



JRC TECHNICAL REPORTS

COIN Tool User Guide

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JRC118407

EUR 29899 EN

PDF ISBN 978-92-76-12385-9 ISSN 1831-9424 doi:10.2760/523877

Luxembourg: Publications Office of the European Union, 2019

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How to cite this report: Becker, W., Benavente, D., Dominguez Torreiro, M., Moura, C., Neves, A., Saisana, M., Vertesy, D., *COIN Tool User Guide*, EUR 29899 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-12385-9, doi:10.2760/523877, JRC118407

Contents

- Abstract3
- 1 Quick-start guide.....4
 - 1.1 Full and Lite versions4
 - 1.2 Before you start4
 - 1.3 Get started!5
- 2 Introduction7
 - 2.1 About composite indicators7
 - 2.2 Constructing composite indicators.....7
 - 2.3 Why the COIN Tool 10
 - 2.4 Organisation and workflow of the COIN Tool 10
 - 2.5 Before you start 12
- 3 Data entry 13
 - 3.1 Database 13
 - 3.2 Framework 19
- 4 Data inspection and treatment 20
 - 4.1 Statistics 20
 - 4.2 Winsorisation 22
 - 4.3 Box-Cox 23
 - 4.4 Scatterplots 25
 - 4.5 TreatedData 26
- 5 Correlations and rebalancing 28
 - 5.1 IndCorrel: Indicator correlations 28
 - 5.2 Rebalancing 29
- 6 Index scores and ranks 32
 - 6.1 Heatmap 32
 - 6.2 Scores..... 33
 - 6.3 Rankings 34
- 7 Analysing the index 35
 - 7.1 ScoreCorrel: Correlations between aggregation levels 35
 - 7.2 RankCorrel: Rank correlations 36
 - 7.3 IndWeights: Effective weighting 37
- 8 Alternative aggregations..... 38
 - 8.1 Borda 38
 - 8.2 Outranking Matrix..... 39
 - 8.3 Copeland 40
 - 8.4 Scenaria 41

9 Methodological variations and further tabs.....	44
9.1 Imputation.....	44
9.2 Methodological variations.....	46
9.3 Leaving out indicators	46
Glossary	48
Troubleshooting and FAQs	50
Troubleshooting.....	50
FAQs.....	51

Abstract

The COIN Tool is a free Microsoft Excel-based tool designed to help users from research institutions, international organisations, European Union institutions, national and local governments, among others, in the process of building and analysing composite indicators. It was developed by the European Commission's Competence Centre on Composite Indicators and Scoreboards (COIN), at the Joint Research Centre.

There are two versions of the COIN Tool: the Full version, and the Lite version. The Lite version is the same as the Full version but has some functionalities removed in order to make it run faster.

Both versions, with and without example data, can be downloaded at <https://composite-indicators.jrc.ec.europa.eu/>.

How to use this manual:

- If you want to begin building your composite indicator as quickly as possible, read the **Quick-Start Guide** in Section 1.
- For more depth, a longer introduction can be found in Section 2, followed by a detailed description of each tab in Sections 3 to 9, grouped under headings which relate to the overall steps in the construction and analysis process.
- Troubleshooting and FAQ are can be found at the end of this Guide.

Note that data used to illustrate the COIN tool (i.e. the screenshots) has been altered to illustrate particular cases.

1 Quick-start guide

This section gives a fast entry point into the COIN Tool, for users who wish to build their composite indicator quickly and simply. Please read the following tips in Sections 1.1 and 1.2 before proceeding to the workflow steps in Section 1.3.

1.1 Full and Lite versions

The CT is built in Excel in order to be accessible to the widest range of users, and also aims to provide maximum flexibility in accommodating many different possible composite indicator structures and methodological approaches. This combination results in a large Excel file, which can be slow to work with due to its size and the way that Excel works.

To partly address this issue, the COIN Tool comes in two versions: a "Full" version, and a "Lite" version. The Lite version is the same as the Full version, but has a number of tabs removed - this results in a file that is around half of the size, and is faster to run. The details of the differences between the two tools can be found in the rest of this User Guide, but as a general rule, the Lite version is sufficient for building a composite indicator and analysing its correlations. If you want to investigate uncertainties and non-compensatory aggregation, you should use the Full version.

Consider that it is relatively easy to begin in the Lite version, and then to switch to the Full version, if required, by simply copying over the input data.

1.2 Before you start

To make the CT experience as user-friendly as possible, we recommend that you **disable automatic workbook calculation**. This is done as follows:

- Go to the "File" menu
- Go to Options -> Formulas -> Workbook calculation and set to MANUAL

This will make the CT much faster to use, but remember to manually re-calculate formulas when needed by pressing F9, or the "Calculate" button in the bottom left of the screen.

The COIN Tool is "friendly-user" software. It is sensitive to the way that the data and structure is input. To minimise errors:

- Use the correct format for sub-pillar, pillar and sub-index codes:
 - sp.XX - e.g. sp.01, sp.02 (note that e.g. sp.1 will not work - should be sp.01)
 - p.XX - e.g. p.01, p.07
 - si.01 - e.g. si.02, si.03
- Missing data should be denoted by "n/a" (excluding the inverted commas). Any other descriptor will not be recognised and will cause errors. For example, "NA", "na", "nd", "NaN" are not accepted.

Finally, working in the Excel environment, you have to be careful how you enter and remove data. When entering data, always copy the data in and paste as text. When removing data, delete the values of the cells (i.e. clear contents), do not delete the cells themselves.

Do not alter any cells that are not coloured dark or light blue, as this will likely cause errors.

Some troubleshooting and FAQ can be found in at the end of this document.

1.3 Get started!

The COIN Tool is generally meant to be used by moving through the tabs one-by-one, in order. This Quick-Start Guide gives the basic steps to follow in order to go from a set of data to a constructed composite indicator. Tips can also be found as pop-out notes over cells on each tab (see cells with a red triangle in the corner). For full details consult the rest of this guide. These steps can be performed in both the Full and Lite versions of the COIN Tool.

Note that this guide is also available inside the COIN Tool.

1) Enter your data:

- a) Go to the **Database** tab. Copy your numerical data in (only values, no formatting). Enter unit names (e.g. country names), unit codes (e.g. country codes) and unit numbers (i.e. "unit.001").
- b) Enter indicator names and the sub-pillar, pillar, and sub-index codes assigned to each indicator, along with the aggregation type at each level (arithmetic or geometric mean). See annotations (including pop-out notes) in the **Database** tab for how to do this, as well as Box 1.
- c) Enter Goalpost upper and lower bounds if Goalpost normalisation method is chosen. Enter the weights and direction associated with each indicator.
- d) Enter the normalisation method to be applied to indicators.

Remember not to add or delete columns and rows (simply add/delete the contents), and to press F9 after entering your data to recalculate the workbook.

2) Specify framework details:

after re-calculating formulas, the structure of your framework should appear in the **Framework** tab. Hide unused rows by clicking the button in the top left corner.

- a) Enter the weights assigned to sub-pillars, pillars and sub-indexes.
- b) Enter the names of the sub-pillars, pillars and sub-indexes.

3) Check your data:

The **Statistics** tab gives various information about your data, highlighting missing values, zeros, showing the minimum and maximum of each indicator, as well as the mean and skew/kurtosis. The skew and kurtosis, as well as quartile information, indicate whether each indicator may need to be treated to improve the statistical properties of your index. You do not need to enter anything in this tab unless you want to change the threshold values.

4) Treat your data:

- a) The **Winsorisation** tab automatically treats each indicator to try to correct for excess skew and kurtosis, and shows the resulting absolute skew and kurtosis, and whether the correction has been successful. You can choose whether to use these adjustments later in the **TreatedData** tab.
- b) Where Winsorisation has not been successful, the **Box-Cox** tab shows different data transformations which can correct for skew and kurtosis. Again, these adjusted values are optional.
- c) The **Scatterplots** tab gives a visual comparison of the treated data to the untreated data.
- d) Finally, check the adjusted data set in the **TreatedData** tab. A summary of transformations applied (if any) to each indicator is given in the *Selected transformation* row. There is a global option to use the treated dataset or the original dataset for the remaining calculations, in the blue drop-down box.

- 5) **Check indicator correlations:** Correlations between indicators give a good indication of coherence within pillars and sub-pillars, check to what extent the index represents the underlying indicators, and may signal errors.
 - a) The **IndCorrel** tab visually illustrates correlations between indicators. Negative correlations and very strong positive correlations may indicate issues that need resolving.
 - b) The **Rebalancing** tab shows correlations between indicators and various aggregation levels of the index. The *Adjusted Indicator Weights* rows give the opportunity to alter weights to improve correlation balance. If you do not want to adjust the weights, copy the original weights into these rows.
- 6) **Check the results:** The scores and ranks of the composite indicator can now be calculated.
 - a) The **Heatmap** tab gives a visual summary of the unit scores at each aggregation level, sorted by overall score.
 - b) The **Ranking** tab sorts the units by score and shows the overall ranking, as well as normalised scores at each aggregation level.
- 7) **Review and explore the index:** Further tabs give more information on rankings and explore alternative methods for constructing the index. See the rest of this manual for more information.

