# JRC Statistical Audit of the Global Talent Competitiveness Index 2018

*Michaela Saisana, Marcos Domínguez-Torreiro, and William Becker*

European Commission Joint Research Centre

The Global Talent Competitiveness Index (GTCI) aims to summarise complex and versatile concepts related to human capital and talent competitiveness at the national scale in 119 countries worldwide. In so doing, it raises some conceptual and practical challenges, which are discussed in the GTCI 2018 report. This chapter focuses on the practical challenges related to the data quality and the methodological choices made in the grouping of 68 variables into 14 sub-pillars, six pillars, two sub-indices, and an overall index.

The GTCI 2018 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 $\pm 2$ positions with respect to the simulated median in 95% 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 one-third of the countries included in this year's GTCI.

This audit represents the fifth analysis of the GTCI performed by the European Commission's Competence Centre on Composite Indicators and Scoreboards at the Joint Research Centre (JRC). The previous two audits identified a few minor issues concerning variables that had little correlation with the output, but those remaining in the 2017 index have largely been addressed in the 2018 edition. Overall, the JRC concluded that the GTCI 2018 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, and potentially to guide their choices on priority setting and policy formulation.

As in the previous audits, the present JRC assessment of the GTCI 2018 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 competitiveness and innovation. Its main conclusions can be summarised as follows: the version of the GTCI model presented in 2018 is coherent, balanced, and robust, displaying strong associations between the underlying variables and the GTCI sub-pillars, pillars, and sub-indices, and hence offers a sound basis for policy interpretations. Some minor issues, which are outlined in this chapter, are also recommended for examination in the next version of the GTCI.

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 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.

## [a]Statistical Coherence in the GTCI Framework

An initial assessment of the GTCI 2018 was undertaken by the JRC in July 2017. The latest GTCI model provided by the development team largely incorporated the issues identified and discussed in the previous edition, in particular full normalisation of the data in order to scale all

variables onto the same scale. No critical issues were identified in the 2018 model during this preliminary phase of the audit.

The underlying concepts and framework used to describe global talent competitiveness in the GTCI 2018 have remained essentially the same as those in the GTCI 2017. However, with the aim of improving the quality of the data, several variables have been removed and several others have been added to the model. As a result of the deletion/replacement of some of the indicators, the total number of variables in the GTCI 2018 is now 68, three more than the 65 used in the 2017 version.

Five new variables coming from the World Economic Forum's Executive Opinion Survey have been added to enhance the conceptual framework of the GTCI 2018. Active labour market policies has been included in the Business and Labour Landscape sub-pillar, while Collaboration within organisations and Collaboration across organisations provide significant added value to the Access to Growth Opportunities sub-pillar. The variable Social protection has been included in the Sustainability sub-pillar. Finally, two new indicators, Skills matching with secondary education and Skills matching with tertiary education have been added to the Employability sub-pillar.

Two variables have also been re-allocated to a better-fitting sub-pillar. The Scientific journal articles indicator has been moved to the Talent Impact sub-pillar, for both conceptual and statistical reasons. And the Availability of scientists and engineers indicator has been reallocated to the High-Level Skills sub-pillar.

Two variables—Skills gap as a major constraint and Taxation—have been deleted entirely from the framework since, as pointed out by the JRC last year, they did not have a solid showing in the correlations matrix.

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 2018 followed four steps:

**[b]Step 1: Relevance**

Candidate variables were selected for their relevance to a specific pillar on the basis of the literature review, expert opinion, country coverage, and timeliness. To represent a fair picture of

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

**[b]Step 2: Data Checks**

The most recently released data were used for each country. The cut-off year was changed from 2002 to 2005, thus affecting country coverage figures. Countries were included if data availability was at least 80% at the index level and at least 40% at the sub-pillar level. As a result, the GTCI 2018 data set comprises 119 countries and 68 variables. Consequently, data availability is at least 88% at the Input sub-index level and 63% at the Output sub-index level. Potentially problematic variables that could bias the overall results were identified by the GTCI development team as those having absolute skewness greater than 2 and kurtosis greater than 3.5,[3] and were treated either by Winsorisation or by taking the natural logarithm (in the case of five or more outliers). For variables with five outliers or more, a log transformation is used (see the Technical Notes of the main GTCI report for details). These criteria follow the WIPO-INSEAD Global Innovation Index practice (formulated with the JRC in 2011). Data checks confirm that no outliers or problematic indicators are present in the normalised data set as facilitated by the development team.

**[b]Step 3: Statistical Coherence**

This section presents the JRC's analysis of the statistical coherence of the GTCI 2018, which consists of a principal components analysis to analyse the structure of the data, a multi-level analysis of the correlations of variables, and a comparison of GTCI rankings with its pillars and with other similar composite indicators. This latter investigation demonstrates the added value of the GTCI both against its component pillars and against other similar indexes.

*[c]1. Principal Components Analysis and Reliability Analysis*

Principal component analysis (PCA) was used to assess the extent to which the conceptual framework is compatible with statistical properties of the data. PCA confirms the presence of a single statistical dimension (i.e., no more than one principal component with an eigenvalue significantly greater than 1.0) in the great majority (11) of the 14 sub-pillars, which captures 53% (Formal Education) to 83% (Employability) of the total variance in the underlying variables.[4] A

more detailed analysis of the correlation structure within and across the six pillars confirms the expectation that the sub-pillars are more correlated to their own pillar than to any other, and all correlations within a pillar are positive, strong, and similar and well above 0.7 (see Table 1). These results suggest that the conceptual grouping of sub-pillars into pillars is statistically confirmed and that the six pillars are statistically well balanced in the underlying sub-pillars.

