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JRC Statistical Audit of the ICT Development Index

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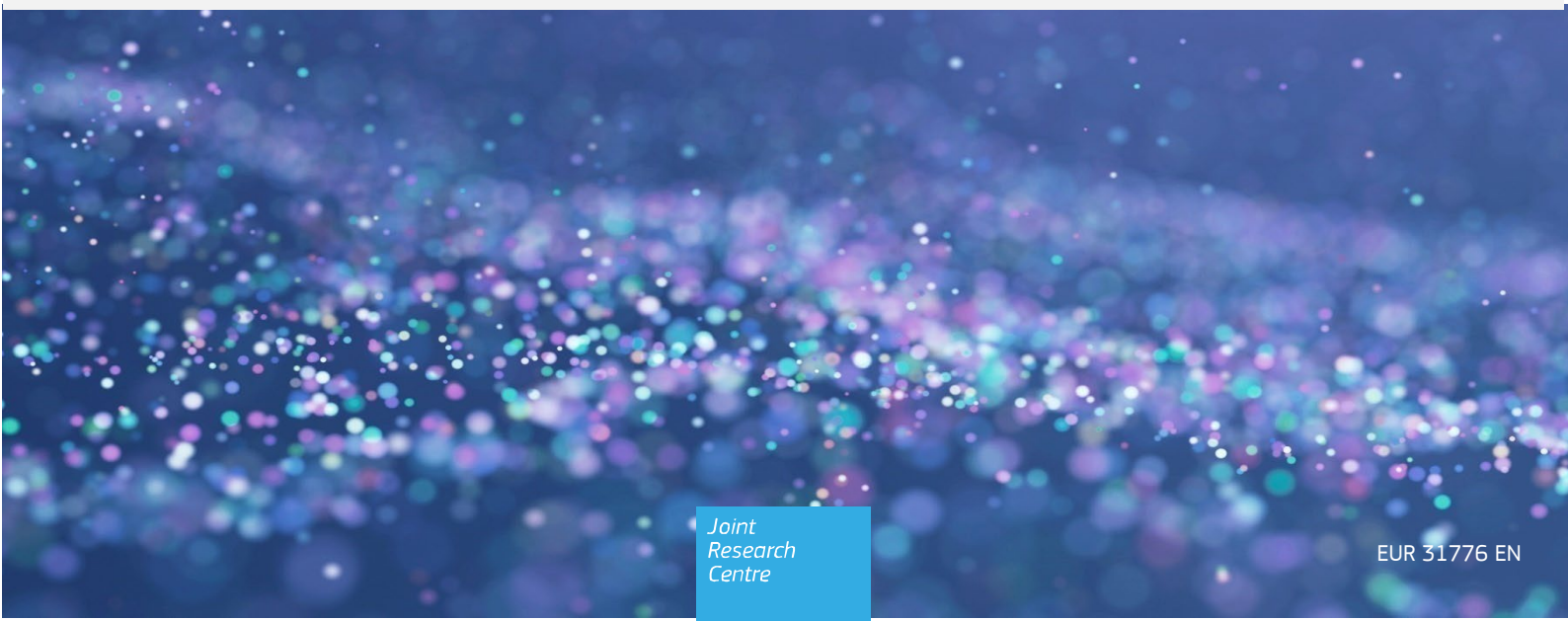

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Abstract

The JRC was invited to statistically audit the 2023 ICT Development Index developed by The International Telecommunications Union which aims to assess economies on their level of meaningful and universal connectivity as defined by the United Nations. The audit covers the data quality and coverage, correlation structure and uncertainty in scores due to methodological assumptions, which were all found to be more than adequate. The developers have implemented JRC-COIN guidelines on outlier treatment, missing data imputation and created an index with a low level of uncertainty in the final scores. The JRC-COIN concludes that the ICT Development Index is statistically robust and reliable.

