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JRC Statistical Audit of the 2020 Commitment to Reducing Inequality index

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Contents

Abstract

The 2020 Commitment to Reducing Inequality Index (CRII) is a multidimensional index which ranks 159 countries for their policy performance across three pillars covering public services, progressive taxation and labour rights.

The statistical audit presented herein was performed by the European Commission's Joint Research Centre and aims to contribute to ensuring the transparency of the index methodology and the reliability of the results. The report touches upon data quality issues, the conceptual and statistical coherence of the framework and the impact of modelling assumptions on the results. The analysis suggests that meaningful inferences can be drawn from the index. The CRII is reliable and has a statistically coherent framework. CRII ranks are shown to be representative of a plurality of scenarios and robust to changes in the aggregation method and pillar weights. Nonetheless the good statistical properties of the CRI index, some suggestions are made for possible refinements.

1 Introduction

The Commitment to Reducing Inequality Index (CRII) aims at measuring the extent to which governments are undertaking the task of reducing inequality. It is a multidimensional index composed of nine different sub-pillars organized into three pillars, each of which corresponds to a policy area found to be critical in reducing inequality:

i. Public services (in the previous edition known as “spending”);

ii. Taxation, and

iii. Labour rights.

With respect to previous editions (2017, 2018), the 2020 CRI Index introduced some changes within these three pillars. Each pillar is now also arranged to track:

i. The policies that each government has enacted in the pillar area;

ii. The implementation or coverage of these policies in practice, and

iii. The impact of these policies on reducing income inequality (as measured by their impact on the respective Gini coefficient).

This “three-tiered” structure has been introduced to better identify the impact of the government’s policy commitments, taking into account its implementation efforts. The index is developed by Development Finance International and Oxfam. Each pillar carries the same weight in the overall score of the index. Within each pillar, the policy score is weighted equally with the implementation and impact scores. To compute a pillar’s policy or implementation score, all indicators making up that pillar’s scores are averaged or weighted equally. Because the number of indicators making up each policy or implementation score varies, the weight of each individual indicator in the overall index varies.

The CRI framework is well constructed and a lot of thought has clearly been put into it. However, conceptual and practical challenges are inevitable when trying to summarise with a single composite indicator the commitment of countries to reducing inequality. An analysis is needed to ensure and validate the statistical soundness of any composite index. This audit was performed by the European Commission’s Competence Centre on Composite Indicators and Scoreboards at the Joint Research Centre (JRC), and was conducted upon the invitation of the developers. The analysis herein aims at shedding light on the transparency and reliability of the CRI Index 2020 and thus to enabling policymakers to derive more accurate and meaningful conclusions, and to potentially guide choices on priority setting and policy formulation.

In general, statistical soundness should be regarded as a necessary, yet not a sufficient, condition for a sound index, since the correlations underpinning the majority of the statistical analyses carried out herein need not necessarily represent the real influence of the individual indicators on the phenomenon being measured. The development of any index must thus be nurtured by a dynamic iterative dialogue between the principles of statistical and conceptual soundness. In that respect, prior to undertaking the present statistical assessment, Oxfam and JRC engaged in discussions. Suggestions for fine tuning, aimed at setting the foundation for a balanced index, were taken into account by Oxfam and the Development Finance International research teams for the final computation of the CRII scores and rankings.

The JRC assessment of the CRI Index presented here focuses on two main issues: the statistical coherence of the structure, and the impact of key modelling assumptions on the

CRII ranks. The statistical analysis is based on the adequacy of aggregating indicators into pillars, and pillars into the overall index. Finally, the JRC analysis complements the reported country rankings for the CRI index 2020 with estimated intervals, in order to better appreciate the robustness of these ranks to the modelling choices.

2 Conceptual framework

The CRII is based on three pillars, each of which relates to one policy area found to be critical in reducing inequality: public services; taxation; and labour rights. The CRII includes 18 indicators grouped within 9 sub –pillars (Table 1). The index is aggregated at each level using a simple weighted arithmetic average.

Table 1. Conceptual framework of the 2020 Commitment to Reducing Inequality Index.

Pillar	Sub - pillar	Indicator	Code
PUBLIC SERVICES	PS1 Policy	Education spending % budget	PS1A
		Health spending % budget	PS1B
		Social protection spending % budget	PS1C
	PS2 Implementation	Education coverage (% completion by poorest quintile of upper secondary)	PS2A
		Universal Health Coverage & low Out of Pocket health spending	PS2B
		Social Protection coverage	PS2C
	PS3 Impact	Impact of Spending on the Gini coefficient	PS3
TAX	T1 Policy	VAT rate	T1VAR
		Progressivity of Personal Income Tax (PIT)	T1PIT
		Corporate income tax (CIT) rate & Harmful Tax Practices (HTP)	T1CIT&HTP
	T2 Implementation	Tax productivity	T2
	T3 Impact	Impact of Tax on the Gini coefficient	T3
LABOUR RIGHTS	L1 Policy	Labour Rights	L1A
		Women's Rights	L1B
		Minimum Wage legislation	L1C
	L2 Implementation	Unemployment	L2A
		Vulnerable Employment	L2B
	L3 Impact	Wages Gini	L3

Source: Developers of the Index and European Commission's Joint Research Centre, 2020.

The CRII hierarchical framework is conceptually well justified and its structure into the three pillars allows for meaningful conclusions to be made.

3 Data quality and availability

The data coverage of the framework is very good. Most indicators contain no missing values. The ones that do have, are only eight and they have less than four missing values each, as can be seen in **Table 2**.

As in the previous edition of the Index,[1] for reasons of transparency and replicability, the CRII developing team opted to not estimate the missing values, i.e., countries missing sufficient or reliable data for at least one indicator for each pillar were excluded from the Index.

Table 2. Summary statistics of the indicators included in the 2020 CRII.