**Table 1**

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

| | | Enable | Attract | Grow | Retain | Vocational and Technical Skills | Global Knowledge Skills |
|---|---|---|---|---|---|---|---|
| Input | 1.1 Regulatory Landscape | 0.96 | 0.88 | 0.85 | 0.86 | 0.82 | 0.73 |
| | 1.2 Market Landscape | 0.94 | 0.77 | 0.90 | 0.88 | 0.88 | 0.84 |
| | 1.3 Business and Labour Landscape | 0.91 | 0.80 | 0.74 | 0.71 | 0.74 | 0.62 |
| | 2.1 External Openness | 0.80 | 0.93 | 0.69 | 0.64 | 0.69 | 0.56 |
| | 2.2 Internal Openness | 0.80 | 0.90 | 0.77 | 0.71 | 0.70 | 0.56 |
| | 3.1 Formal Education | 0.70 | 0.51 | 0.87 | 0.82 | 0.79 | 0.85 |
| | 3.2 Lifelong Learning | 0.84 | 0.81 | 0.94 | 0.73 | 0.81 | 0.68 |
| | 3.3 Access to Growth Opportunities | 0.90 | 0.84 | 0.94 | 0.83 | 0.85 | 0.78 |
| | 4.1 Sustainability | 0.91 | 0.82 | 0.88 | 0.94 | 0.87 | 0.79 |
| | 4.2 Lifestyle | 0.70 | 0.54 | 0.72 | 0.92 | 0.81 | 0.80 |
| Output | 5.1 Mid-Level Skills | 0.68 | 0.53 | 0.69 | 0.83 | 0.86 | 0.73 |
| | 5.2 Employability | 0.79 | 0.76 | 0.81 | 0.68 | 0.82 | 0.65 |
| | 6.1 High-Level Skills | 0.76 | 0.61 | 0.80 | 0.83 | 0.83 | 0.95 |
| | 6.2 Talent Impact | 0.72 | 0.55 | 0.79 | 0.78 | 0.73 | 0.94 |

Source: European Commission, Joint Research Centre (2018).

Note: The values are the bivariate Pearson correlation coefficients; values greater than 0.70 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.

The six pillars also share a single statistical dimension that summarises 86% of the total variance, and the six loadings (correlation coefficients) are quite high and very similar to each other, ranging from 0.85 to 0.95. The latter suggests that the six pillars contribute in a similar way to the variation of the GTCI scores, as envisaged by the development team: all six pillars are assigned equal weights. The reliability of the GTCI, measured by the Cronbach's alpha value, is very high at 0.97—well above the 0.7 threshold for a reliable aggregate.[5]

An important part of the analysis relates to clarifying the importance of the Input and Output sub-indices with respect to the variation of the GTCI scores. As mentioned above, the 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.

*[c]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.

This section assesses the importance of all 68 variables at the various levels of aggregation in the GTCI structure. As a statistical measure of the importance of variables in an index we use the squared Pearson correlation coefficient (otherwise known as the *coefficient of determination* $R^2$).[6] The importance of the selected variables is taken to be equivalent to the contribution of those variables to the variation of the aggregate scores, be those sub-pillars, pillars, sub-indices, or the overall GTCI. The overarching consideration made by the GTCI development team was that all variables should be important at all levels of aggregation. The results of our analysis appear in Table 2. Examining the importance measures of the 68 variables, we see that almost all variables are important at the various levels of aggregation. For example, country variations in 1.1.1 Government effectiveness scores can capture 91% of the variance in the respective sub-pillar scores (Regulatory Landscape), 90% of the variance in the respective pillar (Enable), and 91% both in the Input sub-index and overall GTCI scores. Similarly, country variations in 2.1.1

Foreign direct investment (FDI) and technology transfer scores can capture 62%, 57%, 56%, and 52% of the variance in the External Openness, Attract, Input, and GTCI scores, respectively. In the 2018 data set, there are five variables that have a very low impact on the GTCI variance (less than 10%): 1.3.1 Ease of hiring, 2.2.5 Gender earnings gap, 3.1.3 Tertiary education expenditure, 3.2.2 Prevalence of training in firms, and 6.2.3 New product entrepreneurial activity. Although conceptually enriching the current GTCI framework and despite the sufficient though modest statistical relevance (ranging between 12% and 24%) of four of them to last year's framework, these variables are not found to be important at the overall index level in the 2018 data framework. In fact, 1.3.1 Ease of hiring has consistently been a low-impact variable in the overall index and has been flagged in the JRC's audits since 2014. Accordingly, the GTCI development team should monitor closely how the statistical relevance of all five of these low-impact variables evolve over time in next year's release.

