Organization (WIPO)'s 2022 Global Innovation Index; the European House Ambrosetti's 2022 Global Attractiveness Index; and the International Institute for Management Development (IMD)'s 2022

Table 2 (continued)

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

PILLAR		SUB-PILLAR	VARIABLE	SUB-PILLAR	PILLAR	INPUT/OUTPUT	GTCI
			3.1.1 Vocational enrolment	44%	24%	20%	22%
			3.1.2 Tertiary enrolment	65%	57%	56%	58%
		3.1 Formal Education	3.1.3 Tertiary education expenditure	50%	53%	56%	56%
		Ladeation	3.1.4 Reading, maths, and science	76%	59%	56%	59%
			3.1.5 University ranking	66%	67%	51%	51%
	2	3.2 Lifelong Learning	3.2.1 Business school ranking	64%	53%	35%	34%
	. Gro		3.2.2 Prevalence of training in firms	40%	24%	15%	13%
	m		3.2.3 Employee development	59%	63%	64%	63%
			3.2.4 Formal and non-formal studies	74%	73%	71%	71%
L			3.3.1 Delegation of authority	65%	56%	60%	60%
INPU		3.3 Access to Growth Opportunities	3.3.2 Youth inclusion	47%	44%	36%	37%
_			3.3.3 Use of virtual social networks	69%	56%	60%	60%
			3.3.4 Use of virtual professional networks	75%	67%	70%	68%
			4.1.1 Pension coverage	64%	65%	45%	46%
		4.1 Sustainability	4.1.2 Social protection	73%	63%	72%	67%
		4.1 Sustainability	4.1.3 Brain retention	40%	26%	41%	39%
	etain		4.1.4 Environmental performance	69%	71%	67%	67%
	4. Re		4.2.1 Personal rights	57%	47%	37%	35%
		4.2 Lifestule	4.2.2 Personal safety	70%	66%	63%	63%
		4.2 Lifestyle	4.2.3 Physician density	76%	70%	59%	61%
			4.2.4 Sanitation	62%	59%	50%	52%
	10	5.1 Mid-Level	5.1.1 Workforce with secondary education	66%	50%	36%	26%
	Skills		5.1.2 Population with secondary education	77%	55%	40%	31%
	nical	Skills	5.1.3 Technicians and associate professionals	76%	68%	72%	69%
	Tech		5.1.4 Labour productivity per employee	62%	65%	77%	80%
	ıl and	5.2 Employability	5.2.1 Ease of finding skilled employees	34%	7%	5%	5%
	ationa		5.2.2 Relevance of education system to the economy	69%	45%	47%	50%
	5. Voca		5.2.3 Skills matching	41%	65%	55%	49%
			5.2.4 Highly educated unemployment	36%	17%	14%	12%
5			6.1.1 Workforce with tertiary education	79%	71%	69%	64%
DUTP			6.1.2 Population with tertiary education	78%	64%	60%	56%
	10	6.1 Higher-Level	6.1.3 Professionals	79%	79%	79%	77%
	Skill	Skills	6.1.4 Researchers	69%	78%	74%	74%
	edge		6.1.5 Senior officials and managers	51%	41%	35%	29%
	lwou		6.1.6 Digital skills	28%	16%	14%	18%
	bal K		6.2.1 Innovation output	81%	75%	74%	75%
	5. Glo		6.2.2 High-value exports	37%	30%	23%	20%
	Ū	6.2 Talent Impact	6.2.3 Software development	81%	77%	69%	72%
			6.2.4 New business density	47%	40%	31%	33%
			6.2.5 Scientific journal articles	84%	83%	77%	78%

Source: European Commission Joint Research Centre (2022).

Note: The values are the squared Pearson correlation coefficients, expressed as percentages (*n* = 133 countries). It is reassuring that almost all 69 variables in this 2022 edition are found to have a noteworthy impact (i.e., at least 10%) on the GTCI variance and the variances of the respective sub-indices, pillars, and sub-pillars. The single variable (5.2.2 Ease of finding skilled employees) for which the coefficients are less than 10% are shaded in white.