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1 Introduction

Since 2009, the International Telecommunication Union (ITU) has published its ICT Development Index (IDI), which benchmarks countries' performance with regard to ICT infrastructure, use and skills. The JRC previously conducted an analysis in 2015 at ITU's invitation, concluding that the conceptualised three-level structure of was statistically sound in terms of coherence and balance. However, the IDI was discontinued in 2018. In 2022, ITU's Plenipotentiary Conference in Bucharest adopted a revised text of Resolution 131 detailing a development plan for the construction and release of a new IDI in 2023. The goals set out in Resolution 131 include a broadly accepted methodology that sets minimum data availability and quality criteria while all statistical work must follow the UN principles on good statistics. Additionally, members of the ITU agreed the IDI will be published without rankings. Accordingly, this audit will exclusively deal with scores.

In this statistical audit the JRC will provide its guidance and suggestions on the data, methodology and statistical coherence of the IDI in line with the best-practices laid out in the JRC/OECD handbook (2008). These include checks on the data quality and coverage, correlation structure and uncertainty in scores due to methodological assumptions carried out in R using the COINr package (Becker et al. 2022). The independent statistical assessment of the IDI provided by the JRC-COIN guarantees the transparency and reliability of the index for both policymakers and other stakeholders, thus facilitating more accurate priority setting and policy formulation. The JRC-COIN analysis complements the economy scores with confidence intervals for the IDI, in order to allow a better appreciation of the robustness of the scores to the choice of computation methodology.

2 Conceptual Framework

Following the 2022 consultations, the concepts included in the IDI developed from focusing on quantity, access and use toward quality and impacts. This choice aims to distinguish between the use of connectivity with the Universal pillar and the quality of connectivity, with the Meaningful one. This choice is clear and intuitive, and is well justified in the methodological report related to it, improving the transparency of this tool. The shift is embodied in the concept of "universal and meaningful connectivity" as defined by the UN Secretary-General's Roadmap for Digital Cooperation (UN 2020). Accordingly, the 2023 version of the IDI has two pillars "Universal Connectivity" and "Meaningful Connectivity", the first has three indicators and the second six indicators which are aggregated to an overall index using the arithmetic mean and equal weights.

The conceptual framework and indicators are shown in Table 1. Indicators *i271G* and *i271GA* are used in the IDI after aggregation into a unique indicator referred to as iCover in this audit. It is computed as the arithmetic average of the two. Here, 3G coverage is weighted less (0.4) and 4G Coverage more (0.6). This is a more intuitive version of previous proposals and aims to reward the economies with the best coverage, while considering the efforts that have been done with the 3G technology.

The indicators were selected based on seven criteria: relevance to the concept; clarity/interpretability (i.e. clear impact on connectivity); quality of the source of data, which should be primarily official sources; reliability through the use of harmonised methodology developed by ITU; applicability as measure of countries performance (sufficient variation of values among countries and in time, quantitative indicators are preferred); availability for as many of the 196 considered economies as possible; and timeliness. Expert consultation was used in the process, relying on two international groups: The Expert Group on ICT Household Indicators (EGH) and the Expert Group on Telecommunication/ICT Indicators (EGTI).

Table 1. Conceptual framework of the SDG Index.

Pillar	***Id***	***ITU Code***	***ICT Development Index (IDI)***	***Dir.***
Universal Connectivity	*iNet.ind*	*i99H*	*Proportion of individuals who used the Internet*	*+*
	iNet.hh	*xHH6_IDI*	*Proportion of households with Internet access at home*	*+*
	iNet.m	*i911mw*	*Active mobile-broadband subscriptions per 100 inhabitants*	*+*
Meaningful Connectivity	*iCover*	*i271G*	*Population covered by at least a 3G mobile network (%)*	*+*
		i271GA	*Population covered by at least an 4G mobile network (%)*	*+*
	iMNet	*i136mwi_subs*	*Mobile broadband Internet traffic per mobile broadband subscriptions (GB)*	*+*
	iFNet	*i135tfb_subs*	*Fixed broadband Internet traffic per fixed broadband subscriptions (GB)*	*+*
	iMPrice	*i271mb_high_ts_GNI*	*Mobile data and voice high-consumption basket price (as % of GNI per capita)*	*-*
	iFPrice	*i154_FBB_ts_GNI*	*Fixed-broadband Internet basket price (as % of GNI per capita)*	*-*
	iPercMob	*xHH18_IDI*	*Percentage of individuals owning a mobile phone*	*+*

Source: European Commission, 2023

The IDI framework includes a total of 10 global indicators. While the conceptual relevance of the indicators underpinning the framework is not addressed in this document, we would like to flag the following:

— The number of indicators across the pillars is uneven, six for Meaningful Connectivity and three for Universal Connectivity. As recognised also by the authors, this means that the six indicators in Meaningful Connectivity weight individually less than the indicators in Universal Connectivity. This aspect does not determine any implicit error and can serve as an additional layer of interpretation, improving readability without increasing complexity.