**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 sub-index | GTCI Index |
|---|---|---|---|---|---|---|
| 1. ENABLE | 1.1 Regulatory Landscape | 1.1.1 Government effectiveness | 91% | 90% | 91% | 91% |
| | | 1.1.2 Business-government relations | 45% | 43% | 32% | 26% |
| | | 1.1.3 Political stability | 69% | 52% | 54% | 48% |
| | | 1.1.4 Regulatory quality | 88% | 84% | 83% | 81% |
| | | 1.1.5 Corruption | 90% | 82% | 84% | 82% |
| | 1.2 Market Landscape | 1.2.1 Competition intensity | 56% | 47% | 40% | 38% |
| | | 1.2.2 Ease of doing business | 65% | 65% | 62% | 64% |
| | | 1.2.3 Cluster development | 65% | 61% | 56% | 53% |
| | | 1.2.4 R&D expenditure | 67% | 50% | 49% | 53% |
| | | 1.2.5 ICT infrastructure | 72% | 63% | 74% | 80% |
| | | 1.2.6 Technology utilisation | 82% | 79% | 79% | 76% |
| | 1.3 Business and Labour Landscape | 1.3.1 Ease of hiring | 39% | 17% | 9% | 8% |
| | | 1.3.2 Ease of redundancy | 31% | 18% | 13% | 11% |
| | | 1.3.3 Active labour market policies | 62% | 63% | 62% | 61% |
| | | 1.3.4 Labour-employer cooperation | 67% | 61% | 53% | 49% |
| | | 1.3.5 Professional management | 66% | 77% | 76% | 72% |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | 1.3.6 Relationship of pay to productivity | 79% | 71% | 63% | 62% |
| 2. ATTRACT | 2.1 External Openness | 2.1.1 FDI and technology transfer | 62% | 57% | 56% | 52% |
| | | 2.1.2 Prevalence of foreign ownership | 55% | 54% | 45% | 39% |
| | | 2.1.3 Migrant stock | 55% | 43% | 31% | 30% |
| | | 2.1.4 International students | 69% | 57% | 40% | 38% |
| | | 2.1.5 Brain gain | 70% | 63% | 44% | 38% |
| | 2.2 Internal Openness | 2.2.1 Tolerance of minorities | 61% | 44% | 43% | 39% |
| | | 2.2.2 Tolerance of immigrants | 32% | 30% | 21% | 17% |
| | | 2.2.3 Social mobility | 64% | 75% | 72% | 66% |
| | | 2.2.4 Female graduates | 17% | 8% | 13% | 14% |
| | | 2.2.5 Gender earnings gap | 30% | 14% | 9% | 7% |
| | | 2.2.6 Leadership opportunities for women | 51% | 44% | 35% | 31% |
| 3. GROW | 3.1 Formal Education | 3.1.1 Vocational enrolment | 44% | 27% | 19% | 21% |
| | | 3.1.2 Tertiary enrolment | 71% | 44% | 38% | 45% |
| | | 3.1.3 Tertiary education expenditure | 18% | 12% | 8% | 7% |
| | | 3.1.4 Reading, maths, and science | 72% | 52% | 50% | 54% |
| | | 3.1.5 University ranking | 65% | 63% | 51% | 54% |
| | 3.2 Lifelong Learning | 3.2.1 Quality of management schools | 78% | 72% | 65% | 65% |
| | | 3.2.2 Prevalence of training in firms | 45% | 28% | 9% | 8% |
| | | 3.2.3 Employee development | 80% | 73% | 75% | 71% |
| | 3.3 Access to Growth Opportunities | 3.3.1 Delegation of authority | 82% | 75% | 73% | 69% |
| | | 3.3.2 Personal rights | 46% | 38% | 34% | 33% |
| | | 3.3.3 Use of virtual social networks | 61% | 49% | 56% | 57% |
| | | 3.3.4 Use of virtual professional networks | 73% | 67% | 67% | 67% |
| | | 3.3.5 Collaboration within organisations | 76% | 69% | 71% | 69% |
| | | 3.3.6 Collaboration across organisations | 52% | 49% | 46% | 45% |
| 4. RETAIN | 4.1 Sustainability | 4.1.1 Pension system | 65% | 80% | 56% | 63% |
| | | 4.1.2 Social protection | 86% | 69% | 78% | 74% |
| | | 4.1.3 Brain retention | 56% | 31% | 55% | 49% |
| | 4.2 Lifestyle | 4.2.1 Environmental performance | 81% | 69% | 54% | 59% |
| | | 4.2.2 Personal safety | 51% | 57% | 50% | 51% |
| | | 4.2.3 Physician density | 79% | 63% | 38% | 44% |
| | | 4.2.4 Sanitation | 77% | 61% | 39% | 44% |
| AND | 5.1 Mid-level Skills | 5.1.1 Workforce with secondary education | 67% | 31% | 28% | 19% |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | 5.1.2 Population with secondary education | 69% | 32% | 29% | 19% |
| | | 5.1.3 Technicians and associate professionals | 79% | 73% | 73% | 67% |
| | | 5.1.4 Labour productivity per employee | 59% | 66% | 60% | 65% |
| | 5.2 Employability | 5.2.1 Ease of finding skilled employees | 83% | 56% | 51% | 56% |
| | | 5.2.2 Relevance of education system to the economy | 86% | 58% | 52% | 59% |
| | | 5.2.3 Skills matching with secondary education | 82% | 61% | 53% | 56% |
| | | 5.2.4 Skills matching with tertiary education | 81% | 47% | 38% | 46% |
| **6. GLOBAL KNOWLEDGE SKILLS** | 6.1 Higher-Level Skills | 6.1.1 Workforce with tertiary education | 84% | 72% | 69% | 56% |
| | | 6.1.2 Population with tertiary education | 61% | 45% | 39% | 29% |
| | | 6.1.3 Professionals | 75% | 74% | 73% | 66% |
| | | 6.1.4 Researchers | 76% | 75% | 75% | 71% |
| | | 6.1.5 Senior officials and managers | 49% | 45% | 37% | 27% |
| | | 6.1.6 Availability of scientists and engineers | 58% | 53% | 60% | 57% |
| | 6.2 Talent impact | 6.2.1 Innovation output | 75% | 77% | 77% | 74% |
| | | 6.2.2 High-value exports | 38% | 35% | 31% | 28% |
| | | 6.2.3 New product entrepreneurial activity | 18% | 9% | 6% | 4% |
| | | 6.2.4 New business density | 39% | 31% | 23% | 23% |
| | | 6.2.5 Scientific journal articles | 65% | 60% | 55% | 46% |

Source: European Commission Joint Research Centre (2018).
Note: The values are the squared Pearson correlation coefficients, expressed as percentages.

*[c]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 2018 ranking differs from any of the six pillar rankings by 10 positions or more in at least one-third of the 119 countries included in the 2018 edition, peaking at two-thirds in 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.

**Table 3**

**Distribution of differences between pillar and GTCI rankings**

| | GTCI Input Sub-Index | | | | GTCI Output Sub-Index | |
|---|---|---|---|---|---|---|
| Shifts with respect to the overall GTCI rank | Enable | Attract | Grow | Retain | Vocational and Technical Skills | Global Knowledge Skills |
| More than 30 positions | 5% | 18% | 6% | 2% | 2% | 7% |
| 20 to 29 positions | 7% | 13% | 10% | 7% | 8% | 18% |
| 10 to 19 positions | 26% | 30% | 17% | 27% | 29% | 24% |
| ***More than 10 positions*** | ***38%*** | ***61%*** | ***33%*** | ***35%*** | ***39%*** | ***48%*** |
| 5 to 9 positions | 27% | 18% | 26% | 27% | 31% | 29% |
| Less than 5 positions | 29% | 18% | 34% | 34% | 26% | 23% |
| 0 positions | 6% | 3% | 8% | 4% | 3% | 1% |
| Total | 100% | 100% | 100% | 100% | 100% | 100% |

Source: European Commission Joint Research Centre (2018).

In addition, we compared the GTCI 2018 with both the World Economic Forum's 2016–2017 Global Competitiveness Index and Cornell University, INSEAD, and WIPO's 2017 Global Innovation Index. After having extracted data from both projects' websites, we find that the rank correlation between GTCI 2018 with both indices is substantially high (correlation ≈ 0.9), which suggests that the GTCI has many aspects in common with both these two indices. Looking at the shifts in rankings (see Table 4), we nevertheless find that 41% and 44% out of the countries included in the GTCI 2018 that feature in the other two indices differ in ranking by more than 10 positions when comparing the GTCI 2018 with, respectively, the 2016–2017 Global Competitiveness Index and the 2017 Global Innovation Index. This indicates that the GTCI 2018 offers additional insights into nations' human capital and competitiveness compared to the two other international indices.