Distribution of differences between pillar and GTCI rankings

		GTCI INPUT	GTCI OUTPUT SUB-INDEX			
Rank differences with respect to the GTCI 2022	Enable	Attract	Grow	Retain	Vocational and Technical Skills	Global Knowledge Skills
30 or more positions	2%	7%	6%	3%	5%	6%
20 to 29 positions	11%	23%	11%	8%	15%	8%
10 to 19 positions	20%	27%	23%	22%	29%	23%
10 or more positions*	33%	57%	40%	32%	50%	36%
5 to 9 positions	25%	20%	29%	26%	19%	29%
Less than 5 positions	36%	17%	29%	35%	29%	31%
0 positions	6%	6%	2%	6%	2%	5%
Total	100%	100%	100%	100%	100%	100%

Source: European Commission Joint Research Centre (2022).

Note: * This row is the sum of the prior three rows.

Table 4

Rank differences between the GTCI 2022 and other international rankings

Rank differences with respect to the GTCI 2022	Global Innovation Index 2022 (Cornell, INSEAD, WIPO)	Global Attractiveness Index 2022 (The European House Ambrosetti)	World Competitiveness Index 2022 (IMD)
More than 30 positions	6%	11%	0%
20 to 29 positions	9%	19%	7%
10 to 19 positions	27%	30%	22%
More than 10 positions*	42%	60%	28%
5 to 9 positions	27%	18%	23%
Less than 5 positions	29%	19%	43%
0 positions	2%	3%	5%
Total	100%	100%	100%
Pearson correlation coefficient with the GTCI	0.93	0.84	0.84
Spearman rank correlation coefficient with the GTCI	0.91	0.87	0.85
Common countries with the GTCI	124	130	60

Source: European Commission Joint Research Centre (2022).

Notes: The comparison between the GTCI and the other indices was based on the common set of countries. *This row is the sum of the prior three rows.

World Competitiveness Index—using the most recent rankings extracted from these projects' websites (see Table 4). The rank correlation between the GTCI 2022 and all three indices is substantially high (correlation ≈ 0.9), which suggests that the GTCI framework is consistent with the frameworks on global innovation, global attractiveness, and global competitiveness. At the same time, looking at the shifts in rankings, 42%, 60%, and 28% of the countries included in the GTCI 2022 that feature in the other three indices differ in ranking by more than 10 positions when comparing the GTCI 2022 with the three selected international indices. This indicates that the GTCI 2022 offers additional insights into nations' human capital and competitiveness compared to the 2022 Global Innovation Index, the 2022 Global Attractiveness Index, and the 2022 World Competitiveness Index.

Step 4: Qualitative Review

Finally, the GTCI results, including overall country classifications and relative performances in terms of the Input and Output subindices, 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 GTCl, it is important to mention that the GTCl 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,⁶ 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.

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 6% to 26%. 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 6.7% of data were missing in the data set of 133 countries for all 69 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.⁷

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.⁸ 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 2022).

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 90% interval across all simulations. Table 6 reports the published rankings and the 90% confidence intervals that account for

Table 5

Uncertainty analysis for the GTCI 2022: 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 ago	regation formula at pillar level	Arithmetic average	Geometric average
III. Uncertainty in the weights		Poforance value for the weight	Distribution assigned for robustness analysis
GTCI sub-index	Pillar	(within the sub-index)	(within the sub-index)
	Enable	0.25	U[0.15, 0.35]
laaut	Attract	0.25	U[0.15, 0.35]
input	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]
Output	Global Knowledge Skills	0.50	U[0.40, 0.60]
		Reference value for the weight (when calculating the overall GTCI)	Distribution assigned for robustness analysis (when calculating the overall GTCI)
Overall GTCI	All six pillars	0.16	U[0.06, 0.26]

Source: European Commission Joint Research Centre (2022).



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

Figure 1b





Figure 1c



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

Source: European Commission Joint Research Centre (2022).