2 Introduction

2.1 About composite indicators

A composite indicator is an aggregation of indicators which aims to measure a particular concept. Composite indicators are typically used to measure complex and multidimensional concepts which are difficult to define, and cannot be measured directly. Examples include innovation, human development, environmental performance, and so on. Composite indicators are closely related to *scoreboards*, which are also groups of indicators aiming to capture a concept. However, scoreboards do not aggregate indicator values. Composite indicators also usually use a hierarchical structure which breaks the concept down into elements, known as *sub-pillars*, *pillars* and *sub-indexes*.

Composite indicators and scoreboards have become increasingly common in recent decades for many uses, including:

- Advocacy (typically by NGOs, and measuring e.g. slavery, corruption, tax havens)
- Informing policy-making and providing analysis (e.g. the monitoring social issues, cultural issues, international connections)
- Monitoring the progress and effect of policies (e.g. indicators used to monitor EU budget programs)
- Informing decision-making (e.g. university rankings)

These concepts are measured across a number of *units*, which are often countries or regions, but can be other things, such as universities or businesses. The composite indicator results are usually used to compare, or rank, the units against one another.

Composite indicators are powerful practical tools that can help policy makers summarise complex and interdependent phenomena. They provide the big picture, are easy to interpret, easy to communicate, and attractive for the public. They are also drivers of behaviour and of change by forcing institutions and governments to question their standards. On the other hand, caution is needed to avoid situations where composite indicators may send misleading or partial policy messages because they are poorly constructed or misinterpreted.

The COIN Tool aims to provide a powerful yet accessible platform for developers to build, analyse and adjust their composite indicator. This can help to build high-quality composite indicators that are methodologically sound and legitimate to end users.

2.2 Constructing composite indicators

The following table presents ten steps for the construction and analysis of a composite indicator, including assessing the statistical associations of the indicators in a scoreboard. This table has been rearranged and extended from the information contained in the 2008 *OECD/JRC Handbook on Constructing Composite Indicators*. These steps are widely used by developers and by the European Commission's Joint Research Centre in reviewing and auditing a wide range of composite indicators.

It is important to stress that these steps are normally followed in an iterative manner, for example, changing the selection of indicators and even the conceptual framework, based on the index results or the statistical analysis. The COIN Tool roughly addresses steps 3-8 in this table.

Step 1: Concept definition

A theoretical framework provides the basis for the selection and combination of variables into a meaningful composite indicator which is fit for purpose. The involvement of experts and stakeholders is important. This step involves:

- Clearly defining the objectives and the end-users of the index.
- A clear understanding and definition of the concept to be measured.
- Map existing literature, indicator frameworks and definitions and assess the added-value of your index.
- Building a hierarchical structure of the various sub-groups of the phenomenon (if relevant).

Tips: You may need to spend up to 2/3 of the overall time in defining the conceptual framework and indicators. 5-7 indicators per dimension is good practice. A minimum of 3 indicators by dimension is acceptable.

Step 2: Indicator selection

The selection of data and indicators should be based on criteria such as the relevance, value-added, data availability, and statistical considerations. Again, the involvement of experts and stakeholders is important. This step involves:

- Research, data downloading, data mining.
- A quality assessment of the available indicators, based on indicator criteria, potentially using a summary table of indicator characteristics (data, relevance, statistical properties, etc.).
- Scaling indicators by an appropriate size measure to have an objective comparison across countries, e.g. population, GDP, etc.

Tips: Aim for at least 65% of data coverage across each indicator and each country.

Step 3: Data treatment and analysis

Missing data can be imputed, outliers treated and transformations can be applied to indicators where necessary and appropriate. Specifically, this may involve:

- Visualising the distribution of each indicator using histograms and scatter-plots.
- Checking for missing data and carefully deciding whether or not to impute the data, and which method to use.
- Discussing and treating outliers, if necessary and appropriate (e.g. by Winsorisation, or transformations).

Tips: Plot first and consider indicators for outlier treatment if: (a) absolute skewness > 2.0 and kurtosis > 3.5 or, (b) kurtosis is very high (> 10).

Step 4: Normalisation

Normalisation brings indicators onto a common scale, which renders the variables comparable. Generally this involves:

- Making directional adjustment, so that higher indicator values correspond to better performance in the concept being measured.
- Selecting and applying a suitable normalisation method that respects the conceptual framework, the data properties, and can be easily interpreted by users.

Tip: A commonly-adopted normalisation method is the Min-Max approach, which rescales indicators onto an identical range (0-100)

Step 5: Weighting

When indicators are aggregated into a composite measure, they can be assigned individual weights. This allows the effect or importance of each indicator to be adjusted according to the concept being measured. Weighting methods can be statistical, based on public/expert opinion, or both. This step can involve:

- Expert/public consultation to understand the relative importance of indicators or components of the index to stakeholders.
- Selecting the appropriate weighting method—note that different methods can be trialled but keep in mind that the ability to communicate the final weighting scheme is important. Simpler methods can be more effective in this respect.

Step 6: Aggregating indicators

Aggregation combines the values of a set of indicators into a single summary 'composite' or 'aggregate' measure. This step can involve:

- Selecting the appropriate aggregation method, based on the concept being measured, particularly considering whether high values of one indicator should be allowed to compensate for low values of another, relating to the goals of the index.
- Considering up to which level to aggregate.

Tip: Popular aggregation methods include the arithmetic average, geometric average, and the Borda and Copeland methods.

Step 7: Statistical and conceptual coherence

This can be used to study the overall structure of the dataset, assess its suitability, and guide subsequent methodological choices (e.g., weighting and aggregation). This can involve:

- Check correlations between aggregations and the underlying indicators - are some over or under-represented in the aggregate scores?
- Assessing whether statistical properties can be improved by moving indicators under different dimensions or merging/splitting dimensions.
- Checking whether a bias has been introduced in the composite indicator, e.g. a strong correlation with population (>0.6) or GDP.

Tip: Check whether indicators: dominate the framework (correlation > 0.95), or are under-represented ($-0.3 < \text{correlation} < -0.3$).

Step 8: Uncertainty and sensitivity analysis

Uncertainty analysis quantifies the uncertainty in the scores and ranks of the composite indicator, as a result of uncertainty in the underlying assumptions. *Sensitivity analysis* quantifies the uncertainty caused by each individual assumption, which identifies particularly sensitive assumptions which might merit closer consideration, for example. This step involves:

- Identifying which are the main uncertainties underlying the composite indicator (e.g. methodological choices, indicator selection, alternative frameworks, etc.)
- Assessing the impact of the uncertainties on the scores or ranks (e.g. by assigning confidence intervals). Use sensitivity analysis to see which assumptions cause the most uncertainty.
- Explaining why certain countries notably improve or deteriorate their relative position given changes in the assumptions

Step 9: Making sense of the data

The scores of the composite indicator (or its dimensions) can be compared (e.g. plotted, correlated) with other existing composite indicators and other indicators/data to identify possible links with other concepts. This can involve:

- Correlating the composite indicator with relevant measurable phenomena (similar composite indicators but also relevant quantities e.g. GDP, GDP/capita, etc.) and explain similarities or differences.
- Develop data-driven narratives based on the results. What question(s) did you set out to answer? Keep in mind the significance level of the correlations and the implications of multiple testing.
- Don't assume causality from correlation. Perform causality tests (if time series data is available).

Step 10: Visualisation

Composite indicators are ultimately a communication tool, which can be greatly enhanced by proper visualisation, both static and interactive (online). Good visualisation helps to effectively communicate the message, gives a sense of professionalism, and online data exploration tools give full transparency to the data set and allow users to drill down to underlying data. This step can involve:

- Identifying the target audience and the best means of visualisation (e.g. simple vs technical).
- Communicating key messages/conclusions through carefully selected charts and infographics which are clear and do not over-complicate or obscure the information.
- Constructing a web platform for visualising the data, reporting methodology, making data available for download, etc.

2.3 Why the COIN Tool

The developers of composite indicators have a very wide range of backgrounds, from scientists, statisticians and data analysts to lawyers and policy-makers. At the same time, properly constructing a composite indicator is a delicate process which can be subject to criticism, due its subjective nature. It is therefore essential to the legitimacy and accuracy of the composite indicator, that it is constructed as carefully as possible, including a statistical analysis.

Recognising this fact, the COIN Tool aims to provide an accessible platform for developers to build and analyse composite indicators. It is deliberately constructed in Excel, and although this places some limitations on what can be done, it ensures that it is accessible to the widest range of users. Currently, this seems to be the only tool that addresses this need.