**Table 4**

**Distribution of differences between the GTCI 2018 and other international rankings**

| Shifts with respect to the GTCI 2018 | 2017Global Innovation Index (Cornell, INSEAD, and WIPO) | 2016–2017 Global Competitiveness Index (World Economic Forum) |
|---|---|---|
| More than 30 positions | 4% | 8% |
| 20 to 29 positions | 13% | 10% |
| 10 to 19 positions | 25% | 25% |
| ***More than 10 positions*** | ***41%*** | ***44%*** |
| 5 to 9 positions | 26% | 21% |
| Less than 5 positions | 29% | 25% |
| 0 positions | 4% | 9% |
| Total | 100% | 100% |

Source: European Commission Joint Research Centre (2018).

**[b]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 become available.

## [A]Impact of Modelling Assumptions on the GTCI Results

Every country score on the overall GTCI and its two sub-indices depends on modelling choices: the six-pillar structure, the selected variables, the imputation or not of missing data, , and the weights and aggregation method, among other elements. These choices are based on expert opinion (e.g., selection of variables), or common practice (e.g., min-max normalisation in the [0,100] range), driven by statistical analysis (e.g., treatment of outliers) or simplicity (e.g., no imputation of missing data). The robustness analysis is aimed at assessing the simultaneous and

joint impact of these modelling choices on the rankings. The data are assumed to be error-free since potential outliers and any errors and typos were corrected during the computation phase.

As suggested in the relevant literature on composite indicators,[7] 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, 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 4.7% of data were missing in the data set of 119 countries for all 68 variables). The 'no imputation' choice, which is common in similar contexts, might encourage countries not to report low data values. To overcome this limitation, the JRC also estimated missing data using the Expectation Maximisation (EM) algorithm.

Regarding the aggregation formula, decision-theory practitioners have challenged the use of simple arithmetic averages because of their fully compensatory nature, in which a comparatively high advantage for a few variables can compensate for a comparative disadvantage for many variables. 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 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.

**Table 5**

**Uncertainty analysis for the GTCI 2018: Missing data, aggregation, and pillar weights**

| | | Reference | Alternative |
|---|---|---|---|
| **I. Uncertainty in the treatment of missing values** | | **No estimation of missing data** | **Expectation Maximization (EM)** |
| **II. Uncertainty in the aggregation formula at pillar level** | | **Arithmetic average** | **Geometric average** |
| **III. Uncertainty in pillar weights** | | | |
| **GTCI sub-index** | **Pillar** | **Reference value for the weight** | **Distribution assigned for robustness analysis** |
| 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 (2018).

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 2018).

**[b]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 (black line), the 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 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 for meaningful inferences to be drawn.

GTCI ranks are shown to be both representative of a plurality of scenarios and robust to changes in the imputation method, the pillar weights, and the aggregation formula. If one considers the median rank across the simulated scenarios as being representative of these scenarios, then the fact that the GTCI rank is close to the median rank (differing by two positions or less) for 95% 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 95% of the countries) imply that the GTCI ranks are also, for most countries, robust to changes in the pillar weights, the imputation method, and the aggregation formula.

Results for the Input and Output sub-index are also robust and representative of the plurality of scenarios considered. The Input rank is close to the median rank (less than or equal to two positions away) for 97% of the countries and the rank intervals are less than or equal to 10 positions for 88% of the countries. Similarly, the Output rank is close to the median rank (less than or equal to two positions away) for 81% of the countries, and the rank intervals are less than or equal to 10 positions for 87% 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.