Pillar	Code	Countries	% Missing data	Mean	Min. value	Max. value	Range	Skewness	Kurtosis
Public Services	PS1A	159	0	14.8	6.3	29.4	23.1	0.5	0.0
	PS1B	159	0	11.0	2.2	24.6	22.4	0.5	0.0
	PS1C	159	0	18.5	0.2	47.8	47.6	0.5	-1.1
	PS2A	157	1.3	44.0	0.0	108.5	108.5	0.1	-1.5
	PS2B	158	0.6	5875.4	1786	8665	6879	-0.4	-0.8
	PS2C	158	0.6	55.2	0.0	100.0	100.0	-0.1	-1.7
	PS1	159	0	0.4	0.0	0.7	0.7	0.0	-0.8
	PS2	159	0	0.5	0.0	1.0	1.0	-0.2	-1.4
	PS3	159	0	-0.1	-0.4	0.0	0.4	-1.4	1.7
	PS	159	0	0.4	0.0	0.8	0.8	0.3	-1.1
Tax	T1VAT	159	0	8.0	0.0	25.0	25.0	0.5	-0.6
	T1PIT	159	0	0.0	0.0	0.2	0.2	1.4	2.1
	T1CITeHTP	159	0	0.7	0.2	0.9	0.7	-1.0	1.2
	T1	159	0	0.5	0.1	0.9	0.8	0.1	-0.6
	T2	159	0	0.4	0.0	0.8	0.8	0.1	-0.5
	T3	159	0	0.0	-0.1	0.1	0.2	1.0	3.7
	T	159	0	0.5	0.3	0.7	0.4	-0.4	0.2
Labour Rights	L1A	156	1.9	3.3	0.0	10.0	10.0	1.1	0.9
	L1B	159	0	0.7	0.2	1.0	0.8	-1.4	1.5
	L1C	159	0	0.5	0.0	2.2	2.2	1.5	2.6
	L2A	158	0.6	6.9	0.5	28.2	27.7	1.6	2.5
	L2B	158	0.6	38.8	1.1	94.6	93.5	0.4	-1.2
	L1	159	0	0.5	0.2	0.8	0.6	-0.4	-0.2
	L2	158	0.6	1.4	0.7	2.0	1.3	0.0	-1.1
	L3	156	1.9	0.5	0.3	0.9	0.6	0.6	-0.7
	L	159	0	0.6	0.2	0.9	0.8	0.1	-0.8

Source: European Commission's Joint Research Centre, 2020.

The presence of outliers, which could potentially bias the effect of the indicators on the aggregates, was investigated. The JRC recommends an approach for outlier identification

[1] Lawson, M., & Martin, M. (2018). The Commitment to Reducing Inequality Index 2018: A global ranking of governments based on what they are doing to tackle the gap between rich and poor.

based on the skewness and kurtosis values[2], i.e. when the variables have simultaneously absolute skewness greater than 2.0 and kurtosis greater than 3.5. As shown in Table 2, none of the main indicators used in the calculation of the CRI Index shows critical values. Table 2 offers summary statistics for the indicators included in the CRII.

3.1 Normalisation

The indicators are rescaled to a 0–1 scale, with 0 as the lowest score for progressivity achieved by countries, and 1 as the highest, which is a common and usually desired practice at the composite indicators' construction. In the CRII case though, the results of the aggregations (sub-pillars and pillars) are again normalised to (0, 1).

While the (0, 1) normalisation (also called MIN-MAX normalisation), allows for clarity and readability of the index, implications should be always considered. This point is further discussed in section 5.1.1.

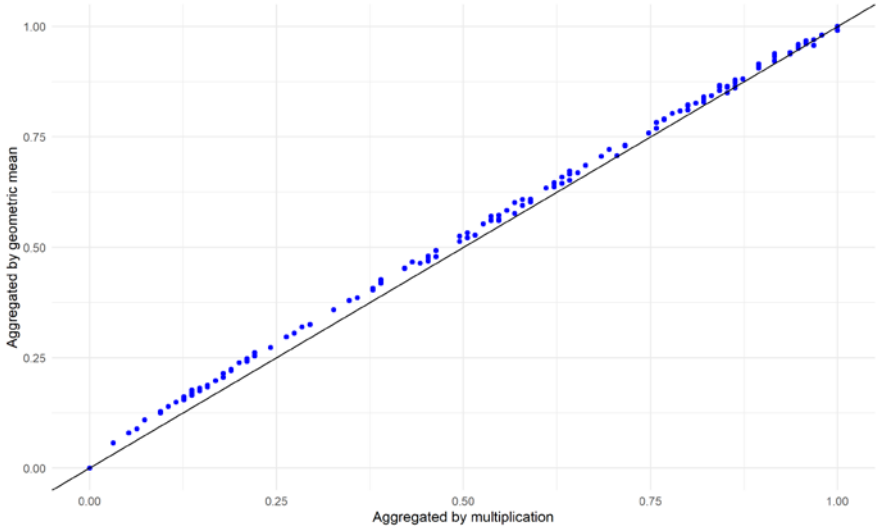
3.2 Computation of the indicator PS2B

In the definition of Universal Health Coverage & Low Out of Pocket health spending, the two components, PS2BUHC and PS2BOOP, are aggregated with multiplication. A more common and established alternative would be the geometric mean, which is the square root of the product.

The JRC team computed the indicator PS2B using the geometric mean and the comparison of the original score of the sub-pillar PS2 with the one computed with the alternative PS2B is depicted in Figure 1.

Although the results are very similar, by using the geometric mean almost all countries gain from 0.01 to 0.05 units in the PS2 score. That can be easily seen in the graph, where almost all values are above the diagonal. This happens as the geometric mean is slightly less penalising than the multiplication. Another advantage of this method is that geometric mean is largely used in the field and is easier to communicate. For this reason, the JRC suggests the use of the geometric mean formula instead of the multiplication at sub-indicator level, unless other aggregation methods are required for conceptual reasons.

Figure 1. Comparison of the values of PS2, when PS2B is computed as multiplication or as geometric mean



Source: European Commission's Joint Research Centre, 2020

[2] Groeneveld, R. A. and Meeden, G., "Measuring Skewness and Kurtosis," Journal of the Royal Statistical Society, Series D, vol. 33, pp. 391–99, 1984

3.3 Computation of T1 CIT and HTP

The JRC team computed the indicator T1 excluding the component HTP from T1_CIT and HTP. The comparison of the correlation coming from the original scores and the alternative ones (T1_alt and T_alt), with the other aggregates is represented in **Table 3**.

The effect on the correlations is very small but is always positive (the alternative T1_alt and T_alt perform slightly better). As a conclusion, the inclusion or exclusion of HTP in the framework should not be decided only on a statistical base. Its inclusion is not beneficial for the Index and this is proven by the correlations, but the JRC suggestion is to make this choice on a conceptual ground.

Table 3. Correlation of sub-pillar T1 and pillar T compared with the alternative computed without HTP (T1_alt and T_alt)

	T2	T3	T	T_alt	PS	L	CRI
T1	-0.49	0.09	0.47	0.42	-0.66	-0.59	-0.44
T1_alt	-0.45	0.13	0.49	0.5	-0.62	-0.54	-0.38
T	0.36	0.45	1	0.97	0.03	-0.03	0.38
T_alt	0.37	0.46	0.97	1	0.06	0.01	0.4

Source: European Commission's Joint Research Centre, 2020

4 Statistical coherence

The statistical coherence consists of a multi-level analysis of the correlations of variables, and a comparison of CRII rankings with its pillars and with other indicators measuring the actual level of inequality.