The COIN Tool aims to guide you through a series of simple steps which help to build and visualise your composite indicator, to analyse relationships between indicators, test variations in methodology and check the robustness to certain assumptions.

2.4 Organisation and workflow of the COIN Tool

The COIN Tool is meant to be used mostly by progressing from left to right through the various tabs. The tabs can roughly be grouped as follows, and represent Sections 3-9 of this guide (tabs which are only available in the Full version of the COIN Tool are marked with a ^(f)):

Group	Tabs
Introduction	Intro, QuickStart
Data entry	Database, Framework
Data inspection and treatment	Statistics, Winsorisation, Box-Cox, Scatterplots, TreatedData
Correlations and rebalancing	IndCorrel, Rebalancing
Index scores and ranks	Heatmap, Scores, Rankings
Analysing the index	ScoreCorrel, RankCorrel ^(f) , IndWeights ^(f)
Alternative aggregations	Borda ^(f) , OutrankingMatrix ^(f) , Copeland ^(f) , Scenaria ^(f)
Methodological variations and further tabs	MinmaxImp ^(f) , DatamaxImp ^(f) , GoalpostsImp ^(f) , DatazImp ^(f) , DatapranksImp ^(f) , Minmax, Datamax, Goalposts, Dataz, Datapranks, Dataranks, LeavOutScores ^(f) , LeaveOutRanks ^(f) , ScoresCorrels ^(f)

Some of these tabs require user input, whereas some are solely to give information. Tabs, and the input expected, are described in more detail in the following sections. In general, cells which require user input are coloured in BLUE, and drop-down menus are coloured in **DARK BLUE**. Other cells are simply to return information, and should not be altered.

As with the ten steps of composite indicators, the COIN Tool can be used in an iterative manner, returning to previous tabs. Moreover, depending on your objective, you may not wish to use the full functionalities of the COIN Tool. To this end, some example workflows follow here (examples that can be performed in the Lite version of the COIN Tool are marked as **LITE**).

Example 1: Quick construction **LITE** This is for users who simply wish to visualise scores and ranks, with no data treatment or reweighting. This might be the case where the COIN Tool is to be used as a validation tool for a composite indicator constructed elsewhere, or to give an initial fast impression of scores with no data treatment.

1. Data entry: enter data, structure and methodology in the **Database** and **Framework** tabs.
2. Inspect data for issues/errors in the **Statistics** tab.
3. Select original data set in the **TreatedData** tab.
4. Ensure adjusted weights are set the same as initial weights in the **Rebalancing** tab.
5. Visualise scores and rankings in the **Heatmap**, **Scores** and **Rankings** tabs.

Example 2: Construction and analysis **LITE** To carefully construct the index, investigating correlations and weighting.

1. Data entry: enter data, structure and methodology in the **Database** and **Framework** tabs.
2. Inspect data for issues/errors in the **Statistics** tab.
 - If errors are found, correct outside the COIN Tool and re-enter in the **Database** tab
 - Look at any outliers. Decide whether these should be retained or not, based on the aims of the composite indicator.
3. Attempt to correct for outliers in the **Winsorisation** tab, where required. Consider using transformations in the **Box-Cox** tab if necessary/appropriate. Visualise the difference in the **Scatterplots** tab.
4. Review the treated data set in the **TreatedData** tab.
 - You may only wish to treat certain indicators and not others - if this is the case, you can copy the indicator columns of the data you wish to treat, and paste them in to the **Database** tab. Then select the "original dataset".
 - Alternatively, select from the original or treated data sets.
5. Check indicator correlations in the **IndCorrel** tab. This may lead to re-organising the index, and/or adding/deleting indicators. This can be done by returning to the **Database** tab.
6. Check correlations of indicators with the overall index and other aggregation levels in the **Rebalancing** tab. Try to balance the effect of each indicator and aggregation. Weigh up statistical considerations against communicability.
7. Visualise scores and rankings in the **Heatmap**, **Scores** and **Rankings** tabs. Check that scores and rankings (at index level and lower levels) follow intuition, ideally by consulting experts. This may often lead to adjusting the composite indicator, e.g. by changing indicators, structure, weights, or other methodological aspects.
8. Review correlations at all levels in the **ScoreCorrel** and **RankCorrel** tabs (the latter is only available in the Full version of the COIN Tool).
9. Check the robustness of the index to methodological variations in the **Scenaria** tab. Check the individual tabs that are inputs to this tab to see details of particular alternative rankings.

Example 3: Full audit

For users who wish to dig deep into the properties of their composite indicator, all steps in Example 2 should be followed, with the addition of:

1. Carefully checking effective weights in the **IndWeights** tab.
2. Considering alternative aggregation approaches in the **Borda**, **OutrankingMatrix** and **Copeland** tabs.
3. Checking the imputed values in the imputation group of tabs, and the effects of leaving out indicators in the **LeaveOutScores** and **LeaveOutRanks** tabs.

Additionally, you may wish to perform other steps outside the COIN Tool, including

- Multivariate analysis (e.g. principle component analysis)
- Full Monte Carlo uncertainty analysis and sensitivity analysis

These operations can be performed in many software packages, including open source software such as R and Python.

2.5 Before you start

Before you begin using the COIN Tool, you should have performed the following steps:

- Clearly defined the concept to be measured
- Clearly defined the purpose of the index, its proposed added value, and who the end users should be (this can help guide methodological decisions)
- Outlined an initial conceptual framework
- Populated the conceptual framework with indicators, and gathered the data
- Denominated any indicators where needed, by size-related quantities such as GDP, population, country area
- Made initial decisions on methodology, e.g. on weighting. Equal weights can be used as a starting point (and may indeed be retained in the final version)

Of course, these steps can be returned to and modified later on, but you should have initial ideas in place. Once you are at that point, you are ready to begin using the COIN Tool. Good luck!

3 Data entry

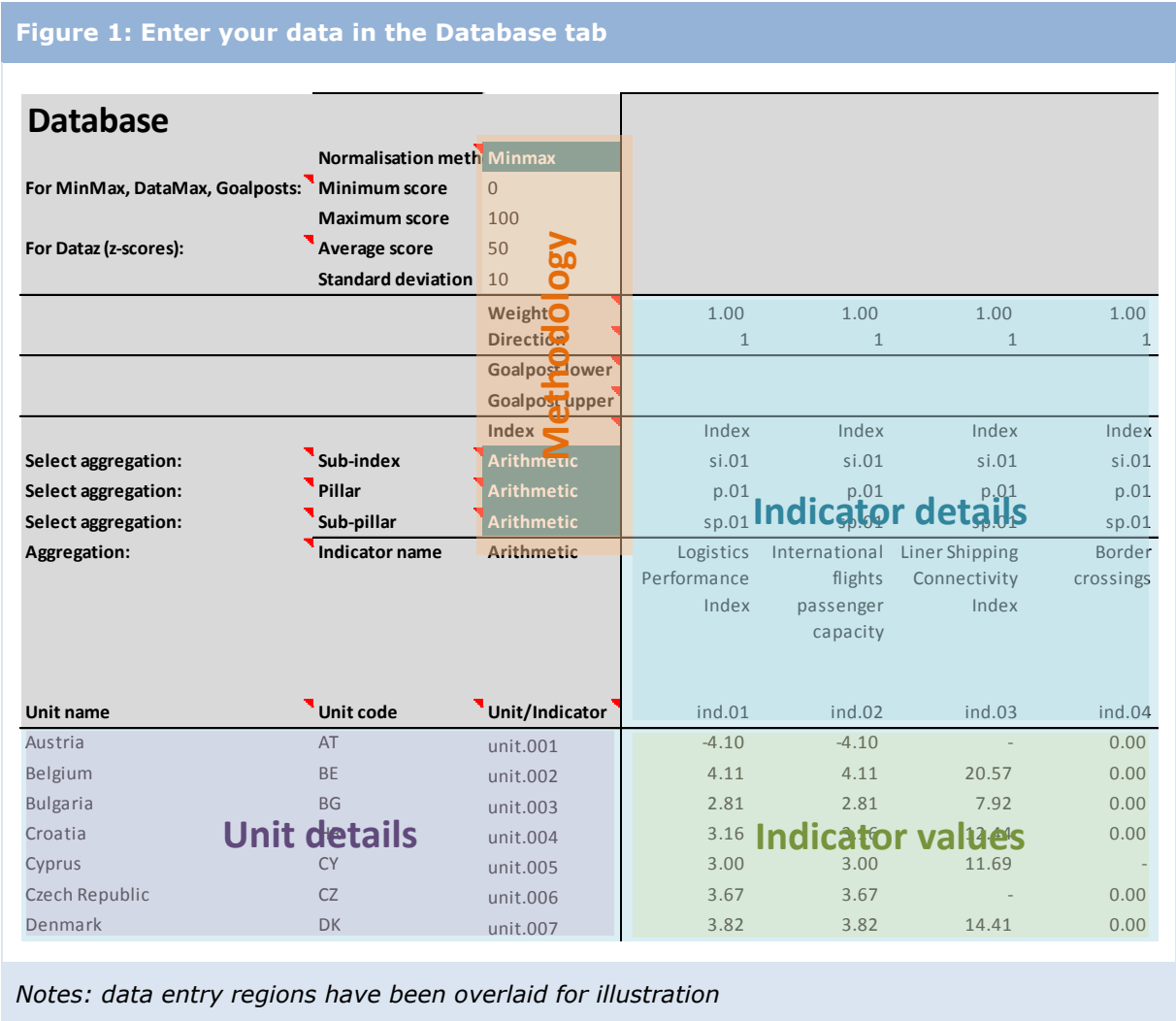
The starting point in the COIN Tool is to enter your data, the structure of your index, and specify methodological details such as the aggregation type, normalisation type and weights. These operations are performed mostly in the **Database** tab, with some additional input in the **Framework** tab.