**Figure 1a**

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

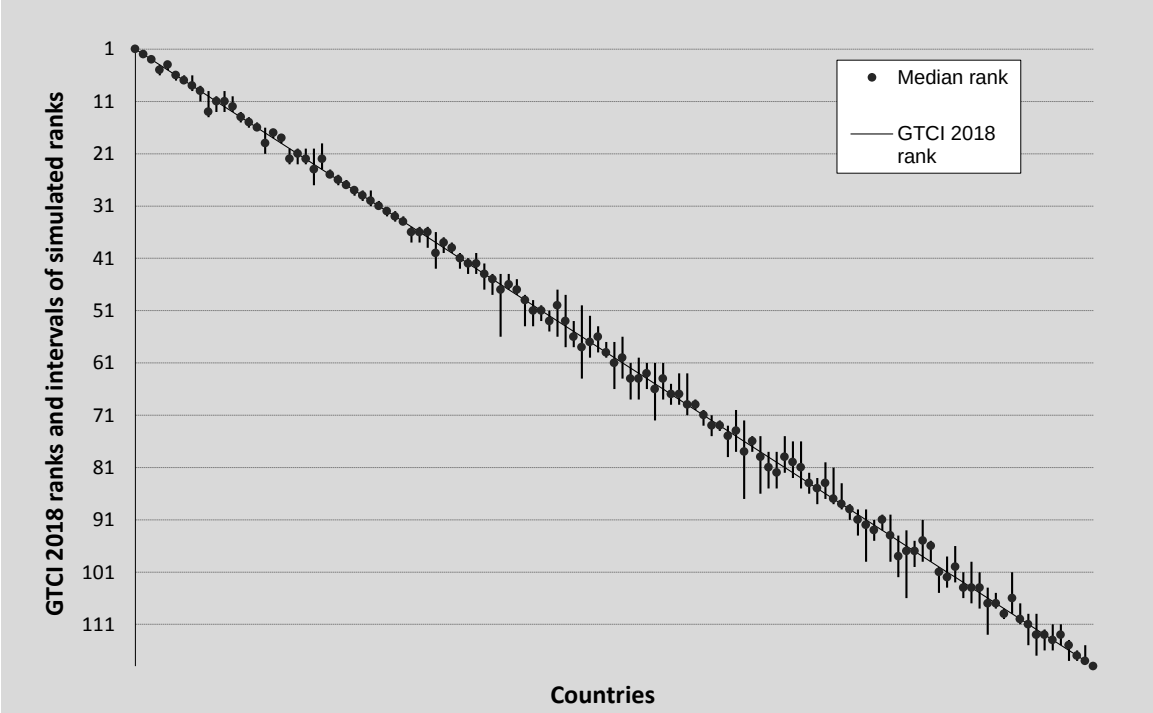



**Figure 1b**

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

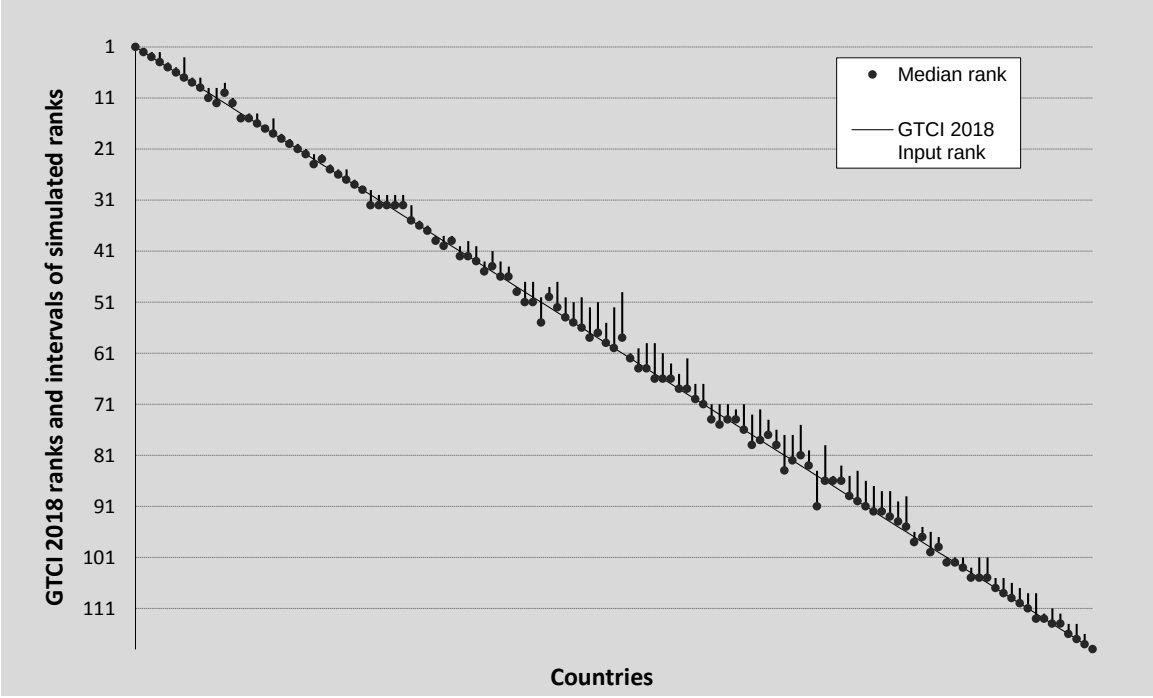
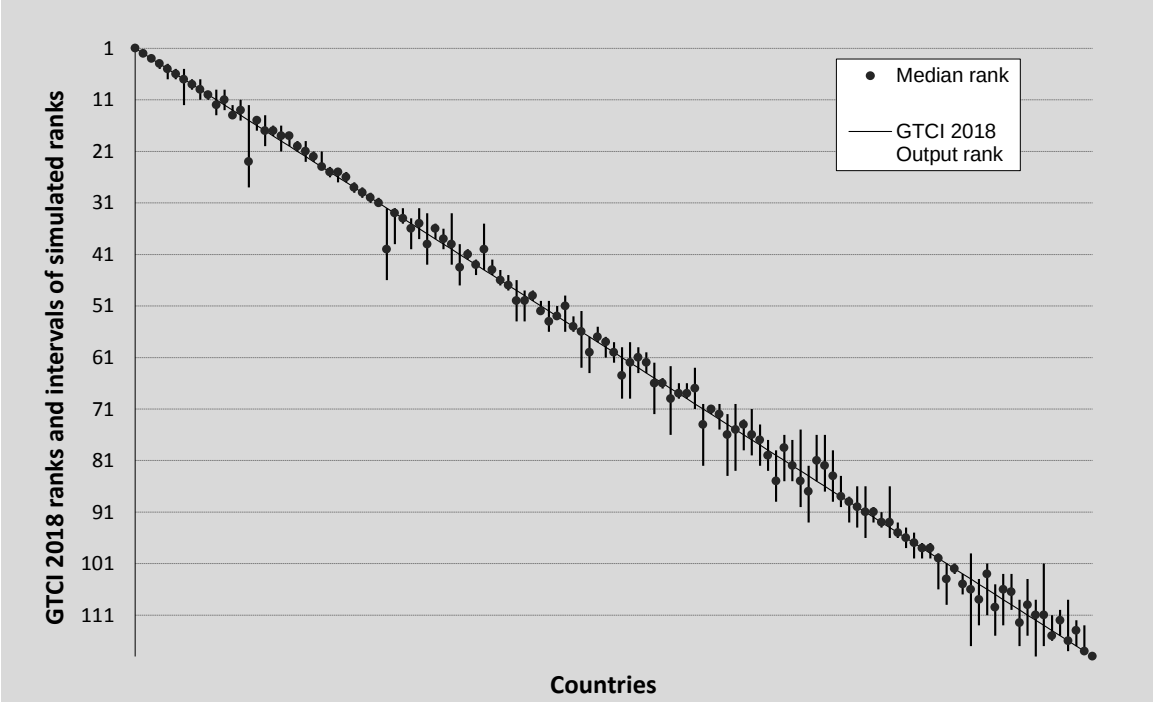


**Figure 1c**

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




Source: European Commission Joint Research Centre (2018).
Notes: The Spearman rank correlation between the median rank and the GTCI 2018 rank is 0.999; between the median rank and the GTCI 2018 Input rank is 0.999; and between the median rank and the GTCI 2018 Output rank is 0.998. 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 2018 and its Input/Output sub-indices

| | GTCI 2018 | | INPUT SUB-INDEX | | OUTPUT SUB-INDEX | |
|---|---|---|---|---|---|---|
| COUNTRY | RANK | INTERVAL | RANK | INTERVAL | RANK | INTERVAL |
| Switzerland | 1 | [1, 1] | 1 | [1, 1] | 3 | [3, 3] |
| Singapore | 2 | [2, 2] | 2 | [2, 4] | 2 | [2, 2] |
| United States of America | 3 | [3, 3] | 11 | [9, 13] | 1 | [1, 1] |
| Norway | 4 | [4, 6] | 3 | [2, 5] | 7 | [5, 12] |
| Sweden | 5 | [4, 5] | 4 | [2, 5] | 6 | [5, 7] |
| Finland | 6 | [6, 7] | 8 | [7, 10] | 4 | [4, 5] |
| Denmark | 7 | [6, 7] | 5 | [4, 7] | 8 | [7, 9] |
| United Kingdom | 8 | [6, 9] | 6 | [5, 7] | 12 | [9, 13] |
| Netherlands | 9 | [8, 11] | 9 | [7, 11] | 11 | [9, 14] |
| Luxembourg | 10 | [9, 14] | 7 | [3, 13] | 20 | [18, 20] |
| Australia | 11 | [10, 13] | 10 | [9, 12] | 14 | [11, 15] |
| New Zealand | 12 | [9, 13] | 12 | [8, 13] | 13 | [12, 14] |
| Ireland | 13 | [10, 13] | 13 | [11, 13] | 10 | [10, 11] |