4.1 Correlation analysis

The statistical coherence of an index should be considered a necessary but not a sufficient condition for a sound index. Given that the statistical analysis is mostly based on correlations, the correspondence of the CRI Index to a real world phenomenon needs to be critically addressed because "correlations do not necessarily represent the real influence of the individual indicators on the phenomenon being measured" (OECD & JRC, 2008)[3]. This relies on the interplay between both conceptual and statistical soundness. The degree of coherence between the conceptual framework and the statistical structure of the data is an important factor for the reliability of an index, among other things.

The correlation analysis is used to address to what extent the data support the conceptual framework. In the ideal case, there should be positive significant correlations within every level of the index. This effectively ensures that the overall index scores adequately reflect the underlying indicator values.

Redundancy should be avoided in the framework because if two indicators are collinear, this may amount to double counting (and therefore over-weighting) the same phenomenon.

[3] OECD/EC JRC (Organisation for Economic Co-operation and Development/European Commission, Joint Research Centre). 2008. Handbook on Constructing Composite Indicators: Methodology and User Guide. Paris: OECD.

4.1.1 Correlation analysis between indicators and aggregates

Table 4 shows the correlation coefficients between indicators and their corresponding sub - pillar, pillar and the index. Most correlations are significant and positive. However a few problematic cases are identified:

- The indicator on Education coverage (PS1A) does not contribute meaningfully to its corresponding sub pillar and moving upwards in the aggregation it becomes even more silent, having a slightly negative correlation with the pillar and CRI Index. Further suggestion would be to keep monitoring the specific indicator in the future editions of the index in order to check its behaviour and modify if appropriate.

- All three indicators of the sub-pillar T1, correlate well within the sub-pillar and weakly but still significantly with the pillar, but their relation to the index is negative.

- The indicator on Minimum Wage legislation (L1C) correlates negatively with the pillar and index, thus we would propose possible refining of it.

- Last, the Unemployment indicator (L2A) remains silent at pillar and index level.

Table 4. Pearson correlation coefficients between variables and its indicator, pillar and overall index.

	Corresponding sub-pillar	Corresponding pillar	CRI
PS1A	0.27	-0.14	-0.15
PS1B	**0.83**	**0.71**	**0.62**
PS1C	**0.72**	**0.85**	**0.75**
PS2A	**0.9**	**0.82**	**0.74**
PS2B	**0.86**	**0.81**	**0.77**
PS2C	**0.91**	**0.86**	**0.79**
T1VAT	**0.73**	**0.36**	**-0.37**
T1PIT	**0.73**	0.28	**-0.3**
T1CITeHTP	**0.66**	**0.33**	**-0.24**
L1A	**0.74**	**0.42**	**0.3**
L1B	**0.58**	**0.52**	**0.5**
L1C	**0.49**	-0.15	**-0.24**
L2A	**0.41**	0.15	0.06
L2B	**0.81**	**0.83**	**0.78**

*Note: Numbers represent the Pearson correlations coefficients. Good correlations (i.e. Pearson correlation coefficients greater than 0.30 and lower than 0.92) are in bold **green**. Correlations with meaningful negative value (here -0.20) are in bold **red**.*

Source: European Commission's Joint Research Centre, 2020

4.1.2 Correlation analysis between pillars and index

The values in Table 4 represent the correlation between the aggregates. This level is the most important as it represents the consistency of the general concepts.

The first pillar appears consistent, with the sub-pillars being well correlated with each other, the pillar and the CRI1. A remark would be on the strong correlation (0.93) between sub-pillar PS2 and pillar PS suggesting that PS2 is dominating the pillar in relation to the

other two sub-pillars. However, this is not a major issue since also the others have a high correlation.

The internal structure of Tax pillar is less reassuring, as T2 shows a negative relation with T1 and T3. Moreover, T1 does not contribute to the overall index having a significant negative correlation. Overall, the Tax pillar contributes much less to the index (0.38) comparing with the other two pillars (PS - 0.9, L – 0.87), as it also emerges from Table 5. This could be due to a combination of the negative relation of sub-pillar T2 with T1 and T3 and the non- significant correlation between T1 and T3.

Pillar L (Labour rights), has a very good overall correlation with the index. Nonetheless, the L1 sub-pillar is not correlating with the other two and it is the only one of the three that contributes very little (0.24) to the overall score. For that reason a possible refining of the indicator and generally the sub-index would be recommended.

Table 5. Pearson correlation coefficients between indicators, pillars and the index.

	PS1	PS2	PS3	PS	T1	T2	T3	T	L1	L2	L3	L	CRI
PS1	1	0.68	0.61	0.83	-0.5	0.44	0.12	0.05	0.24	0.56	0.6	0.62	0.73
PS2	0.68	1	0.65	0.93	-0.68	0.63	0.05	0.03	0.17	0.75	0.84	0.81	0.85
PS3	0.61	0.65	1	0.84	-0.51	0.36	0.18	0	0.4	0.53	0.59	0.69	0.74
PS	0.83	0.93	0.84	1	-0.66	0.57	0.12	0.03	0.29	0.72	0.8	0.82	0.9
T1	-0.5	-0.68	-0.51	-0.66	1	-0.49	0.09	0.47	-0.14	-0.55	-0.65	-0.59	-0.44
T2	0.44	0.63	0.36	0.57	-0.49	1	-0.23	0.36	0.07	0.48	0.56	0.51	0.67
T3	0.12	0.05	0.18	0.12	0.09	-0.23	1	0.45	0	0.03	-0.01	0.01	0.24
T	0.05	0.03	0	0.03	0.47	0.36	0.45	1	-0.05	0	-0.06	-0.03	0.38
L1	0.24	0.17	0.4	0.29	-0.14	0.07	0	-0.05	1	0.04	0.05	0.46	0.34
L2	0.56	0.75	0.53	0.72	-0.55	0.48	0.03	0	0.04	1	0.77	0.86	0.76
L3	0.6	0.84	0.59	0.8	-0.65	0.56	-0.01	-0.06	0.05	0.77	1	0.86	0.78
L	0.62	0.81	0.69	0.82	-0.59	0.51	0.01	-0.03	0.46	0.86	0.86	1	0.87

Note: Numbers represent the Pearson correlations coefficients between the CRI variables. Good correlations (i.e. Pearson correlation coefficients greater than 0.30 and lower than 0.92) are shaded in green. Correlations with values greater than 0.93 are written in red. Correlations with meaningful negative value (here -0.20) are shaded in red. Shading provided only for the "blocks" of indicators.