3.1 Database

LITE **FULL**

Objective	Input the raw indicator data, as well as the structure of the index, weights and directions. Select the normalisation and aggregation methods.
User input	<p>Required: Indicator data, unit data, index structure, indicator weights and directions</p> <p>Optional: Normalisation method and parameters, aggregation method.</p>

The Database tab is where you enter your data, the index structure, index weights, and specify methodological details. The basic layout is shown in Figure 1.



Important note

The COIN Tool is “friendly-user” software. It is sensitive to the way that the data and structure is input. Please read the steps below carefully. In particular, to minimise errors:

- Use the correct format for sub-pillar, pillar and sub-index codes
- Missing data should be denoted by “n/a” (excluding the inverted commas). Any other descriptor will not be recognised and will cause errors. For example, “NA”, “na”, “nd”, “NaN” are not accepted.

To begin entering your data, you will need to prepare it the form used by the COIN Tool. Indicator values should be arranged in a table, where each row corresponds to a *unit* (typically a country, region, or other entity that you wish to produce a score for), and each column corresponds to an indicator. You can then enter your data as follows (the order is not important).

1. **Enter indicator values:** Indicator values are entered in the section illustrated in green in Figure 1. Note that:
 - a. Missing data points should be marked as “n/a” (without the inverted commas). Any other form will result in an error.
 - b. For decimals, use a point rather than a comma.
 - c. Enter zeros as “0” but notice that the COIN Tool represents them as “-”. This is done to distinguish very small numbers from true zeros.
 - d. Do not add or delete columns and rows. Indicator values (and all other data) should be simply copied in as plain text. If there is existing indicator data, delete it by using the “delete” key or by right clicking and selecting “clear contents”.
2. **Enter unit details:** Each unit should be assigned a full name (e.g. country name), and a shortened code (e.g. ISO codes).
3. **Enter indicator details:** Working from the top row in the blue *Indicator details* area in Figure 1:
 - a. Enter a **weight** for each indicator. These are used as weights when indicators are aggregated to the sub-pillar level. Weights are relative and do not need to sum to 1. For instance, setting all weights to 1 is equivalent to setting equal weights, a weight of 0 implies not considering the particular indicator in the aggregation.
 - b. Enter a **direction** for each indicator. A value of 1 means that higher values of the indicator are associated with higher values of the index/concept (e.g. higher values of indicator “income” indicate higher values of index “quality of life”). A value of -1 means that higher values of the indicator are associated with *lower* values of the index/concept (e.g. higher values of indicator “deforestation” are associated with lower values of index “environmental performance”).
 - c. Enter upper and lower **goalposts** for each indicator. These values are only used in the *Goalposts* normalisation method (see Box 3). If the goalpost bounds are left blank, they default to the minimum and maximum values of each indicator: in this case goalpost normalisation is identical to min-max.
 - d. Enter **structure** of the index: the index, sub-index, pillar and sub-pillar to which each indicator belongs. See Box 1 for details on this.

- e. Enter a **name** for each indicator. Shorter names can help readability in the COIN Tool.
4. **Enter methodological details:** working from the top row in the orange *Methodology* area in Figure 1:
- The **normalisation method** is selected from the drop down menu (see Box 3 for details on normalisation).
 - Enter the **minimum and maximum scores** - these represent the ranges that each indicator will be scaled onto for the min-max, goalposts and datamax methods (see Box 3). Typical (and default) values are 0 and 100 respectively.
 - Enter the **mean and standard deviation**, which are parameters of the DataZ method. Typical (and default) values here are 50 and 10 for the mean and standard deviation, respectively.
 - Enter the **aggregation type** for each level of the index (see Box 2). Indicators may only be aggregated to sub-pillars by the arithmetic mean, but all other aggregations can be selected either as an arithmetic or geometric mean.

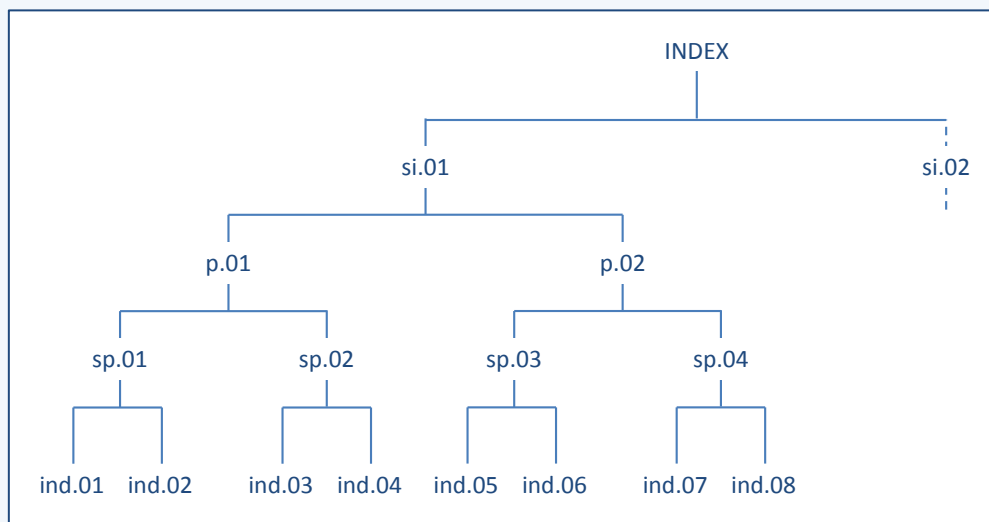
Box 1: Defining the structure of the index

The structure of the index in the COIN Tool is defined by three identifiers for each indicator:

- sp.XX: where XX specifies the sub-pillar to which the indicator belongs
- p.XX: where XX specifies the pillar
- si.XX: where XX specifies the sub-index

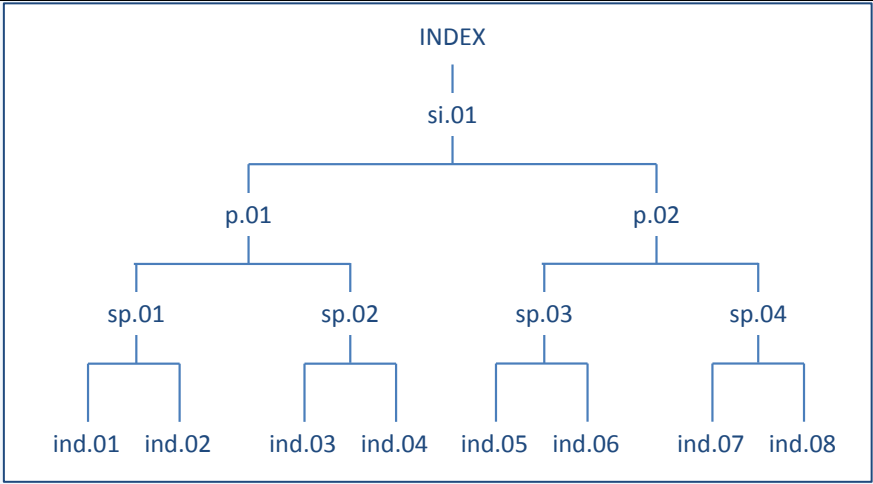
Each identifier is unique, meaning that e.g. the numbering of sub-pillars does not re-start within each new pillar.

An example is shown below, for an index with indicators, sub-pillars, pillars and sub-indexes.