| | | | | | | |
|---|---|---|---|---|---|---|
| Iceland | 14 | [13, 15] | 17 | [17, 18] | 5 | [4, 7] |
| Canada | 15 | [14, 16] | 15 | [14, 16] | 16 | [15, 17] |
| Belgium | 16 | [15, 16] | 14 | [14, 16] | 18 | [16, 18] |
| United Arab Emirates | 17 | [16, 21] | 18 | [15, 19] | 15 | [12, 28] |
| Austria | 18 | [17, 18] | 16 | [14, 17] | 22 | [19, 23] |
| Germany | 19 | [18, 19] | 19 | [18, 20] | 17 | [14, 20] |
| Japan | 20 | [20, 23] | 21 | [20, 24] | 23 | [21, 23] |
| France | 21 | [20, 23] | 22 | [21, 23] | 21 | [19, 21] |
| Estonia | 22 | [20, 23] | 24 | [22, 24] | 19 | [16, 21] |
| Qatar | 23 | [20, 27] | 20 | [19, 21] | 32 | [32, 46] |
| Israel | 24 | [19, 24] | 27 | [25, 28] | 9 | [7, 11] |
| Czech Republic | 25 | [24, 25] | 23 | [22, 24] | 27 | [25, 27] |
| Malta | 26 | [25, 27] | 26 | [25, 27] | 26 | [25, 27] |
| Malaysia | 27 | [26, 27] | 25 | [24, 27] | 29 | [28, 30] |
| Slovenia | 28 | [28, 29] | 33 | [30, 34] | 25 | [24, 26] |
| Portugal | 29 | [28, 30] | 28 | [27, 28] | 34 | [32, 35] |
| Korea, Rep. | 30 | [28, 31] | 35 | [32, 37] | 24 | [21, 24] |
| Spain | 31 | [30, 31] | 29 | [29, 30] | 38 | [35, 38] |
| Lithuania | 32 | [32, 33] | 31 | [30, 34] | 39 | [36, 40] |
| Chile | 33 | [32, 34] | 34 | [30, 34] | 42 | [40, 42] |
| Latvia | 34 | [33, 34] | 37 | [36, 37] | 30 | [29, 31] |
| Costa Rica | 35 | [35, 38] | 32 | [30, 34] | 52 | [50, 56] |
| Italy | 36 | [35, 38] | 42 | [39, 45] | 31 | [30, 31] |
| Cyprus | 37 | [35, 39] | 45 | [41, 46] | 28 | [27, 29] |
| Bahrain | 38 | [36, 43] | 30 | [29, 35] | 62 | [58, 69] |
| Poland | 39 | [37, 40] | 41 | [40, 43] | 33 | [32, 39] |
| Slovakia | 40 | [38, 40] | 40 | [38, 41] | 43 | [42, 45] |
| Saudi Arabia | 41 | [40, 43] | 38 | [38, 41] | 48 | [46, 54] |
| Greece | 42 | [41, 44] | 47 | [44, 50] | 37 | [33, 43] |
| China | 43 | [40, 44] | 46 | [43, 49] | 40 | [33, 43] |
| Uruguay | 44 | [42, 47] | 36 | [35, 36] | 73 | [70, 75] |
| Panama | 45 | [44, 48] | 43 | [40, 46] | 58 | [55, 58] |
| Mauritius | 46 | [44, 56] | 39 | [38, 42] | 67 | [63, 76] |
| Bulgaria | 47 | [44, 47] | 48 | [48, 53] | 46 | [44, 47] |
| Croatia | 48 | [45, 48] | 56 | [50, 62] | 45 | [42, 45] |
| Argentina | 49 | [48, 54] | 50 | [47, 59] | 51 | [50, 52] |
| Jordan | 50 | [49, 54] | 49 | [47, 56] | 55 | [53, 56] |
| Kazakhstan | 51 | [50, 53] | 54 | [50, 57] | 53 | [51, 53] |
| Hungary | 52 | [51, 55] | 59 | [55, 64] | 50 | [48, 50] |
| Russian Federation | 53 | [47, 56] | 66 | [61, 71] | 36 | [32, 38] |
| Philippines | 54 | [48, 58] | 55 | [51, 61] | 54 | [49, 56] |
| Trinidad and Tobago | 55 | [53, 58] | 52 | [48, 54] | 57 | [57, 64] |
| Oman | 56 | [50, 64] | 44 | [43, 48] | 75 | [70, 83] |
| Azerbaijan | 57 | [52, 60] | 57 | [52, 63] | 56 | [52, 63] |
| Montenegro | 58 | [54, 59] | 69 | [62, 70] | 41 | [39, 47] |
| Macedonia, FYR | 59 | [57, 60] | 51 | [50, 59] | 63 | [59, 64] |
| Lebanon | 60 | [57, 66] | 82 | [77, 84] | 35 | [34, 40] |
| Ukraine | 61 | [56, 64] | 78 | [72, 85] | 44 | [35, 44] |
| Botswana | 62 | [61, 68] | 53 | [47, 59] | 79 | [77, 83] |
| South Africa | 63 | [60, 68] | 61 | [49, 64] | 72 | [71, 72] |
| Romania | 64 | [61, 66] | 63 | [60, 67] | 64 | [60, 64] |
| Kuwait | 65 | [61, 72] | 58 | [51, 62] | 78 | [74, 82] |
| Armenia | 66 | [61, 68] | 77 | [73, 85] | 47 | [45, 48] |
| Colombia | 67 | [65, 69] | 64 | [59, 67] | 68 | [66, 69] |
| Turkey | 68 | [63, 69] | 71 | [67, 77] | 59 | [57, 61] |
| Serbia | 69 | [63, 71] | 84 | [80, 88] | 49 | [48, 54] |