Source: European Commission's Joint Research Centre, 2020.

Table 6. Pearson correlation coefficients between the pillars and the index

	Public services	Tax	Labour rights	CRI
Public services	**1**	0.03	**0.82**	**0.9**
Tax	0.03	**1**	-0.03	**0.38**
Labour rights	**0.82**	-0.03	**1**	**0.87**

*Note: Numbers represent the Pearson correlations coefficients. Good correlations (i.e. Pearson correlation coefficients greater than 0.30 and lower than 0.92) are in bold **green**. Correlations with meaningful negative value (here -0.20) are in bold **red**.*

Source: European Commission's Joint Research Centre, 2020

4.1.3 Correlation analysis of an alternative framework structure

The structure of the CRI Index is intended to supply a dual narrative. The main structure is based on the policy areas: Public Services, Taxation and Labour Rights. Secondly, an alternative point of view is to re-organise the sub pillars into three groups representing Policy, Implementation and Impact. This alternative interpretation of the index may allow to draw a different interpretation of the data.

The JRC team tested the statistical coherence of the index from this alternative point of view. From the right-hand side of **Table 7**, it is clear that the structure of the CRI index could also work that way. Apart from the Tax pillar (T1), which is generally more problematic, all the sub-pillars are well correlated with the aggregate of their level. The Implementation level is particularly balanced despite the strong correlation of PS2. In general, this kind of aggregation is good, and only the elements of Taxation look a little less represented in their level and in the overall Index. Respect to the structure based on policy areas, the one based on Policy, Implementation and Impact shows a slightly higher balance among the pillars when they are compared to the overall index (correlations from 0.45 to 0.88).

Both the points of view show an acceptable internal coherence, with the only exception of Pillar T and its components.

Table 7. Pearson correlation coefficients according to two different structures

	PS	T	L	CRI
PS1	0.83	0.05	0.62	0.73
PS2	0.93	0.02	0.8	0.85
PS3	0.84	0	0.69	0.74
PS	1	0.03	0.82	0.9
T1	-0.66	0.47	-0.59	-0.44
T2	0.57	0.36	0.51	0.67
T3	0.12	0.45	0.01	0.24
T	0.03	1	-0.03	0.38
L1	0.29	-0.05	0.46	0.34
L2	0.72	0	0.86	0.76
L3	0.8	-0.06	0.86	0.78
L	0.82	-0.03	1	0.87
PS	0.35	0.87	0.87	0.90
T	0.3	0.13	0.11	0.38
L	0.35	0.84	0.78	0.87

	LEV1	LEV2	LEV3	CRI
PS1	0.54	0.66	0.66	0.73
T1	0.2	-0.67	-0.57	-0.44
L1	0.75	0.11	0.2	0.34
LIV1	1	0.1	0.22	0.45
PS2	0.14	0.93	0.78	0.85
T2	0.05	0.79	0.39	0.67
L2	0.06	0.87	0.67	0.76
LIV2	0.1	1	0.73	0.88
PS3	0.37	0.6	0.84	0.74
T3	0.14	-0.04	0.41	0.24
L3	0.03	0.85	0.84	0.78
LIV3	0.22	0.73	1	0.84
LEV1	0.35	0.3	0.35	0.45
LEV2	0.87	0.13	0.84	0.88
LEV3	0.87	0.11	0.78	0.84

Source: European Commission's Joint Research Centre, 2020.
Note: Lev 1, 2 and 3 correspond respectively to Policy, Implementation and Impact. *Numbers represent the Pearson correlations coefficients. Good correlations are shaded in green. Correlations with values greater than 0.93 are written in red. Shading provided only for the "blocks" of indicators.*

4.2 Added value of the Commitment to Reducing Inequality index

A high statistical reliability among the main components of an index can be the result of redundancy of information. This is clearly not the case with the CRI index. For 57% or more of the countries included in the index, the CRI ranking and any of the three pillar rankings differ by 10 positions or more (see Table 6). This suggests that the CRI ranking highlights aspects of countries' efforts to reducing inequality that do not emerge by looking into the three pillars separately. At the same time, this result points to the value of examining individual pillars and indicators on their own merit.

It is interesting to look further into the relationship between the three components and the CRI index: the Public Services pillar, the Tax pillar and the Labour rights pillar. Figure 3