— In the following sections of this document, the indicators i271G and i271GA would not be analysed separately. Only their aggregate (i271 called iCover) is included in the following analysis.

— The small number of indicators can help make this index a more immediate and readable monitoring tool.

3 Data checks

In this section, the JRC will comment on the distributions of the indicators provided by the ITU. The analysis will depart from data treated for outliers and imputed. However, JRC-COIN found that outlier treatment in the IDI follows best-practice recommendations by log-transforming two indicators where more than five outliers are detected. Regarding data imputation, the developers computed the first two indicators of the universal pillar using estimation methods. This part of the development is not investigated and analysed in the present document. We suggest to refer to the developers' technical notes for further details. When models for the estimation were not available, the ITU performed the imputation of missing data using k-nearest neighbour (kNN). JRC-COIN supports the use of kNN, because it has a conservative impact on the comparison between similar units. The final coverage before imputation is satisfying with only one indicator showing more than 20% of missing values (iMPrice). The suggestion in this case is to work to improve the coverage of this indicator among the economies in the index updates in the future.

To facilitate fair aggregation and comparison, each indicator should have a similar range and be able to discriminate meaningful differences between units. The IDI normalised data meets these criteria. The IDI developers' first action was to log-transform the indicators iFNEt and IMPrice, as their distributions were highly skewed. Second, as part of the normalisation phase, all the indicators involved in the IDI are treated by trimming the data exceeding some fixed bounds. This approach consists of defining thresholds and goalposts for the indicators and adapting the exceeding values to those bounds (increasing values below the threshold and decreasing values above the goalpost). The use of logarithms and fixed bounds has the implicit effect of reducing the impact of outliers because it transforms their values into something less extreme. These two actions have successfully brought all indicators within the thresholds suggested by JRC-COIN for outlier detection, as seen in Table 2, i.e. when the indicators have simultaneously absolute skewness greater than 2.0 and kurtosis greater than 3.5.

There are two indicators where about one-fourth of the units have the same score - iMPrice and iPercMob – meaning these indicators have a reduced power to discriminate between country's ICT developments. Usually, this statistic may highlight the presence of an indicator with a small informative power. But, in this case, the concentration of values is due to the presence of a goalpost, which acts as a reference value and has its conceptual meaning. JRC-COIN may suggest keeping track of the evolution of these indicators in time to evaluate if the proportion of economies reaching the goalpost increases in the future and, possibly, increase the value of the goalpost.

Table 2. Descriptive Statistics of Normalised Data

ID	Min	Max	Mean	SD	Skew	Kurtosis	Imputed (%)	Estimated (%)	Non-unique
iNet.ind	10.50	100	74.0	24.9	-1.02	-0.05	0	73 (43)	18
iNet.hh	3.45	100	74.3	26.0	-0.99	-0.12	0	73 (43)	20
iNet.m	0.49	100	55.1	24.6	-0.16	-0.61	0	1 (0.5)	9
iCover	18.40	100	86.7	19.6	-1.73	2.03	0	1 (0.5)	13
iMNet	3.14	100	63.7	18.5	-0.80	1.23	0	1 (0.5)	3
iFNet	0.20	100	76.8	17.9	-1.92	3.76	17 (10)	0	5
iMPrice	0.00	100	78.3	30.0	-1.58	1.35	48 (28)	0	42
iFPrice	0.00	100	77.7	31.1	-1.54	1.10	0	0	25
iPercMob	19.90	100	84.3	17.8	-1.23	0.92	0	0	46