| | | | | | | |
|---|---|---|---|---|---|---|
| Thailand | 70 | [68, 70] | 62 | [61, 65] | 77 | [71, 80] |
| Mexico | 71 | [70, 73] | 68 | [65, 71] | 76 | [73, 79] |
| Georgia | 72 | [71, 75] | 72 | [71, 81] | 69 | [66, 69] |
| Brazil | 73 | [72, 74] | 67 | [63, 68] | 82 | [77, 85] |
| Peru | 74 | [73, 79] | 74 | [71, 78] | 71 | [70, 82] |
| Mongolia | 75 | [70, 78] | 79 | [74, 80] | 65 | [62, 72] |
| Rwanda | 76 | [72, 87] | 60 | [52, 66] | 99 | [97, 100] |
| Indonesia | 77 | [75, 78] | 75 | [72, 77] | 74 | [72, 84] |
| Albania | 78 | [75, 86] | 70 | [67, 71] | 91 | [86, 96] |
| Dominican Republic | 79 | [78, 85] | 73 | [71, 80] | 88 | [84, 90] |
| Namibia | 80 | [78, 85] | 65 | [59, 72] | 97 | [95, 100] |
| India | 81 | [75, 82] | 88 | [83, 92] | 66 | [65, 67] |
| Sri Lanka | 82 | [76, 83] | 80 | [76, 82] | 81 | [76, 85] |
| Tunisia | 83 | [76, 85] | 94 | [88, 95] | 60 | [58, 62] |
| Guatemala | 84 | [82, 86] | 76 | [71, 81] | 93 | [91, 94] |
| Ecuador | 85 | [83, 88] | 83 | [75, 85] | 89 | [88, 93] |
| Moldova, Rep. | 86 | [80, 87] | 92 | [87, 94] | 70 | [63, 71] |
| Viet Nam | 87 | [81, 88] | 87 | [85, 89] | 83 | [75, 90] |
| Kenya | 88 | [84, 89] | 89 | [85, 95] | 86 | [76, 87] |
| Bosnia and Herzegovina | 89 | [88, 91] | 96 | [89, 98] | 80 | [79, 89] |
| Ghana | 90 | [89, 94] | 86 | [79, 91] | 98 | [97, 100] |
| Bhutan | 91 | [89, 99] | 81 | [77, 87] | 106 | [101, 111] |
| Honduras | 92 | [91, 95] | 91 | [86, 98] | 96 | [94, 98] |
| Kyrgyzstan | 93 | [90, 93] | 98 | [95, 99] | 84 | [82, 93] |
| Iran, Islamic Rep. | 94 | [90, 99] | 105 | [101, 108] | 61 | [59, 69] |
| Lao PDR | 95 | [94, 102] | 85 | [84, 97] | 108 | [103, 113] |
| Gambia | 96 | [93, 106] | 90 | [84, 96] | 104 | [99, 117] |
| Senegal | 97 | [95, 100] | 93 | [88, 96] | 101 | [101, 109] |
| Morocco | 98 | [91, 99] | 97 | [96, 99] | 95 | [93, 96] |
| Paraguay | 99 | [95, 99] | 95 | [90, 96] | 100 | [99, 106] |
| El Salvador | 100 | [100, 105] | 100 | [97, 100] | 105 | [104, 113] |
| Algeria | 101 | [98, 104] | 108 | [105, 110] | 90 | [86, 94] |
| Bolivia, Plurinational St. | 102 | [96, 103] | 106 | [101, 109] | 92 | [90, 93] |
| Uganda | 103 | [101, 106] | 99 | [96, 100] | 110 | [108, 117] |
| Egypt | 104 | [99, 107] | 109 | [106, 113] | 94 | [86, 96] |
| Venezuela, Bolivarian Rep. | 105 | [101, 108] | 112 | [108, 118] | 85 | [76, 85] |
| Lesotho | 106 | [104, 113] | 101 | [101, 105] | 112 | [108, 119] |
| Tanzania | 107 | [105, 108] | 102 | [101, 105] | 115 | [110, 115] |
| Cambodia | 108 | [108, 110] | 104 | [103, 107] | 117 | [112, 117] |
| Pakistan | 109 | [101, 109] | 115 | [112, 116] | 87 | [79, 89] |
| Malawi | 110 | [107, 111] | 107 | [105, 109] | 111 | [104, 115] |
| Nicaragua | 111 | [109, 115] | 103 | [101, 104] | 119 | [118, 119] |
| Ethiopia | 112 | [109, 117] | 110 | [107, 113] | 116 | [108, 118] |
| Mali | 113 | [112, 116] | 111 | [108, 112] | 114 | [111, 116] |
| Bangladesh | 114 | [111, 116] | 113 | [112, 115] | 107 | [105, 115] |
| Zimbabwe | 115 | [111, 115] | 116 | [114, 117] | 102 | [101, 103] |
| Nepal | 116 | [114, 118] | 117 | [114, 118] | 103 | [103, 107] |
| Mozambique | 117 | [116, 118] | 114 | [111, 117] | 118 | [113, 118] |
| Madagascar | 118 | [115, 118] | 118 | [116, 118] | 109 | [103, 110] |
| Yemen | 119 | [119, 119] | 119 | [119, 119] | 113 | [101, 117] |

Source: European Commission Joint Research Centre (2018).