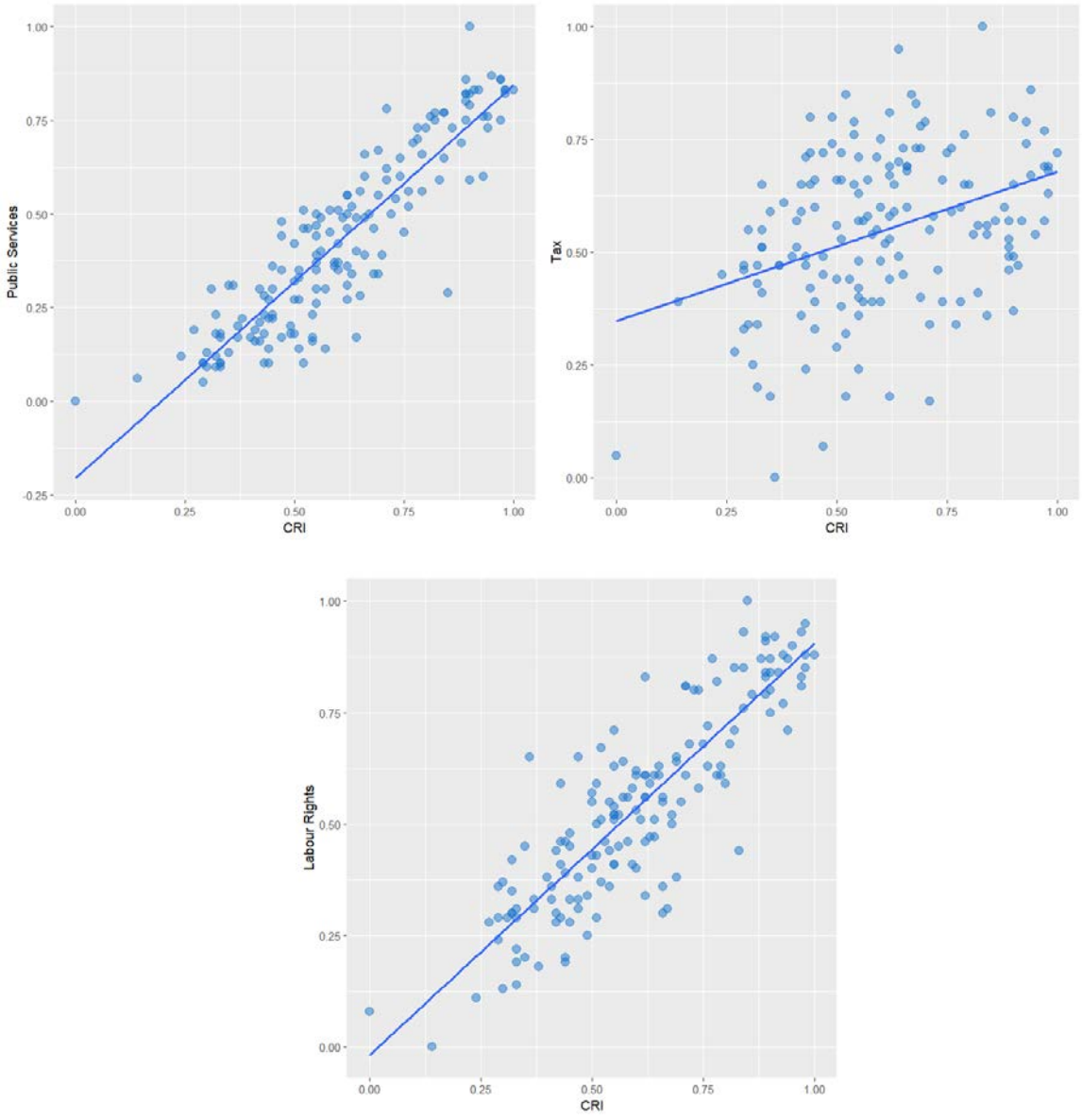
depicts these relationships. The first and third pillar are linearly associated with the Index as can be deduced from the clear pattern in the graphs. On the other side, the graph of Taxation shows a very poor relation between the pillar and the Index.

Table 8. Distribution of differences between pillars and CRI rankings

Shifts with respect to CRI index	Public Services Pillar	Tax pillar	Labour Rights Pillar
More than 30 positions	16%	60%	18%
20 to 29 positions	11%	13%	18%
10 to 19 positions	30%	15%	30%
5 to 9 positions	23%	4%	19%
Less than 5 positions	17%	6%	13%
0 positions	3%	1%	3%

Source: European Commission's Joint Research Centre, 2020.

Figure 2. Relationship between the pillars and the CRI index.



Source: European Commission's Joint Research Centre, 2020.

5 Impact of modelling assumptions on the CRII results

A fundamental step in the statistical analysis of a composite indicator is to assess the effect of different modelling assumptions on the scores and country rankings. Despite the efforts at the development process, there is an unavoidable subjectivity (or uncertainty) in the resulting choices. This subjectivity can be explored by comparing the results obtained under different – alternative – assumptions.

The literature on this topic [4] suggests to assess the robustness of the index by means of a Monte Carlo simulation and by applying a multi-modelling approach, assuming 'error free' data as eventual errors have already been corrected in the preliminary stage of the index construction.

The Commitment to Reducing Inequality Index, as most composite indicators, is the outcome of several choices concerning, among other things, the underlying theoretical framework, the indicators selected, the normalisation method, the weights assigned, and the aggregation method. Some of these choices may be based on expert opinion or other considerations, driven by statistical analysis or by the need to ease communication or to draw attention to specific issues.

This section aims to test the impact of varying some of these assumptions within a range of plausible alternatives in an uncertainty analysis. The objective is therefore to try to quantify the uncertainty in the ranks of the CRII, which can demonstrate the extent to which countries can be differentiated by their scores.

The modelling issues considered in the robustness assessment of the CRI Index are mainly the aggregation formula and dimensions' weights. The data coverage is excellent in this edition of the index. Hence, a method for data imputation has not been included in this analysis.

Aggregation formula. For this edition of the index, the CRII team opted for the arithmetic averaging of the three pillars, which implies a strong compensability allowing for an outstanding performance in some aspects to balance the weaknesses in others and vice-versa. This approach puts at the same level countries with both high and low results with more "balanced" countries showing average results. To assess the impact of this choice, the JRC included in the analysis a comparison with the geometric mean. The comparison of the two aggregation approaches should be able to highlight countries with unbalanced profiles, since the geometric mean tends to penalize low values, especially in the presence of other values that are not so low (unbalanced profiles). The tested aggregation formulas are both different from the one used in the previous edition of the CRI index, that was based on a combination of a geometric mean (for Public Services and Taxes) and an arithmetic mean (aggregating Labour Rights to the others). The JRC supports the simplification that comes from using a unique method, which implies the same treatment for all pillars and avoids artificial effects on the results.

Weights. Monte Carlo simulation comprised 1,000 runs of different set of weights for the three pillars constituting the CRI Index. The weights are the result of a random extraction

[4] Saisana, M., B. D'Hombres, and A. Saltelli. 2011. 'Rickety Numbers: Volatility of University Rankings and Policy Implications'. Research Policy 40: 165–77.
Saisana, M., A. Saltelli, and S. Tarantola. 2005. 'Uncertainty and Sensitivity Analysis Techniques as Tools for the Analysis and Validation of Composite Indicators'. Journal of the Royal Statistical Society A 168 (2): 307–23.

based on uniform continuous distributions centred in the reference value (1/3) plus or minus 25% of this value.

Two models were tested comparing the different aggregation formulas which resulted in a total of 2,000 runs of simulations.

Table 9. Alternative assumptions considered in the analysis.

	Reference	Alternative
I. Aggregation formula	Arithmetic average	Geometric average
II. Weighting system	Equal weights (0.33)	Varying: U [0.25; 0.42]
Public Services	0,33	U[0,25;0,42]
Taxation	0,33	U[0,25;0,42]
Labour	0,33	U[0,25;0,42]

Source: European Commission, Joint Research Centre, 2020.