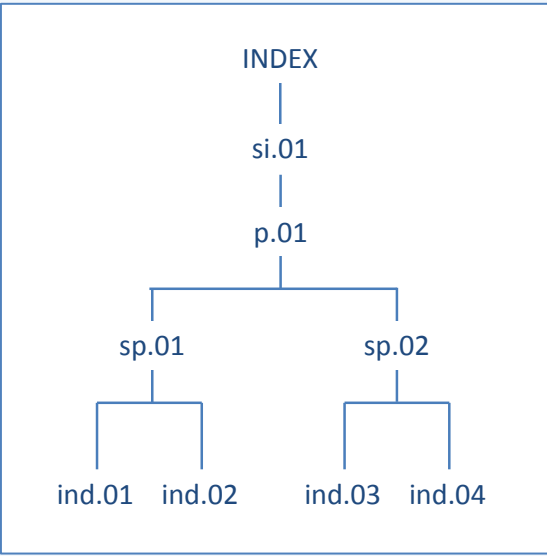


Here for example, ind.05 would be assigned sp.03, p.02, and si.01.

What happens if your index has fewer aggregation levels? The COIN Tool requires that you specify all levels of aggregation. The example below with three levels of aggregation shows that you simply assign all indicators to a single sub-index (si.01), which is then exactly equal to the index.



For an index with only two levels of aggregation, the idea is the same: you should assign all indicators to the same single sub-index (si.01) *and* the same single pillar (p.01) - see below.



Box 2: Aggregation methods

Scores are aggregated from indicators to sub-pillars, and to higher aggregation levels, using either the arithmetic or geometric mean of scores.

The arithmetic mean is the well-known weighted average of scores. Let $x_{1,c}, x_{2,c}, x_{3,c}$ be the values of three indicators comprising a sub-pillar s , for unit c . The sub-pillar score is calculated as follows:

$$s_c = \frac{1}{3}(w_1x_{1,c} + w_2x_{2,c} + w_3x_{3,c})$$

where w_1, w_2 and w_3 are the indicator weights that sum to 1 for indicators x_1, x_2 and x_3 respectively. More generally, it is defined as

$$s_c = \frac{1}{\sum w_i} \sum_{i=1}^n w_i x_{i,c}$$

where n is the number of indicators in the sub-pillar.

The geometric mean is calculated as follows:

$$s_c = \sqrt[3]{x_{1,c}^{w_1} x_{2,c}^{w_2} x_{3,c}^{w_3}}$$

i.e. weights are used as exponents, and indicators are multiplied rather than added. More generally,

$$s_c = \left[\prod_{i=1}^n x_{i,c}^{w_i} \right]^{\frac{1}{\sum w_i}}$$

Arithmetic averages are often described as *compensatory*, meaning that high scores in one indicator can compensate for low scores in another. Geometric averages, in contrast, reward units with balanced profiles, so that high scores in one indicator only provide a small compensation for low scores in another.

Note that geometric means require non-zero pillar values. If zero-value pillar scores occur, set the normalisation parameters to ensure that normalised indicators do not encounter zero values.

Box 3: Normalisation methods

Normalisation brings different indicators onto a comparable scale. Five normalisation methods are available in the COIN Tool.

Min-max normalisation is probably the most common approach. For a raw indicator X , the normalised scores x are calculated as:

$$x = \frac{X - \min(X)}{\max(X) - \min(X)} \times 100$$

This is a linear transformation, which scales values onto the interval $[0,100]$. The COIN Tool allows the user to adjust this range.

DataZ (Z-score) normalisation is similar to min-max:

$$x = \frac{S(X - \text{mean}(X))}{\text{std}(X)} + M$$

but rather than constraining the indicator to a fixed interval, it constrains it to have a mean of M and a standard deviation of S . It is a linear transformation. Setting $M=0$ and $S=1$ results in a standard Z-score, but this will result in negative values. Recommended values are $M=50$ and $S=10$, although this can be adjusted in the COIN Tool.

Datamax normalisation is another linear transformation that uses the maximum value of the indicator as a reference point:

$$x = \frac{X}{\max(X)}$$

This results in values that are less than 1. The COIN tool allows you to scale these onto a range specified by the minimum and maximum parameters.

Goalpost normalisation normalises the indicators against "theoretical" minimum and maximum values (the goalpost bounds), usually covering a wider interval than the indicator values. For example, indicators with percentage values might take goalpost values of 0% and 100%, even though none of the indicators have these values. It is calculated as:

$$x = \frac{X - L(X)}{U(X) - L(X)}$$

where $L(X)$ and $U(X)$ are the lower and upper bounds, specified individually for each indicator in the **Database** tab. These scores are then scaled onto the interval defined by the minimum and maximum scores, also specified in the **Database** tab.

Percentranks normalisation simply replaces the scores of each indicator with their percentile ranks. The percentile ranks are simply the ranks, as percentage values. Since they are based on the ranks, this is a nonlinear transformation, because the relative distances between units are not retained. The implication is that outliers are automatically treated, and all indicators will assume a uniform distribution. This may be desirable where indicators have problematic distributions, and only rankings are important. If outlying values should be preserved however, this option should not be used.

Note that the COIN Tool has the following limits:

- A maximum of 300 units (e.g. countries, universities, etc.)
- A maximum of 99 indicators
- A maximum of four aggregation levels, with:
 - a maximum of 33 sub-pillars

- a maximum of 11 pillars
- a maximum of three sub-indices

[Remember to press F9 after entering your data to recalculate the workbook.](#)

3.2 Framework

LITE **FULL**

Objective	A summary of the structure of the index. To assign weights and names to each aggregation level (sub-pillars, pillars, sub-indexes and index).
User input	Required: weights at sub-pillar level and above, and names of sub-pillars/pillars/sub-indexes/index.

In the **Framework** tab, the COIN Tool automatically summarises the index structure provided by the user in the **Database** tab: see Figure 2. Here, some additional details are required before the data analysis begins.

Figure 2: Specify aggregation weights and names in the Framework tab

Conceptual framework

Item	Dimension/indicator	Supra-dimension	Weight	Aggregation	Direction	Name of dimension/indicator
Index	Index		1	Arithmetic	1	Connectivity
Sub-indices	si.01	Index	1	Arithmetic	1	Connectivity
Pillars	p.01	si.01	1	Arithmetic	1	P1
	p.02	si.01	1	Arithmetic	1	P2
Sub-pillars	sp.01	p.01	1	Arithmetic	1	Physical
	sp.02	p.01	1	Arithmetic	1	Econ/Fin
	sp.03	p.01	1	Arithmetic	1	Political
	sp.04	p.02	1	Arithmetic	1	Institutional
	sp.05	p.02	1	Arithmetic	1	P2P
Indicators	ind.01	sp.01	1	Arithmetic	1	Logistics Performance Index
	ind.02	sp.01	1	Arithmetic	1	International flights passenger capacity
	ind.03	sp.01	1	Arithmetic	1	Liner Shipping Connectivity Index
	ind.04	sp.01	1	Arithmetic	1	Border crossings
	ind.05	sp.01	1	Arithmetic	1	Trade in electricity
	ind.06	sp.01	1	Arithmetic	1	Trade in gas
	ind.07	sp.01	1	Arithmetic	1	Average connection speed
	ind.08	sp.01	1	Arithmetic	1	Population covered by at least a 4G mobile network
	ind.09	sp.02	1	Arithmetic	1	Trade in goods
	ind.10	sp.02	1	Arithmetic	1	Trade in services
	ind.11	sp.02	1	Arithmetic	1	Foreign direct investment

As in every tab of the COIN Tool, the only cells that should be changed are those in light blue. Figure 2 shows that in this tab, the cells to enter information correspond to the aggregation weights and the names.

First, the **aggregation weights** should be specified. As with the indicator weights, these are relative and do not need to sum to 1. The weights are those used to aggregate to the next level; for example, the weights assigned to the sub-pillars are used as weights in the arithmetic or geometric mean which leads to the pillar scores.

Next, each aggregation level should be given a **name**. These are simply used to identify the aggregation levels in later tabs. Shorter names may help readability.

Note, the direction of each aggregation is assumed to be one (i.e. higher scores of each aggregation are associated with higher scores of the index). If it is not the case, then the COIN tool will not function properly.

[Remember to press F9 after entering your data to recalculate the workbook.](#)

4 Data inspection and treatment

The COIN Tool dedicates five tabs to illustrating the properties of your data and offering possibilities to treat outliers.

4.1 Statistics

LITE **FULL**

Objective	An overview of the statistical properties of the data, before any treatment. Users can check missing data, min/max values, mean and standard deviation, and outliers are flagged.
User input	Optional: skew and kurtosis thresholds, outlier identification parameters, minimum indicator coverage percentage.

The **Statistics** tab is a summary of the information provided in the **Database** tab. The objective is to highlight potentially “unusual” values, such as missing data, zeros, negative values, and outliers. You can then decide whether or not to treat or correct these values in later tabs.