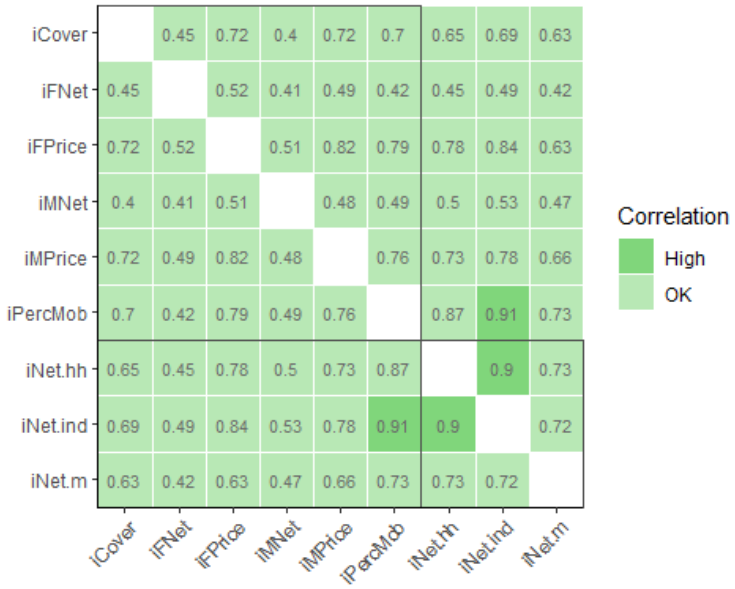
Source: European Commission, 2023

4 Correlation Analysis

In this section, the JRC-COIN team reviews the correlation structure of the IDI. Correlation structures are essential in composite indicators as they facilitate the meaningful aggregation of the information contained at the indicator level. For these purposes, the JRC-COIN recommends correlations between indicators within the same pillar to be at least 0.30 and up to 0.92 (to avoid redundancy).

Figure 3 shows the correlations between indicators; those that share the same pillar are outlined in black. All correlations are stronger than 0.3 in both pillars. It is clear that the IDI has a good correlation structure. It is useful to notice how two indicators of the first pillar, iNet.ind and iNet.hh share a very high correlation. This result highlights that they are sharing a relevant part of their variance, narrating similar aspects. Correlation 0.9 is not enough to consider it as a source of redundancy. At the same time, the third indicator of the pillar still has a good correlation with the others, so there is no specific reason to worry for this aggregation.

Figure 1. Correlations between indicators



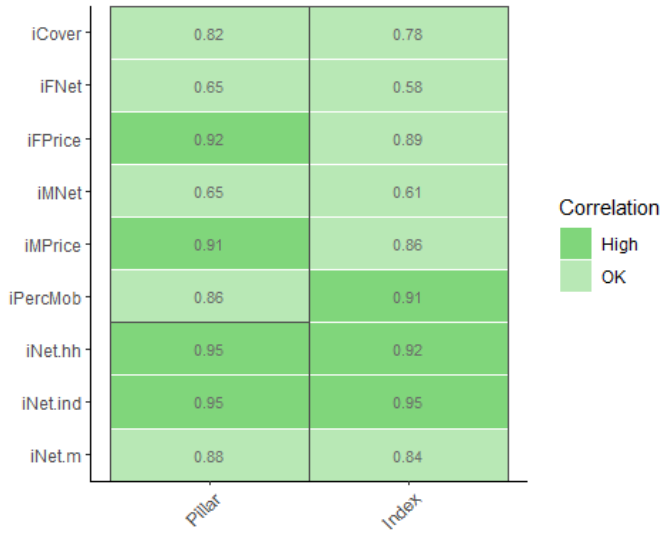
Source: European Commission, 2023

Similarly, Figure 2, column one, shows the correlations between indicators and pillar scores are also good, ranging from 0.6 to 0.95, indicating most information from the indicators is summarised in the pillars.

Correlations between the indicators and the index score are equally good, as shown in Figure 2, column two. It is clear how the elements of the Universal connectivity pillar are strongly correlated with their pillar and with the index. Most of their information is passed and represented in the final score. Since all the other indicators strongly correlate with the higher aggregates, there is no reason to identify a possible imbalance in favour of the two most correlated elements. In the future evolution of the IDI, JRC-COIN suggest keeping the role of these two indicator under control, also considering the inclusion of other indicators in the Universal connectivity pillar, if their correlation with the index improves further or the correlation of the Meaningful connectivity pillar's elements decreases.