Notes: The Spearman rank correlation between the median rank and the GTCI 2022 rank is 0.999 (n = 133); between the median rank and the GTCI 2022 Input rank it is 0.999; and between the median rank and the GTCI 2022 Output rank it is 0.997. Median ranks and intervals are calculated over 4,000 simulated scenarios combining random weights, imputation versus no imputation of missing values, and geometric versus arithmetic average at the pillar level.

Country ranks and 90% confidence intervals for the GTCI 2022 and its Input/Output sub-indices

	GTCI	2022	INPUT SUB-INDEX		OUTPUT SUB-INDEX	
	RANK	INTERVAL	RANK	INTERVAL	RANK	INTERVAL
Switzerland	1	[1, 2]	1	[1, 1]	2	[2, 2]
Singapore	2	[1, 7]	6	[4, 10]	1	[1, 1]
Denmark	3	[2, 4]	2	[2, 3]	6	[5, 7]
United States	4	[3, 11]	9	[5, 12]	3	[3, 7]
Sweden	5	[3, 7]	5	[5, 8]	7	[5, 7]
Netherlands	6	[3, 8]	3	[2, 3]	10	[9, 11]
Norway	7	[4, 7]	10	[6, 10]	4	[3, 4]
Finland	8	[4, 10]	4	[4, 7]	8	[8, 10]
Australia	9	[7, 10]	7	[5, 9]	11	[9, 11]
United Kingdom	10	[8, 11]	11	[9, 11]	9	[8, 10]
Luxembourg	11	[7, 12]	8	[5, 11]	12	[12, 12]
Iceland	12	[11, 16]	18	[18, 19]	5	[4, 5]
Ireland	13	[12, 17]	17	[14, 17]	14	[14, 14]
Germany	14	[12, 17]	13	[13, 17]	19	[16, 20]
Canada	15	[12, 18]	15	[13, 17]	17	[17, 22]
Belgium	16	[14, 17]	16	[14, 17]	18	[16, 18]
Austria	17	[14, 18]	14	[13, 16]	21	[21, 23]
New Zealand	18	[12, 19]	12	[11, 12]	24	[15, 25]
France	19	[18, 20]	19	[18, 19]	22	[20, 23]
Estonia	20	[19, 21]	25	[24, 26]	13	[13, 13]
Czech Republic	21	[21, 25]	26	[24, 26]	20	[18, 22]
Malta	22	[21, 25]	23	[20, 24]	25	[23, 26]
Israel	23	[21, 28]	28	[28, 30]	15	[15, 16]
Japan	24	[20, 28]	20	[20, 24]	35	[25, 35]
United Arab Emirates	25	[21, 29]	21	[20, 26]	31	[30, 33]
Portugal	26	[23, 28]	24	[22, 24]	30	[28, 32]
South Korea	27	[22, 29]	29	[27, 31]	16	[16, 19]
Slovenia	28	[26, 29]	27	[27, 29]	23	[23, 25]
Spain	29	[26, 30]	22	[20, 23]	45	[36, 46]
Cyprus	30	[29, 32]	30	[28, 32]	28	[27, 31]
Latvia	31	[30, 31]	33	[32, 33]	26	[26, 27]
Lithuania	32	[32, 33]	32	[32, 34]	32	[29, 35]
Italy	33	[31, 33]	31	[30, 31]	36	[36, 38]
Chile	34	[34, 35]	36	[34, 37]	40	[39, 41]
Slovakia	35	[34, 38]	40	[38, 41]	34	[29, 35]
China	36	[33, 43]	38	[32, 41]	48	[43, 50]
Hungary	37	[35, 38]	41	[41, 43]	29	[28, 33]
Qatar	38	[35, 44]	37	[34, 40]	51	[51, 56]
Poland	39	[37, 42]	46	[43, 47]	27	[27, 32]
Greece	40	[38, 44]	39	[38, 41]	52	[45, 53]
Brunei Darussalam	41	[39, 44]	45	[42, 46]	33	[33, 46]
Costa Rica	42	[39, 48]	35	[34, 36]	69	[68, 75]
Saudi Arabia	43	[40, 48]	44	[43, 50]	39	[38, 47]
Uruguay	44	[40, 53]	34	[34, 38]	77	[76, 81]