Figure 3: Check your data in the Statistics tab

Descriptive statistics		Missing values (%)	0.0%	0.0%	0.0%	0.0%	2.0%	
	Missing values (#)	0	0	0	0	0	1	
	Min	-4.10	-4.10	-	-	-	-	
	Max	4.23	4.23	21.17	0.00	4.52		
	Mean	3.25	3.24	11.98	0.00	0.80		
	Standard deviation	1.18	1.17	6.84	0.00	1.05		
Skewness threshold	1.50	Skewness	-5.03	-5.06	-0.58	4.21	1.80	
Kurtosis threshold	2.00	Kurtosis	31.37	31.69	-0.68	19.90	3.17	
Indicators with outliers	13	Outliers detected	yes	yes	no	yes	yes	
IQR parameter <i>a</i>	2.00	First quartile (Q1)	2.98	2.98	9.09	0.00	0.02	
Std. dev. factor <i>b</i>	3.00	Median (Q2)	3.41	3.39	12.69	0.00	0.38	
Percentile level <i>c</i>	0.00	Third quartile (Q3)	3.79	3.77	16.80	0.00	1.24	
	Low outliers	1	1					
	High outliers				5	1		
	Weight	1	1	1	1	1	1	
	Direction	1	1	1	1	1	1	
Number of indicators:	30	Sub-index	si.01	si.01	si.01	si.01	si.01	
Number of units:	51	Pillar	p.01	p.01	p.01	p.01	p.01	
		Sub-pillar	sp.01	sp.01	sp.01	sp.01	sp.01	
Min. indicator coverage	90%	Indicator name	Logistics Performance Index	International flights passenger	Liner Shipping Connectivity Index	Border crossings	Trade in electricity	
Indicators with data	Coverage	Unit name	Unit/Indicator	ind.01	ind.02	ind.03	ind.04	ind.05
30	100.0%	AT	unit.001	-4.10	-4.10	-	0.00	1.31
30	100.0%	BE	unit.002	4.11	4.11	20.57	0.00	0.63
30	100.0%	BG	unit.003	2.81	2.81	7.92	0.00	1.13
30	100.0%	HR	unit.004	3.16	3.16	12.44	0.00	2.79
30	100.0%	CY	unit.005	3.00	3.00	11.69	-	0.31
30	100.0%	CZ	unit.006	3.67	3.67	-	0.00	1.83
30	100.0%	DK	unit.007	3.82	3.82	14.41	0.00	1.51
30	100.0%	EE	unit.008	3.36	3.36	9.17	0.00	3.34

The tab shows some general information, such as the number of indicators and the number of units.

For each *indicator*, the following information is displayed:

- Missing values as a percentage and number of the total number of units
- Maximum and minimum values
- Moments: mean, standard deviation, skewness and kurtosis
- Presence of outliers, and whether they are high or low (see Box 2)
- Quartile and median information
- Weight, direction, structural information and indicator name (repeated from the **Database** tab)

For each *unit*, the following information is given:

- Number of indicators with available data
- Data coverage, as a percentage. Note that units that have less than the minimum indicator coverage parameter are highlighted in red.
- Unit name

Finally, the data values themselves are displayed, but with zero values, missing data and negative values highlighted (see COIN Tool for the key). Additionally, outliers are highlighted using quartile-based information. See Box 2 for details on outlier detection.

The intention of all this information is to give as much information about indicators, units, and individual data points as possible. This enables you to check, for example, that:

- Maximum and minimum values are within expected ranges
- The missing data for each indicator and unit is within acceptable ranges. A rule of thumb might be at least 65 percent indicator coverage per unit and dimension (this threshold is case-dependent and may depend on the degree of correlation between indicators within a dimension, among other things)
- Zeros and negative values are not due to errors. Note that Excel assigns a value of 0 to blank cells. It is therefore crucial to double check for blanks that could be taken as zero values in original data sources.

Box 4: Outlier detection in the **Statistics tab**

Outliers are data points that differ significantly from other observations. An outlier may be due to an error, but it may be also simply due to a skewed indicator distribution. To deal with outliers, one must first detect their presence, and then decide whether they should be treated or not.

Detecting outliers is not straightforward, and many approaches exist. The COIN Tool offers a simple univariate approach based on the moments of the indicator distributions, as well as quartiles.

Presence of outliers is detected as “yes” or “no” in row 9. An indicator distribution is defined as having outliers if its absolute skewness *and* kurtosis *both* exceed specified thresholds. Default values for these thresholds are 2 and 3.5, respectively¹.

Indicators for which these thresholds are exceeded are treated by the COIN Tool in the **Winsorisation** and **Box Cox** tabs. However, users have the option to use the original dataset if desired.

Individual outliers are highlighted using a different approach. Let x_i be any value of the i th indicator. Values are highlighted in green as *low outliers* if any of the following are true:

1. $x_i < Q_1 - a(Q_3 - Q_1)$, where Q_1 and Q_3 are the first and third quartiles of the i th indicator, and a is a parameter that can be adjusted (default 2). In other words, it flags whether x_i is below a certain multiple of the interquartile range.
2. $x_i < \mu_i - b\sigma_i$, where μ_i and σ_i are the mean and standard deviation, respectively,

¹ Groeneveld, R. A., & Meeden, G. (1984). Measuring skewness and kurtosis. *Journal of the Royal Statistical Society: Series D (The Statistician)*, 33(4), 391-399.

of the i th indicator, and b is a parameter that can be adjusted (default 3). In other words, it flags whether x_i is below a certain multiple of the standard deviation.

3. $x_i < P_c$, where P_c is the c th percentile of the i th indicator. The default for c is zero, which means this criteria is usually switched off, otherwise outliers will be identified in all indicators.

For *high* outliers, the criteria are analogous:

1. $x_i > Q_1 - a(Q_3 - Q_1)$
2. $x_i > \mu_i - b\sigma_i$
3. $x_i > P_{1-c}$

By accepting any of these criteria, the COIN Tool gives a “cautious” picture of the data, highlighting values that might be considered outliers by several criteria.

Importantly, the highlighting of outliers via these three criteria is separate from the outlier identification via skew and kurtosis. Outlier highlighting is illustrative only, and does not affect calculations in the rest of the COIN Tool.

Based on the information in the **Statistics** tab, you may wish to check and adjust your data manually, and then re-enter it into the **Database** tab, or to proceed to the **Winsorisation** tab for outlier treatment.

4.2 Winsorisation

LITE **FULL**

Objective	To treat outliers using Winsorisation, and to highlight the treated values
User input	Optional: Winsorisation type and maximum number of Winsorised points

The Winsorisation tab attempts to “correct” indicators with outlying values, defined as those indicators which exceed the skew and kurtosis thresholds (see Box 2). Winsorisation is the process of replacing outliers with the closest non-outlying value. The method is usually used in the presence of few outlier values (roughly 5 percent of units).

For each indicator, the COIN Tool iteratively Winsorises outlying values, up to a specified maximum number (defaulting to five values), until the skew and kurtosis are within the specified thresholds. If Winsorisation does not bring skew and kurtosis within thresholds, the COIN Tool recommends a Box-Cox transformation - see **Box Cox** tab.

Note that indicators are Winsorised here where possible, but you have the option to use the original data set in the index calculation if desired. You may prefer to manually treat outliers outside of the COIN Tool and re-enter the treated data in the **Database** tab.

Figure 4 shows a screenshot. Each indicator has the following information, starting from Row 3 downwards:

- Whether outliers are detected or not - defined by those indicators exceeding the skew and kurtosis thresholds
- Whether skewness is small (i.e. left-skewed distribution with outliers at the lower end of the scale), or right (the opposite)
- A recommendation: either “Winsorise”, if it is possible to Winsorise and bring skew and kurtosis within thresholds; or “Box-Cox” if it is not possible. In cases where no outliers are identified, this will be left blank
- Winsorisation levels: the first row shows the result of Winsorising the first most outlying point for each indicator.

- If this successfully brings skew and kurtosis within the thresholds, it will display "OK"
- If the skew and kurtosis still surpass the thresholds, it will display "not OK"
- If Winsorisation was not required in the first place, it will display "not required"
 - The next row shows the same, but for Winsorising the second most outlying value. The third row shows the Winsorisation of the third most outlying point, and so on.
- If the indicator cannot be successfully Winsorised, the Candidate for Box-Cox row will display a "1"
- The next rows give information about the indicator *after Winsorisation*:
- The new skewness and kurtosis
- Whether outliers are detected *after Winsorisation* (i.e. indicator exceeds both skew and kurtosis thresholds)

Data points which have been Winsorised are highlighted in green.