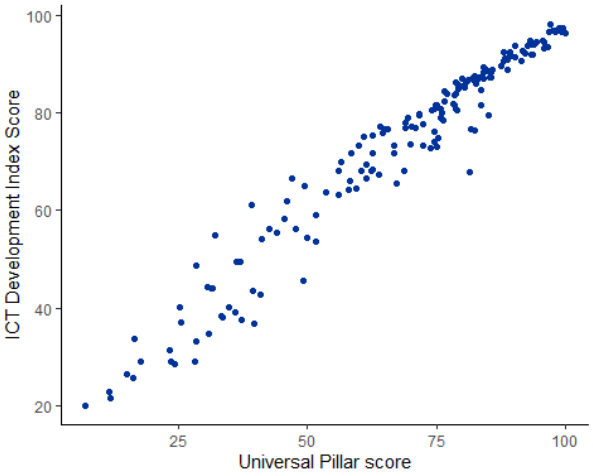
Lastly, the correlation between the two pillars is 0.88, and the respective correlations of the Universal and Meaningful pillars with the index are 0.98 and 0.96, which shows that virtually all information from the separate pillars is aggregated to the index. However, the two pillars are not redundant, as shown in Figure 3 and Figure 4, where economies differ substantively on the pillar score with respect to the index score. This result shows that, despite the clear and strong relation between the pillars and the index, there is an added value in observing the pillars, because they supply a a set of specific and unique information. This is particularly true for the Meaningful connectivity pillar.

Figure 2. Correlations between Indicators and their respective Universal Connectivity and Meaningful Connectivity Pillars and the IDI



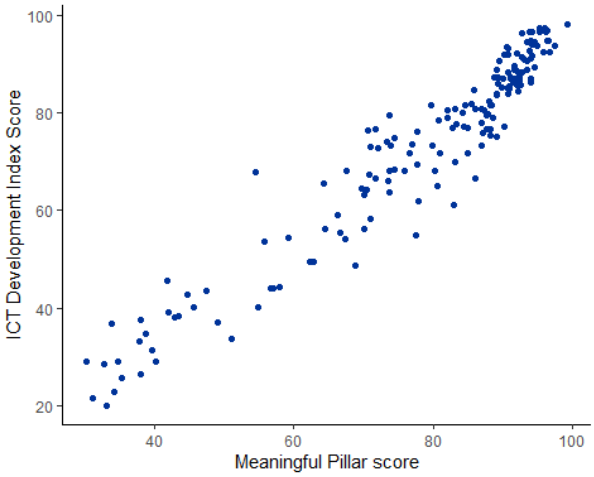
Source: European Commission, 2023

Figure 3. Score comparison of Universal Pillar and ICT Development Index



Source: European Commission, 2023

Figure 4. Score comparison of Meaningful Pillar and ICT Development Index



Source: European Commission, 2023

5 Uncertainty Analysis

An essential part of the statistical audits is to check the effect of varying assumptions within plausible ranges. Modelling assumptions with a direct impact on an Index scores relate to the underlying structure for the index based on pillars, the individual variables to be used as indicators, the method to impute missing data, the procedure to treat outliers, the normalisation approach, the weights assigned and the aggregation formula to be implemented.

As the relevant literature on composite indicators suggested, the robustness assessment was based on Monte Carlo simulation and multi-modeling approaches, applied to "error-free" data where potential outliers, errors and typos have already been corrected at a preliminary stage. Usually, uncertainty analysis are carried out based on a combination of some assumptions including the imputation methods, normalisation, aggregation and weights. However in this case the imputation and normalisation methods are based respectively on a clear conservative choice and on strong conceptual positions, so they are not included in the uncertainty analysis. The only assumptions in the IDI that can be plausibly varied are the pillar weights and the aggregation formula. Considering the choice at the genesis of the IDI of making no reference to ranking and comparison among economies, JRC-COIN decided to exclude the aggregation formula. This is because the arithmetic and geometric mean results are conceptually comparable only in rankings.