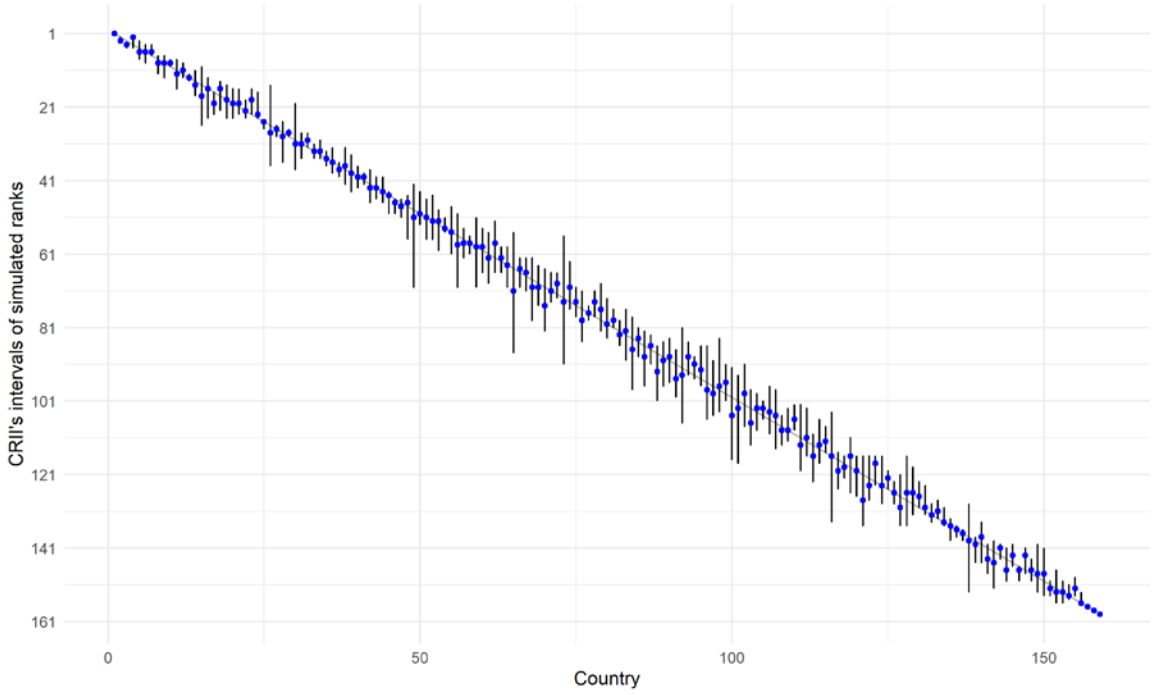
The main results obtained from the robustness analysis are shown in Figure 4, with median ranks and 90% intervals computed across the 2,000 Monte Carlo simulations. Countries are ordered from best to worst according to their CRII rank where the blue dots represent the median rank among the iterations. For each country, the error bars represent the 90% interval across all simulations, that is, from the 5th to the 95th percentile.

CRII ranks are shown to be representative of a plurality of scenarios and robust to changes in the aggregation method and pillar weights. If one considers the median rank across the simulated scenarios as being representative of these scenarios, then the fact that the CRII rank is close to the median rank (less than five positions away) for 88% of the countries suggests that CRII is a suitable summary measure. Furthermore, the reasonable narrow intervals for the majority of the countries' ranks (less than 15 positions for about 85% of countries) imply that the CRII ranks are also, for most countries, robust to changes in the dimensions' weights and the aggregation formula. One can also observe from Figure 4 that the confidence intervals are generally wider for mid-ranking countries, and narrower for top and bottom-ranking countries, which is normal in the context of composite indicators.

Only 9 countries are showing a simulated interval larger than 20 positions, and these are: Kiribati, Lithuania, Togo, Romania, Serbia, Afghanistan, Moldova, North Macedonia and Bahrain. Probably, that is due to the lack of balance among their values on the three pillars. In fact, when a country shows unbalanced values, it is particularly penalised by the geometric mean.

Overall, country ranks in CRII are fairly robust to changes in the pillar weights and the aggregation formula for the majority of the countries considered, enough to allow for meaningful inferences to be drawn. For full transparency and information, Table 8 reports the CRII country ranks together with the simulated intervals (central 90 percentiles observed among the 2,000 scenarios) in order to better appreciate the robustness of these ranks to the computation methodology, and to analyse easier the behaviour of specific countries respect to perturbations.

Figure 3. Robustness analysis on ranks (CRII rank vs median rank and 90% intervals).



Source: European Commission, Joint Research Centre, 2020.

Table 10. CRI rank and 90% interval of all countries.

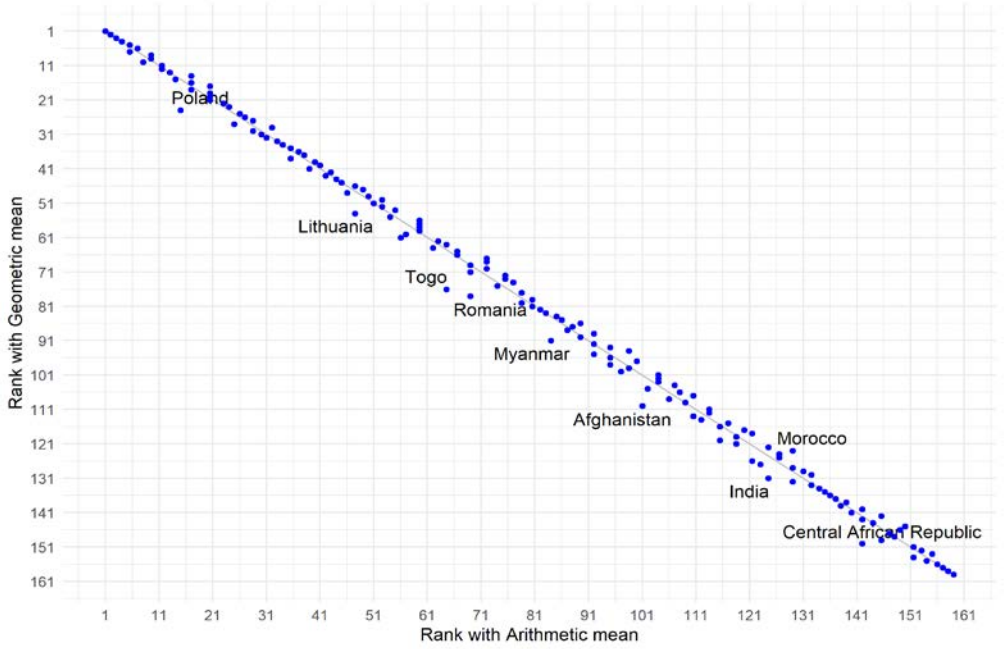
Country	CRI Ranks	Interval	Country	CRI Ranks	Interval
Germany	1	[1,1]	Singapore	80.5	[76,81]
Belgium	3	[2,3]	Armenia	82.5	[79,86]
Ireland	3	[4,5]	Panama	82.5	[76,90]
Norway	3	[2,5]	Myanmar	84.5	[78,98]
Canada	6	[3,8]	Samoa	84.5	[81,89]
Denmark	6	[4,9]	Brazil	86.5	[82,97]
Japan	6	[4,7]	Peru	86.5	[83,91]
Finland	8	[7,12]	Albania	91.5	[86,101]
Australia	9.5	[7,13]	Antigua and Barbuda	91.5	[85,97]
Luxembourg	9.5	[8,10]	The Bahamas	91.5	[84,96]
Malta	11.5	[8,16]	Indonesia	91.5	[87,100]
New Zealand	11.5	[9,13]	Serbia	91.5	[81,107]
Austria	13	[12,14]	Sri Lanka	91.5	[85,94]
Slovenia	14	[11,18]	Turkey	91.5	[89,95]
Poland	16.5	[10,26]	Vietnam	91.5	[86,97]
Seychelles	16.5	[13,24]	Cambodia	97	[86,106]
Sweden	16.5	[17,23]	Malawi	97	[90,105]
United States	16.5	[14,22]	Nepal	97	[84,104]
Czech Republic	21	[15,24]	Tajikistan	99	[91,101]
France	21	[16,24]	Afghanistan	101	[92,117]
Iceland	21	[16,23]	Moldova	101	[94,118]
Netherlands	21	[19,24]	St. Vincent and the Grenadines	101	[91,108]
United Kingdom	21	[16,23]	Bangladesh	104.5	[98,113]
Israel	24	[17,24]	Dominican Republic	104.5	[99,109]
Portugal	25	[25,27]	Philippines	104.5	[101,106]
Kiribati	26	[15,37]	Solomon Islands	104.5	[97,110]
Italy	28	[26,29]	Cabo Verde	108.5	[98,114]
Slovak Republic	28	[25,36]	Guatemala	108.5	[105,113]
Switzerland	28	[27,29]	Mozambique	108.5	[103,112]
South Africa	30	[20,38]	St. Lucia	108.5	[102,109]