Figure 4: Treat your data in the Winsorisation tab

Winsorisation		Select: Normal winsorization				
Max. points to Winsorise		5				
ORIGINAL DATASET		Outliers detected	yes	yes	no	yes
Skewness			SMALL	SMALL	OK	LARGE
Recommendation			winsorize	winsorize		winsorize
Number of winsorised values			1	1		4
1	Winsorization level		OK	OK	not required	not OK
2	Winsorization level		OK	OK	not required	not OK
3	Winsorization level		OK	OK	not required	not OK
4	Winsorization level		OK	OK	not required	OK
5	Winsorization level		OK	OK	not required	OK
		Candidate for Box-Cox				
WINSORIZED DATASET		Skewness	-0.37	-0.35	-0.58	1.65
		Kurtosis	-0.50	-0.46	-0.68	1.51
		Outliers detected	no	no	no	no
		Unit/Indicator	ind.01	ind.02	ind.03	ind.04
Austria	AT	unit.001	2.07	2.07	-	0.00
Belgium	BE	unit.002	4.11	4.11	20.57	0.00
Bulgaria	BG	unit.003	2.81	2.81	7.92	0.00
Croatia	HR	unit.004	3.16	3.16	12.44	0.00
Cyprus	CY	unit.005	3.00	3.00	11.69	-
Czech Republic	CZ	unit.006	3.67	3.67	-	0.00
Denmark	DK	unit.007	3.82	3.82	14.41	0.00
Estonia	EE	unit.008	3.36	3.36	9.17	0.00
Finland	FI	unit.009	3.92	3.92	10.04	0.00
France	FR	unit.010	3.90	3.30	19.54	0.00

4.3 Box-Cox

LITE FULL

Objective	To offer alternative data treatment for indicators which cannot successfully be Winsorised, based on the Box-Cox family of transformations.
User input	None.

In the **Winsorisation** tab, indicators with outlying values are Winsorised up to a maximum number of points. If the skew and kurtosis values are still not within thresholds after the maximum number of Winsorised points, the recommendation is "Box-Cox". These indicators will appear in the **Box-Cox** tab.

The Box-Cox transformation is a method of transforming a non-normal probability distribution into a distribution that is (closer to) normal. It may be suitable in cases of very skewed data. Although the Box-Cox transformation is actually a parameterised family of transformations, a selected few are implemented in the COIN Tool, which should still cover most cases.

Indicators are displayed in numerical order, with four columns per indicator - see Figure 5. The columns are as follows:

1. The original values of the indicators
2. The log transform with minimum zero, i.e. $\ln(x_i - \min(x_i) + 1)$
3. The square root transform with minimum zero, i.e. $\sqrt{x_i - \min(x_i)}$
4. The log-median transform, which forces the minimum value to zero and the median to be equal to the mid-range value. This implies that in most cases skewness and kurtosis will be within the defined thresholds. It is defined as:

$$100 \frac{\ln(1 + ax_i)}{\ln(1 + 100a)}; \quad a = \frac{100 - 2\tilde{x}_i}{\tilde{x}_i^2}$$

where \tilde{x}_i is the sample median, and in all cases the x_i are previously scaled onto [0,100].

Figure 5: Alternative transformations in the Box-Cox tab

Box-Cox transformations									
Indicators with outliers		1	1	1	1	2	2	2	2
Name		ind.04Original value	ind.04LN	ind.04SQRT	ind.04LNMED	5Original value	ind.05LN	ind.05SQRT	ind.05LNMED
Type of transformation		Original value	LN	SQRT	LNMED	Original value	LN	SQRT	LNMED
Skewness		4.21	4.21	2.15	-0.33	1.80	0.90	0.57	-0.13
Kurtosis		19.90	19.87	5.80	-0.47	3.17	-0.12	-0.51	-1.41
Outliers detected		yes	yes	yes	no	yes	no	no	no
Min		-	-	-	-	-	-	-	-
Max		0.00	0.00	0.07	1.00	4.52	1.71	2.13	1.00
Median		0.00	0.00	0.01	0.50	0.38	0.32	0.62	0.50
Direction		1	1	1	1	1	1	1	1
Unit/Indicator		ind.04	ind.04	ind.04	ind.04	ind.05	ind.05	ind.05	ind.05
AT	unit.001	0.00	0.00	0.02	0.70	1.31	0.84	1.14	0.74
BE	unit.002	0.00	0.00	0.04	0.87	0.63	0.49	0.80	0.60
BG	unit.003	0.00	0.00	0.01	0.59	1.13	0.76	1.06	0.71
HR	unit.004	0.00	0.00	0.03	0.77	2.79	1.33	1.67	0.90
CY	unit.005	-	-	-	-	0.31	0.27	0.55	0.46
CZ	unit.006	0.00	0.00	0.02	0.71	1.83	1.04	1.35	0.81
DK	unit.007	0.00	0.00	0.01	0.48	1.51	0.92	1.23	0.77
EE	unit.008	0.00	0.00	0.01	0.56	3.34	1.47	1.83	0.94
FI	unit.009	0.00	0.00	0.01	0.45	1.00	0.69	1.00	0.69
FR	unit.010	0.00	0.00	0.01	0.55	0.53	0.43	0.73	0.56
DE	unit.011	0.00	0.00	0.02	0.66	0.50	0.41	0.71	0.55
GR	unit.012	0.00	0.00	0.01	0.52	0.15	0.14	0.39	0.33
HU	unit.013	0.00	0.00	0.02	0.66	1.09	0.74	1.04	0.71
IE	unit.014	0.00	0.00	0.01	0.59	0.32	0.28	0.57	0.47
IT	unit.015	0.00	0.00	0.01	0.50	0.41	0.35	0.64	0.51

For each of the four columns per indicator, the new skewness and kurtosis values are reported. They are highlighted red if they still exceed the skew/kurtosis thresholds. The transformations are automatically carried over into the following tabs.

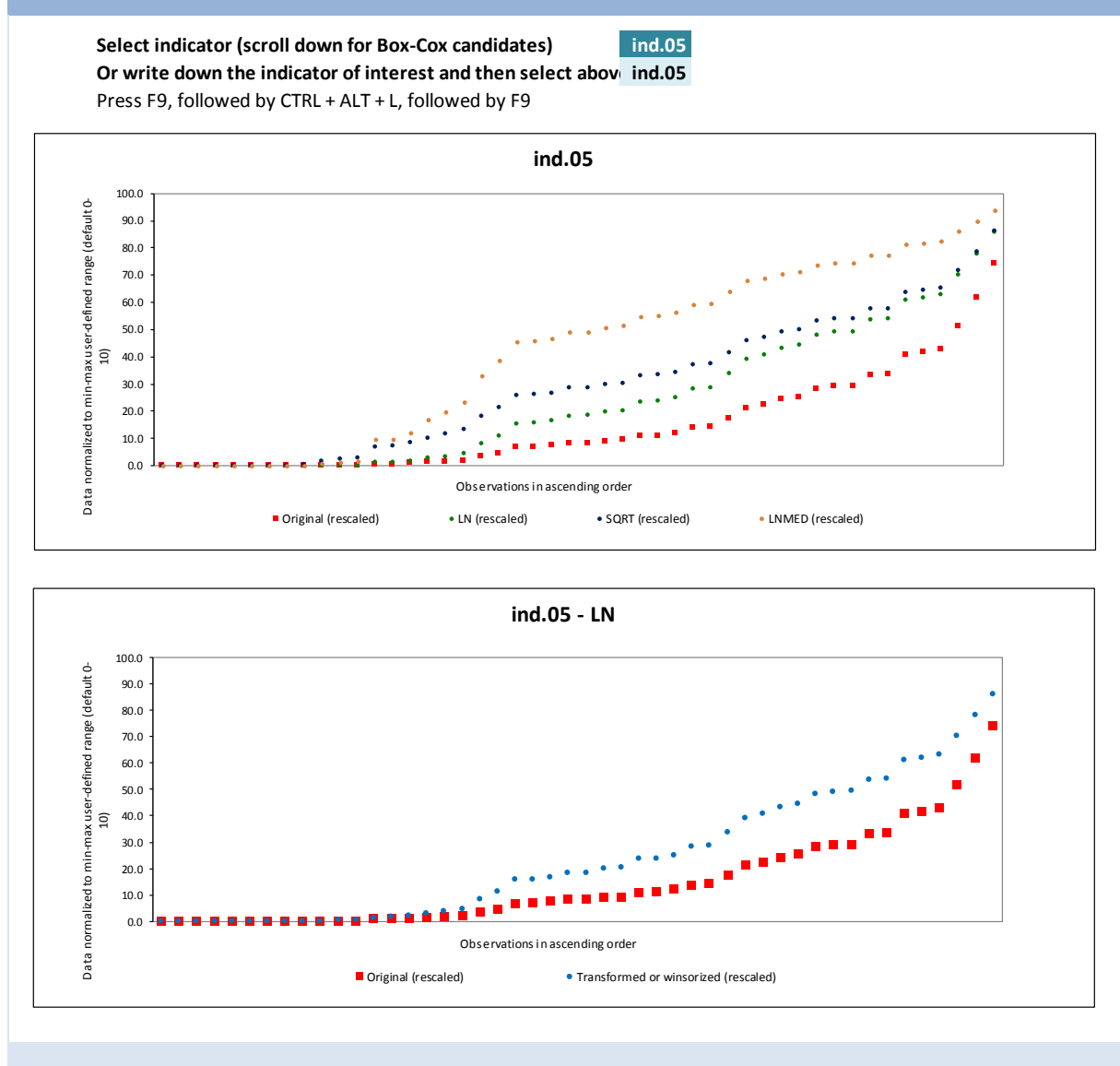
4.4 Scatterplots

LITE **FULL**

Objective	To visualise and compare treated data against untreated values.
User input	Optional: select the indicator that you wish to visualise.