Therefore, the JRC-COIN team ran a Monte Carlo simulation comprising 1,000 runs of different sets of weights for the two IDI pillars. Weights were assigned to the pillars based on random perturbations centred on the reference values. The ranges of simulated weights were defined by considering both the need for a wide enough interval to allow for meaningful robustness checks and the need to respect the underlying principle of the IDI that these should be placed on an equal footing. As a result of these considerations, the limit values of uncertainty for the weights of the two input pillars are between 40 and 60%.

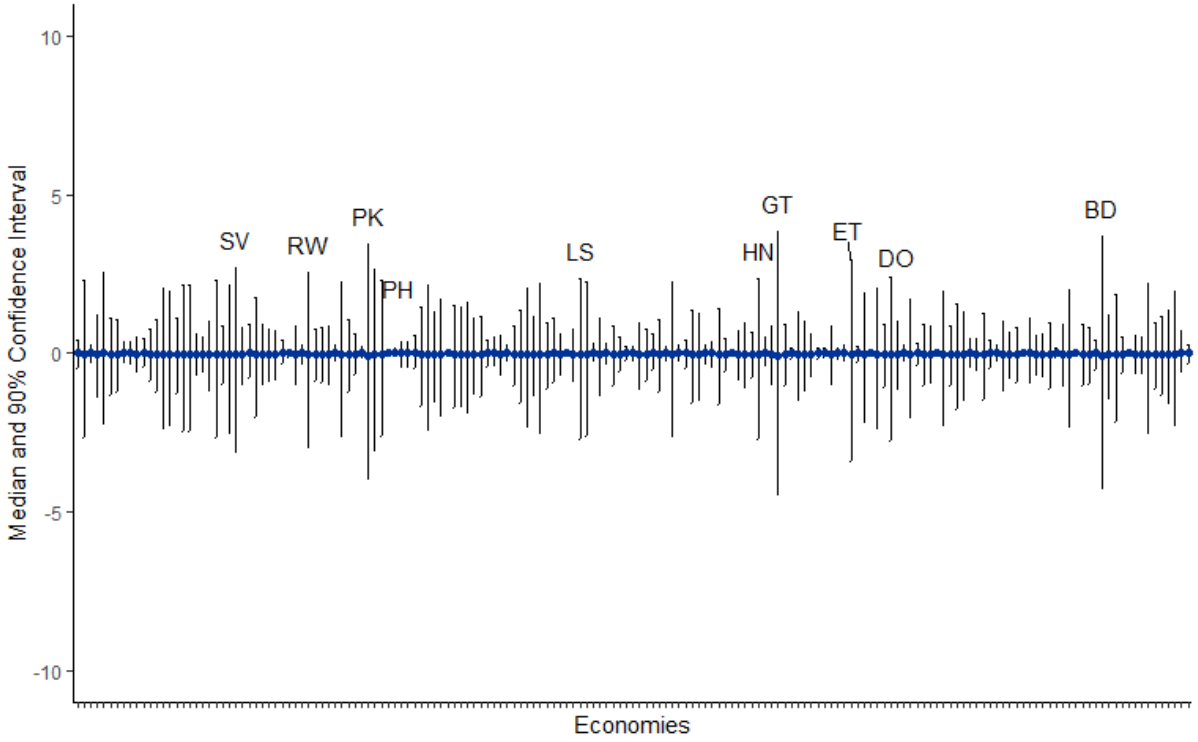
Figure 5 shows the median scores of each economy across the 1000 runs (blue dot) and their 90% confidence intervals. All economies have an IDI score that falls close to the observed median of the runs, indicating they are representative of the scenarios tested. Overall, the confidence intervals are extremely small; 125 economies out of 169 (74%) have a confidence interval of three points or less. Only 16 economies have a confidence interval of five or more points, and these are labelled in Figure 5. A large interval means that the economy has different levels of achievement between the two pillars, and its score can be influenced by rewarding or penalising one of them with different weights. All in all, given that the scores on the IDI range from 20 to 98.2, a confidence interval of five to ten points can still be considered adequate. JRC-COIN suggests keeping this small uncertainty into account while drawing policy messages for the economies with the most significant intervals (e.g. GT, BD, and PK).