Croatia	31.5	[28,35]	Djibouti	111.5	[102,120]
Ukraine	31.5	[28,32]	Yemen Rep.	111.5	[103,116]
Spain	33	[31,35]	Angola	114.5	[110,123]
Belarus	34	[30,35]	Eswatini	114.5	[106,118]
Chile	35.5	[33,37]	Mauritania	114.5	[108,115]
Kyrgyz Republic	35.5	[32,39]	North Macedonia	114.5	[104,134]
Argentina	37.5	[36,40]	Benin	118.5	[115,125]
Estonia	37.5	[32,42]	Ghana	118.5	[116,122]
Hungary	39	[34,44]	Jamaica	118.5	[111,126]
Korea Rep.	40.5	[37,43]	Sao Tome and Principe	118.5	[116,127]
Russian Federation	40.5	[39,42]	India	122.5	[116,135]
Guyana	42	[38,47]	Pakistan	122.5	[116,128]
Costa Rica	43.5	[40,46]	Timor-Leste	122.5	[116,124]
Latvia	43.5	[40,47]	Zambia	122.5	[116,129]
Cyprus	45	[44,50]	Egypt Arab Rep.	126.5	[120,125]
Hong Kong SAR China	46	[46,50]	Lebanon	126.5	[123,129]
Bolivia	48	[46,51]	Mali	126.5	[121,135]
Bulgaria	48	[45,57]	Oman	126.5	[116,135]
Lithuania	48	[42,70]	Morocco	130	[119,132]
Ecuador	50	[44,53]	Papua New Guinea	130	[123,130]
El Salvador	52	[46,57]	Tanzania	130	[124,132]
Georgia	52	[45,57]	Rwanda	132.5	[129,134]
Greece	52	[49,60]	Senegal	132.5	[128,133]
Thailand	54.5	[51,55]	Congo Dem. Rep.	134	[130,135]
Tunisia	54.5	[48,61]	Ethiopia	135	[133,139]
China	56	[50,70]	Burkina Faso	136.5	[135,138]
Belize	58.5	[54,62]	The Gambia	136.5	[136,139]
Mongolia	58.5	[56,61]	Bahrain	138	[129,153]
Namibia	58.5	[51,70]	Cameroon	139.5	[138,145]
Uzbekistan	58.5	[54,66]	Occupied Palestinian Territory	139.5	[134,145]
Honduras	61.5	[55,69]	Burundi	143	[140,148]
Kazakhstan	61.5	[52,66]	Central African Republic	143	[139,152]
Jordan	64	[59,66]	Congo Rep.	143	[140,144]
Mauritius	64	[59,70]	Guinea	143	[141,150]
Togo	64	[55,88]	Lao PDR	143	[140,146]
Colombia	66.5	[62,70]	Cote d'Ivoire	147.5	[146,150]
Malaysia	66.5	[62,71]	Liberia	147.5	[141,148]
Botswana	71	[62,79]	Niger	147.5	[144,150]
Fiji	71	[64,75]	Vanuatu	147.5	[140,153]
Kenya	71	[65,82]	Zimbabwe	150	[141,154]
Maldives	71	[66,74]	Madagascar	151.5	[150,154]
Mexico	71	[66,73]	Uganda	151.5	[147,156]
Romania	71	[56,91]	Chad	154	[150,156]
Trinidad and Tobago	71	[63,76]	Guinea-Bissau	154	[151,155]
Barbados	75	[70,78]	Sierra Leone	154	[149,154]
Algeria	77.5	[71,85]	Bhutan	156	[153,156]
Azerbaijan	77.5	[75,79]	Haiti	157	[157,157]
Paraguay	77.5	[71,78]	Nigeria	158	[158,158]
Uruguay	77.5	[69,82]	South Sudan	159	[159,159]
Lesotho	80.5	[73,84]			

Source: European Commission, Joint Research Centre, 2020.

The uncertainty analysis is also complemented by a sensitivity exercise, in which the EPI ranking is compared with the rankings resulting from specific changes in the modelling assumptions. In Figure 5, it is possible to compare the ranks derived from CRII with the ranks which would have been obtained by changing the aggregation procedure from arithmetic to geometric mean. This comparison allows us to inquire whether the variability in the rank intervals is originating from the modelling assumptions–underlying the aggregation procedure or by the weights' perturbation. The countries placed under the diagonal decrease in rank positions with the geometric mean. Probably, they are penalised by the geometric mean for their unbalanced profiles.