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Table 6 (continued)

$Country\,ranks\,and\,90\%\,confidence\,intervals\,for\,the\,GTCI\,2022\,and\,its\,Input/Output\,sub-indices$

	GTCI	2022	INPUT SUB-INDEX		OUTPUT SUB-INDEX	
	RANK	INTERVAL	RANK	INTERVAL	RANK	INTERVAL
Malaysia	45	[38, 46]	47	[44, 48]	38	[34, 40]
Croatia	46	[42, 49]	52	[48, 53]	37	[37, 39]
Montenegro	47	[45, 52]	51	[50, 55]	43	[41, 48]
Georgia	48	[46, 53]	48	[47, 53]	49	[48, 53]
Bahrain	49	[46, 56]	42	[39, 44]	65	[63, 70]
Bulgaria	50	[43, 51]	54	[49, 56]	46	[41, 46]
Mauritius	51	[45, 60]	43	[40, 49]	60	[60, 69]
Serbia	52	[50, 57]	59	[55, 61]	44	[42, 50]
Trinidad and Tobago	53	[52, 64]	56	[55, 66]	53	[51, 59]
Romania	54	[51, 58]	60	[56, 63]	47	[46, 51]
Azerbaijan	55	[51, 70]	58	[57, 65]	50	[44, 63]
Armenia	56	[51, 62]	55	[53, 63]	55	[50, 60]
Russia	57	[46, 60]	65	[56, 70]	42	[36, 44]
Belarus	58	[50, 63]	73	[68, 80]	41	[37, 43]
Argentina	59	[54, 64]	53	[48, 55]	64	[62, 71]
Oman	60	[52, 69]	50	[47, 53]	73	[68, 83]
Kuwait	61	[56, 66]	49	[48, 54]	86	[72, 86]
Kazakhstan	62	[50, 65]	67	[64, 75]	54	[43, 54]
Colombia	63	[56, 67]	63	[55, 71]	59	[57, 59]
Panama	64	[58, 67]	61	[57, 66]	67	[59, 71]
Albania	65	[62, 78]	62	[57, 63]	70	[70, 84]
Ukraine	66	[59, 71]	68	[64, 76]	63	[53, 64]
Moldova	67	[65, 79]	80	[79, 84]	57	[54, 57]
North Macedonia	68	[67, 76]	77	[73, 79]	62	[61, 64]
Mexico	69	[63, 78]	66	[57, 75]	74	[72, 75]
Botswana	70	[63, 77]	64	[61, 76]	78	[62, 81]
Mongolia	71	[63, 78]	69	[67, 73]	71	[61, 83]
Jordan	72	[66, 80]	57	[56, 68]	90	[87, 90]
Brazil	73	[67, 76]	72	[62, 74]	76	[74, 79]
Viet Nam	74	[65, 78]	79	[69, 81]	66	[66, 68]
Thailand	75	[68, 77]	76	[67, 78]	72	[69, 74]
Jamaica	76	[71, 83]	71	[64, 79]	85	[83, 90]
South Africa	77	[68, 81]	74	[66, 77]	83	[72, 86]
Peru	78	[71, 82]	70	[62, 79]	87	[84, 89]
Cabo Verde	79	[69, 84]	75	[64, 83]	82	[78, 82]
Philippines	80	[65, 87]	87	[83, 93]	56	[51, 56]
Türkiye	81	[72, 84]	81	[75, 84]	80	[69, 80]
Indonesia	82	[79, 89]	84	[80, 85]	81	[79, 93]
Kyrgyzstan	83	[78, 89]	85	[83, 89]	79	[65, 85]
Lebanon	84	[77, 90]	90	[86, 91]	61	[58, 67]
Paraguay	85	[80, 89]	78	[66, 79]	96	[96, 98]
Egypt	86	[82, 91]	94	[91, 94]	58	[57, 68]
Ecuador	87	[83, 91]	83	[78, 84]	92	[91, 96]
Bosnia and Herzegovina	88	[85, 90]	89	[86, 90]	75	[72, 87]
Dominican Republic	89	[84, 91]	86	[85, 90]	84	[84, 88]