Table 3 Uncertainty Analysis Parameters

Method	Pillar	Nominal	Alternative
Weights	Universal	50%	40-60%
	Meaningful	50%	40-60%

Source: European Commission 2023.

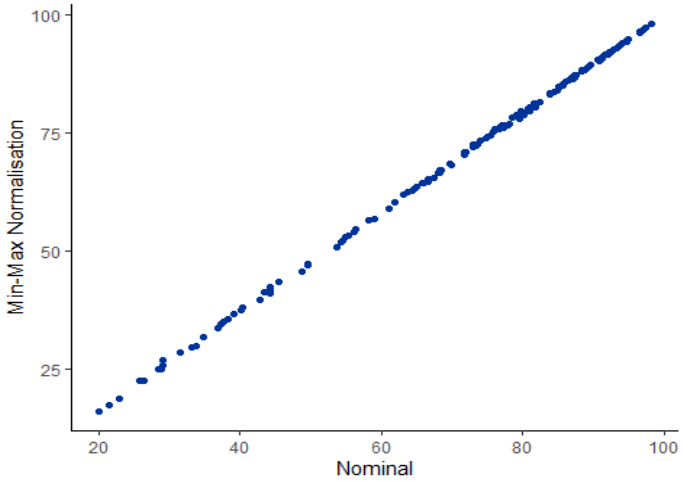
Figure 5. Uncertainty in ICT Development Index scores.



Note: Blue dots show the median score across simulations, the 0 point on the y-axis is the nominal score. The lines represent the 90% confidence interval of the country's score based on the simulation. Labeled economies have a confidence interval of five points or greater.

Source: European Commission, 2023.

Figure 6. Sensitivity of ICT Development Index to alternative normalisation.



Note: the y axis are the IDI score using a 0 to 100 normalisation. The x-axis shows the nominal IDI score using the thresholds and goal posts.

Source: European Commission, 2023.

Figure 6 shows the sensitivity of the IDI scores to alternative normalisation measures. Although the thresholds and goalposts of the IDI are conceptually and statistically justified, their implementation may still impact the results. Here the JRC-COIN shows that a min-max normalisation to 0 – 100 would not have a large impact on the scores. The alternative scores are almost equal to the nominal.

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6 Conclusions

This statistical audit assessed the statistical soundness and robustness of the International Telecommunications Union's ICT Development Index. The 2023 version of the IDI has undergone a complete overhaul. ITU has improved the conceptualisation of the IDI and accordingly updated its framework, measures and methodology.

The JRC-COIN found that the treatment of missing data, outlier treatment, and normalisation are well justified in the documentation based on conceptual and theoretical understandings of the topic and follow best practices in terms of methodology. To ensure a more future-proof index JRC-COIN suggests continuous supervision of thresholds and goalposts in the future to keep track of time and evolution of the indicators.

This statistical audit also assessed the correlation structure in the IDI. The IDI of 2023 is shown to have a strong correlation structure. All correlations between indicators, between indicators with aggregates and between aggregates are within the recommended bounds, and often quiet strong. The correlation structure facilitates information flow from the indicators to the aggregate. JRC_COIN's only suggestion in this regard is to keep the evolution of the correlation structure in time to avoid imbalances due to the evolution of the indicators.

Lastly, the statistical audit assessed the uncertainty in the IDI scores due to methodological choices. In any index, methodological choices such as weights, normalisation and aggregation have valid alternatives. This audit tested whether the weights of pillars and the normalisation approach significantly impact the IDI scores.

The analysis was limited to the analysis of scores and their sensitivity to methodological assumptions. The usual methods based on ranks were avoided because Resolution 131 states that the IDI should have no ranking. . The JRC-COIN found that the alternative weights and normalisation do not have an undue impact on the IDI scores. This indicates that the IDI is robust against changes in methodology and speaks to its highly robust structure.

The present JRC-COIN audit findings confirm that the IDI 2023 has a statistically coherent framework and acknowledge the important efforts made by ITU. In conclusion, the JRC-COIN can confirm the statistical soundness and robustness of the IDI 2023 scores.

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List of abbreviations and definitions

IDI	ICT Development Index
ITU	International Telecommunications Union
JRC-COIN	Joint Research Centre – Competence Centre on Composite Indicators and Scoreboards

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