## [b]Sensitivity Analysis Results

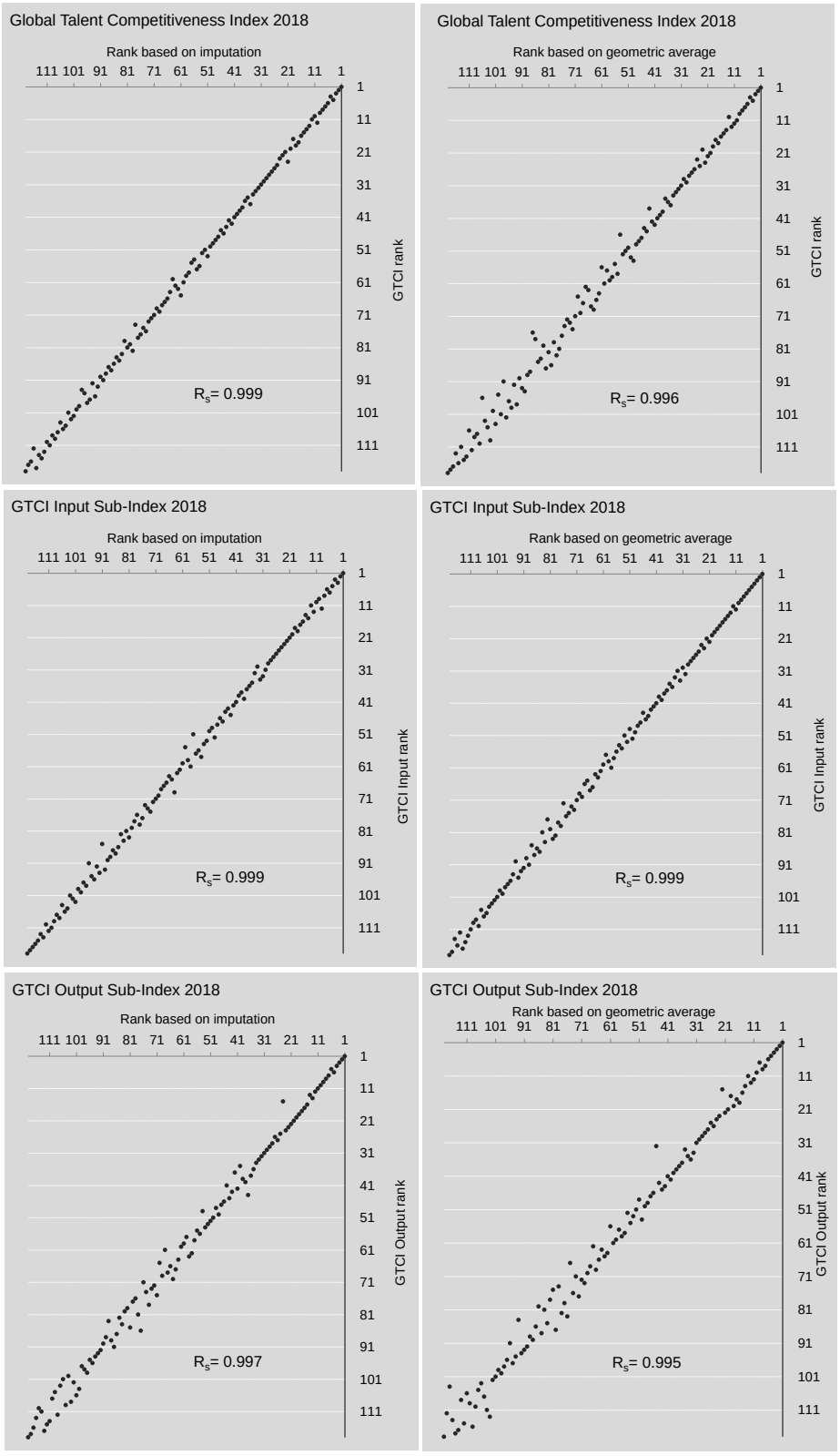
Complementary to the uncertainty analysis, sensitivity analysis has been used to identify which of the modelling assumptions have the highest impact on certain country ranks. Figure 2 plots the GTCI and both sub-index rankings versus one-at-a-time changes of either the EM imputation method or the geometric 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 (given that a lower rank correlation indicates greater sensitivity). This choice has the largest impact on differences in ranking for the GTCI 2018 and the Output sub-index, less so for the Input sub-index. For example, in the most extreme case, a country falls by 13 positions in the Output ranking when geometric aggregation is applied, yet the country increases by four positions if missing data are imputed. 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.[8]

Overall, given the fairly modest ranges of uncertainty on the final rankings, the JRC recommendation is not to alter the GTCI methodology at this point, but to consider country ranks in the GTCI 2018 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 2018 and the Input and Output sub-indices are the result of the underlying data and not of modelling choices.[9]

**Figure 2**

**Sensitivity analysis: Impact of modelling choices**



Source: European Commission Joint Research Centre (2018).
Note: $R_s$ represents the Spearman rank correlation coefficient.

## [A]Conclusions

The JRC analysis suggests that the conceptualised multi-level structure of the GTCI 2018 is statistically coherent and balanced (i.e., not dominated by any pillar or sub-pillar; all variables contribute to the variation of the respective Input/Output sub-indices and to the overall GTCI). Furthermore, the analysis has offered statistical justification for the use of equal weights and arithmetic averaging at the various levels of aggregation, showing that the GTCI 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 0.7 threshold for a reliable aggregate).

Points that call for possible refinements of the GTCI framework were also identified. These refinements mainly concern five out of the 68 variables, namely 1.3.1 Ease of hiring, 2.2.5 Gender earnings gap, 3.1.3 Tertiary education expenditure, 3.2.2 Prevalence of training in firms, and 6.2.3 New product entrepreneurial activity. Although present in the conceptual framework, these variables do not appear to contribute significantly to the variation of the GTCI country scores and, consequently, do not have an impact on the GTCI rankings.

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. 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 2018. 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: the GTCI ranking differs from any of the six pillar rankings by 10 positions or more for at least one-third (up to two-thirds) 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 2018, subject to some minor hints for future releases, in reliably identifying weaknesses and best practices and ultimately monitoring national performance in human capital and competitiveness issues around the world.

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**[a]Endnotes**

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

[2] OECD & EC JRC (2008).

[3] Groeneveld and Meeden (1984) set the criteria for absolute skewness above 1 and kurtosis above 3.5. The skewness criterion was relaxed to account for the small sample (119 countries).

[4] Only in three of the sub-pillars is there a second principal component with an eigenvalue slightly above the 1.0 threshold: 1.3 Business and Labour Landscape (eigenvalue of 1.01), 2.2 Internal Openness

(eigenvalue of 1.05), and 6.2 Talent Impact (eigenvalue of 1.03). This suggests that relevant information might be lost when directly aggregating the variables into sub-pillars.

[5] See Nunnally (1978).

[6] Becker et al. (2017).

[7] Saisana et al. (2005); Saisana & Saltelli (2011), Saisana et al. (2011); Saltelli et al. (2008).

[8] Saltelli & Funtowicz (2014).

[9] As already mentioned in the uncertainty analysis, about 95% of the simulated median ranks for the GTCI and Input (sub-) indices are less than two positions away from the reported 2018 rank—this percentage drops only to 81% in the Output sub-index.