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Table 6 (continued)	ntinued)	6	ble	Tal
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Country ranks and 90% confidence intervals for the GTCI 2022 and its Input/Output sub-indices

	GTCI	2022	INPUT SUB-INDEX		OUTPUT SUB-INDEX	
	RANK	INTERVAL	RANK	INTERVAL	RANK	INTERVAL
Namibia	90	[81, 93]	82	[77, 85]	99	[92, 100]
Tunisia	91	[82, 93]	88	[86, 93]	88	[76, 89]
Sri Lanka	92	[89, 95]	97	[95, 100]	68	[63, 89]
Bolivia	93	[90, 95]	92	[86, 94]	94	[92, 98]
Gambia	94	[92, 107]	91	[87, 96]	103	[101, 119]
Ghana	95	[92, 101]	93	[89, 94]	98	[94, 107]
Morocco	96	[94, 100]	95	[94, 98]	107	[98, 107]
Kenya	97	[94, 101]	104	[101, 105]	91	[91, 94]
El Salvador	98	[96, 102]	102	[96, 103]	97	[97, 103]
Laos	99	[96, 106]	107	[106, 113]	95	[91, 100]
Eswatini	100	[96, 104]	96	[95, 101]	115	[100, 117]
India	101	[94, 108]	101	[96, 107]	108	[95, 108]
Zambia	102	[98, 109]	103	[101, 113]	101	[101, 105]
Cambodia	103	[100, 113]	100	[97, 106]	113	[113, 118]
Algeria	104	[96, 106]	106	[100, 110]	104	[94, 106]
Benin	105	[100, 121]	110	[104, 116]	102	[101, 122]
Rwanda	106	[101, 111]	98	[95, 102]	119	[114, 121]
Senegal	107	[102, 118]	99	[96, 109]	122	[122, 126]
Guatemala	108	[103, 112]	109	[101, 112]	112	[109, 112]
Nigeria	109	[97, 119]	118	[116, 125]	93	[80, 102]
Honduras	110	[105, 112]	111	[104, 112]	111	[110, 114]
Nepal	111	[104, 118]	115	[109, 118]	106	[105, 109]
Iran	112	[98, 120]	121	[116, 129]	89	[80, 89]
Pakistan	113	[105, 117]	113	[106, 116]	110	[108, 112]
Nicaragua	114	[106, 114]	112	[107, 114]	114	[110, 115]
Côte d'Ivoire	115	[108, 117]	105	[101, 107]	121	[117, 127]
Malawi	116	[113, 118]	114	[112, 115]	117	[115, 121]
Tanzania	117	[113, 120]	108	[107, 110]	127	[125, 128]
Zimbabwe	118	[112, 121]	124	[122, 127]	100	[99, 104]
Cameroon	119	[110, 120]	119	[116, 121]	109	[105, 111]
Lesotho	120	[113, 124]	116	[112, 122]	123	[115, 123]
Uganda	121	[119, 123]	117	[115, 119]	125	[123, 127]
Bangladesh	122	[119, 128]	125	[121, 129]	116	[113, 120]
Guinea	123	[120, 125]	120	[118, 124]	124	[120, 126]
Madagascar	124	[122, 125]	122	[119, 124]	120	[119, 126]
Mauritania	125	[121, 128]	130	[130, 131]	105	[98, 112]
Burundi	126	[125, 132]	127	[122, 128]	128	[128, 133]
Mozambique	127	[126, 131]	128	[119, 129]	130	[129, 133]
Burkina Faso	128	[124, 131]	126	[118, 131]	132	[129, 132]
Mali	129	[126, 131]	123	[121, 127]	133	[131, 133]
Angola	130	[123, 131]	129	[127, 129]	129	[116, 130]
Ethiopia	131	[126, 131]	131	[128, 131]	126	[122, 126]
Democratic Republic of the Congo	132	[129, 132]	132	[132, 132]	118	[116, 128]
Chad	133	[133, 133]	133	[133, 133]	131	[130, 132]

Source: European Commission Joint Research Centre (2022).