Figure 4. Sensitivity Analysis: Comparison of ranks according to Arithmetic and Geometric mean.



Source: European Commission, Joint Research Centre, 2020.
Note: Labelled countries show a shift of at least 5 positions between the two aggregation formulas.

5.1.1 Step-by-step Normalisation

This edition of the CRI Index included several suggestions from the previous audit. In particular, the re-normalisation of the pillars before the final aggregation, represents an important improvement.

To test the effect of this choice, the COIN team compared the country ranks of the CRI Index with the ones resulting from the aggregation of the pillars without the 0-1 normalisation. The results are presented in Figure 5.

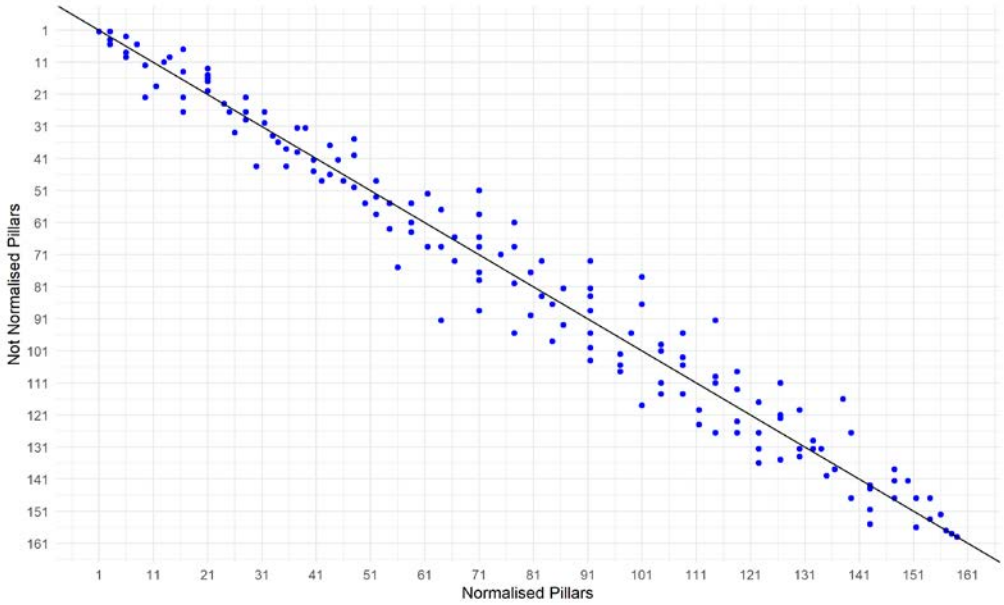
Many countries face a change in their rank due to this choice; one fourth of them has a shift of at least 9 positions, and four countries of at least 20 positions. These results prove that this normalisation choice has meaningful implications in the final index.

The normalisation of the scores at pillar level is meant to increase and to uniform their ranges, while the previous aggregation method determined a strong difference among their ranges.[5] In the context of CRII, it is the Tax pillar that shows a much smaller range than the others. This is probably due to the weak correlation structure among its elements and in particular T2.

Considering this evidence, the JRC team suggests keeping the normalisation of the pillars as it is (and as suggested in the previous audit), but also to consider and test possible alternatives for the next edition of the Index, focusing on the issue related to weak correlations within the Tax pillar.

[5] The three pillars have respectively ranges:
PS =(0.04;0.79), T = (0.29;0.72), L = (0.15;0.92)

Figure 5. Sensitivity Analysis: Comparison of ranks according to normalized and not-normalised pillars (PS, T, L)



Source: European Commission, Joint Research Centre, 2020.

6 Conclusions

The JRC statistical audit delves into the extensive work carried out by the developers of the CRII with the aim of suggesting improvements in terms of data characteristics, structure and methods used. The analysis aims to ensure the transparency of the index methodology and the reliability of the results.

The data coverage of the framework is very good. Most indicators contain no missing values and none of them present outliers. The analysis suggests that generally the CRII is statistically well balanced with respect to its pillars. Correlations between each pillar and the respective sub pillar are mostly significant and positive, except for the Taxation pillar. There are mostly positive correlations between indicators and their corresponding sub pillar, pillar and the index, thus suggesting that most of the indicators provide meaningful information on the variation of the scores.

However, two issues were identified: First, considering the Tax pillar, we notice that its internal structure is more problematic as the indicators correlate negatively with the index. Tax Implementation (T2) shows a negative relation with Tax Policy (T1) and Tax Impact (T3). Moreover, Tax Policy has a significant negative correlation with the CRI index. Overall, the Tax pillar contributes much less to the index comparing to the other two pillars. Given the conceptual importance of it in the framework, JRC would recommend monitoring its performance in future editions of the index and consider refinement or modification of the included indicators.

Second, in the Labour rights pillar, the Labour rights Policy (L1) sub-pillar is not correlating with the other two and it is the only one of the three that contributes very little (0.24) to the overall score. For that reason, a possible refining of the indicator and generally the sub-index would be a good option for future refinement.

JRC analysed a series of different choices that are made during the index construction. The first is the different methods of aggregation at the lower levels. Comparing between

multiplication and geometric mean at sub-indicator level, we would opt for the second, unless other aggregation methods are required for conceptual reasons. The geometric mean is less penalising, more common and thus easier to communicate.

The second choice refers to the structure of the framework. One would be the already proposed by the CRII developers, based on the three policy areas (Public services, Taxation and Labour rights) with the alternative of the pillars on Policy, Implementation and Impact. Although, both points of view have a good internal coherence, the already implemented structure shows a slightly lower balance among the pillars, but not so lower to impose this point of view.

Last, the normalisation of the aggregates at each level was tested against the normalisation only at the base level. The JRC team suggests keeping the normalisation of the pillars as it is (and as suggested in the previous audit), but also to consider and test possible alternatives for the next edition of the Index, focusing on the weak correlations within the Tax pillar. This is because, the need for the normalisation of pillars, derives from their internal structure as described in the document above.

The results of the uncertainty analysis reveal that CRII is a robust summary measure and for most countries, the confidence intervals are narrow enough for meaningful inferences to be drawn from the index: there is a shift of fewer than 15 positions for about 85% of the countries included in the index. Nevertheless, there are 9 countries with 90% confidence interval widths of more than 20 positions, and thus their ranks vary significantly with changes in weights or aggregation method.

In general, the present audit confirms that the CRI Index is reliable, with a statistically coherent framework and acknowledges the important efforts done by the developers' team. The Index can serve as a tool to provide insights for measuring the commitment to reduce inequalities.

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