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 three positions or less) for 93% 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 71% 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 three positions away) for 98% of the countries, and the rank intervals are less than or equal to 10 positions for 82% of the countries. Similarly, the Output rank is close to the median rank (less than or equal to three positions away) for 79% 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 subindices) 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 not imputing missing data, particularly in the case of the Output sub-index (given that a lower rank correlation indicates greater sensitivity). This choice has a greater impact on differences in ranking for the Output sub-index; it has less impact on differences for the Input sub-index or the overall GTCI 2022. For example, in the most extreme cases, by estimating missing data with the EM algorithm, Mongolia falls by 10 positions in the Output ranking (from 71 down to 81); Kyrgyzstan improves by 14 positions (from rank 79 up to 65). Note, however, that these assumptions—on the weights, aggregation method, and missing data estimation—primarily concern methodological choices and might overall be less influential than choices related to the background assumptions in the conceptual framework.⁹

Overall, the ranges of uncertainty in the final rankings are fairly modest. Consequently, the JRC recommendation is not to alter the GTCI methodology, but to consider country ranks in the GTCI 2022 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 2022 and the Input and Output sub-indices are the result of the underlying data and not of modelling choices.¹⁰

CONCLUSIONS

This ninth edition of the Global Talent Competitiveness Index (GTCI) intends to bring 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 constructing the index. The JRC analysis suggests that the conceptualised structure on multiple levels of the GTCI 2022 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 subindices 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 has shown that the GTCI is statistically reliable in its current form as the simple average of the six pillars (as measured by a very high Cronbach's alpha value of 0.97, well above the recommended 0.70 threshold for a reliable aggregate).

It is reassuring that all 69 variables in this 2022 edition are found to have a noteworthy impact on the GTCI variance (i.e., at least 10%); the only exception—the 5.2.1 Ease of finding skilled employees (which can explain only 5% of the GTCI variance) may be due to the influence of the pandemic. Overall, the fact that practically all variables are found to be influential at levels of aggregation in the GTCI 2022 is the direct result of the careful revision of the GTCI framework undertaken by the developers.

The GTCI and both sub-index country ranks are relatively robust to methodological assumptions related to the estimation of missing data, weighting, and the 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. 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 2022. 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 32% (up to almost 57%) of the countries. This outcome both

Figure 2

Sensitivity analysis: Impact of modelling choices

Global Talent Competitiveness 2022



GTCI 2022 Input sub-index



GTCI 2022 Output sub-index





Source: European Commission Joint Research Centre (2022). Note: $R_{\rm s}$ represents the Spearman rank correlation coefficient (n = 133).

Rank based on geometric average

GTCI 2022 rank



Rank based on geometric average



evidences the added value of the GTCI ranking and points to the importance of taking into account the individual pillars, subpillars, and variables on their own merit. By doing so, countryspecific 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 GTCI 2022 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 GTCI 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 Portulans Institute and 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 <u>https://knowledge4policy.ec.europa.eu/</u>composite-indicators_en_and <u>https://composite-indicators.jrc.ec.europa.eu/</u>eu (all audits were carried out upon request of the index developers).
- 2 OECD & EC JRC (2008).
- 3 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 (133 countries).
- 4 See Nunnally (1978).
- 5 In 2021 the GTCI used two indices—the World Bank's Human Capital Index and the World Economic Forum's Global Competitiveness Index—that have not been updated recently, so this year they have been replaced with the Global Attractiveness Index and the World Competitiveness Index.
- 6 Becker et al. (2017); Paruolo et al. (2013); Montalto et al. (2019); Saisana et al. (2005), (2011); Saisana & Saltelli (2011); Saltelli et al. (2008); Vértesy (2016); Vértesy & Deiss (2016).
- 7 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.
- 8 Munda (2008).

- 9 Saltelli & Funtowicz (2014).
- 10 As already mentioned in the uncertainty analysis, about 93% of the simulated median ranks for the GTCI are fewer than three positions away from the reported 2022 rank—this percentage is at 98% in the Input subindex and drops to 79% in the Output sub-index.

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