Two charts are available to visualise all Box-Cox transformations, and the selected transformation, together with the original indicators. The idea here is to show the effect of the various possible Box-Cox transformations (top chart) and the selected transformation (bottom chart), in terms of how far the treated data points are from the original data.

Figure 6: Visualise data treatment in the Scatterplots tab



4.5 TreatedData

LITE **FULL**

Objective	To summarise the treated data set and show its properties. To allow the user to select between the treated and original data sets.
User input	Optional: select the either the treated or original data set to be used in further calculations. The treated dataset appears selected by default.

The **TreatedData** tab summarises the treatments applied in the **Winsorisation** and **Box-Cox** tabs, and illustrates the properties of the treated data set. This dataset is used for all subsequent calculations in the COIN Tool, including the index values, analysis of correlations, and so on.

You have the option to select the original data set if you prefer not to treat the data, or if you have already treated the data prior to entering it into the COIN Tool. See Box 3 for a discussion on whether you should treat data or not.

Figure 7: Review the treated data set in the TreatedData tab

Treated Data		Select: Outlier-free dataset					
		Yes	Yes	No	Yes	Yes	Yes
Data treatment status:	Winsorisation	OK	OK		OK	OK	OK
	LN-transform						
	SQRT transform						
	LNMED transform						
	SELECTED TRANSFORM	WIN	WIN	None	WIN	WIN	WIN
	Missing values	0	0	0	0	1	1
	Min	2.07	2.07	-	-	-	0.00
	Max	4.23	4.23	21.17	0.00	3.34	0.51
	Mean	3.37	3.36	11.98	0.00	0.77	0.15
	Standard deviation	0.56	0.55	6.84	0.00	0.96	0.17
	Skewness	-0.37	-0.35	-0.58	1.65	1.46	1.23
	Kurtosis	-0.50	-0.46	-0.68	1.51	1.39	0.10
	Outliers detected (final)	no	no	no	no	no	no
	Weight	1.00	1.00	1.00	1.00	1.00	1.00
	Direction	1	1	1	1	1	1
Number of units:	51	si.01	si.01	si.01	si.01	si.01	si.01
Number of indicators:	30	p.01	p.01	p.01	p.01	p.01	p.01
	Sub-pillar	sp.01	sp.01	sp.01	sp.01	sp.01	sp.01
Min. indicator coverage:	90%	Indicator name					
	Coverage	Logistics	Perfo	International f	Liner Shipping	Border crossin	Trade in electr
	Unit/Indicator	ind.01	ind.02	ind.03	ind.04	ind.05	ind.06
AT	100.0%	2.07	2.07	-	0.00	1.31	0.01
BE	100.0%	4.11	4.11	20.57	0.00	0.63	0.51
BG	100.0%	2.81	2.81	7.92	0.00	1.13	0.03
HR	100.0%	3.16	3.16	12.44	0.00	2.79	0.06
CY	100.0%	3.00	3.00	11.69	-	0.31	0.02
CZ	100.0%	3.67	3.67	-	0.00	1.83	0.11
DK	100.0%	3.82	3.82	14.41	0.00	1.51	0.03
EE	100.0%	3.36	3.36	9.17	0.00	3.34	0.02
FI	100.0%	3.92	3.92	10.04	0.00	1.00	0.02
FR	100.0%	3.90	3.30	19.54	0.00	0.53	0.20
DE	100.0%	4.23	4.23	20.50	0.00	0.50	0.22
GR	100.0%	3.24	3.24	15.68	0.00	0.15	0.01
HU	100.0%	3.43	3.43	-	0.00	1.09	0.02
IE	100.0%	3.79	3.79	10.58	0.00	0.32	0.21

The information in the **TreatedData** tab largely mirrors that of the **Statistics** tab. Each indicator has the number of missing values, minimum, maximum, mean, standard deviation, skew and kurtosis values. In the top rows there is a summary of the data treatment applied, if any:

- The first row shows whether outliers were detected in the original data set
- The following rows show the result of Winsorisation and Box-Cox transformations. This will display "OK" if the treatment method was successful (in bring skew and kurtosis below thresholds), "not OK" if it was unsuccessful, and blank if it was not applied.
- The selected transform is displayed - this will be the one used if the treated data set is selected. If "Other" is displayed, this indicator cannot be successfully treated within the COIN Tool.

All treated data points, i.e. points that are altered from the original values, are highlighted in green. Other highlighting is the same as the **Statistics** tab.

Box 5: Should outliers be treated or not?

This question must be answered on a case-by-case basis. If an outlier represents a measurement or encoding error, then Winsorisation may be a straightforward way to assign a more realistic value.

If the outlier(s) are due simply to the shape of the distribution, care is required. Outliers are problematic because they fill the scale of the indicator with a lot of empty space, and the indicator will be dominated by the value of a few outlying points. On the other hand, many indicators are naturally skewed, and treating data represents a departure from measured reality.

Winsorisation effectively "caps" the scale at a maximum value. The idea is that values above a certain value are considered to be top values, and the exact values are not important. Consider, however, that Winsorisation does not preserve the ranks of units: a unit with an outlying highest score will (after Winsorisation) have the same score, and therefore the same rank, as the next highest.

Box-Cox transformations, such as the log transform, change the values of the indicators relative to one another, but preserve the ranks. They can correct for skew and kurtosis, but may involve heavy modifications to the original data.

When considering whether to treat data or not, return to the objectives of the index: should outlying units be identified, or is the rank more important? How important is it to be able to communicate any data treatment to stakeholders?

5 Correlations and rebalancing

Correlations illustrate the relationships between indicators and aggregations. The IndCorrel tab gives information on correlations between indicators, while the Rebalancing tab shows correlations between different levels of aggregation. The latter gives an opportunity to adjust weights based on correlations.

5.1 IndCorrel: Indicator correlations

LITE **FULL**

Objective	To calculate and illustrate the correlations between the indicators. Users should pay particular attention to highly collinear indicators (which imply double-counting), and negative correlations within the same sub-pillar (which can lead to issues during aggregation).
User input	Optional: threshold values for high and negative, high and positive and highly collinear indicators. This will only affect which values are highlighted in the correlation matrix.

The **IndCorrel** tab shows a matrix of correlation values between indicators. The values are Pearson correlation coefficients, which measure the linear association between each pair of variables, taking into account the direction of effects. Correlations are taken on the final data set selected in the **TreatedData** tab. The correlation values here are not dependent on the normalisation and aggregation methods.

The correlation matrix is colour-coded to help the analysis, with pillars and sub-pillars shaded in purple (see Figure 8). High correlations are coloured green, and very high correlations are shaded dark green. Negative correlations are also coloured red.

The correlation matrix helps to spot issues with the way that indicators are associated. In the ideal case, indicators would all be positively well-correlated, but not so strongly correlated that they are collinear.

Users should pay attention in particular to the following cases:

Negative correlations:

This implies that high values of one indicator are associated with low values of the other, and vice versa. Negative correlations are not necessarily a problem if they occur between indicators in different pillars (these are coloured with red text), but if strong negative correlations occur within the same sub-pillar (coloured with red fill), they can lead to mixed messages on aggregation: the sub-pillar score will typically be negatively correlated with some of the underlying indicators, and therefore it will not be a representative measure.

Negative correlations could be due to an error, such that the desired direction of the indicator is wrong, or simply that there are trade-offs between indicators. Small negative correlations may not be significant, depending on sample size.

Collinear indicators:

Very high correlations, i.e. above 0.9 or thereabouts, imply that the indicator pair is collinear. This means that one is effectively a linear function of the other, and when normalised, they will amount to the same indicator. Having collinear indicators, particularly within the same sub-pillar (highlighted in green by the COIN Tool), is undesirable because the indicators represent the same information twice, so it implies double-counting. Typical fixes include either eliminating one of the indicators, or assigning half the weight to both indicators.

Figure 8: Check correlations between indicators in the IndCorrel tab

Indicator correlations										
Negative correlation threshold	-0.50									
Positive correlation threshold	0.30									
Collinear threshold	0.92									
Initial weights	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
Sub-index	si.01	si.01	si.01	si.01	si.01	si.01	si.01	si.01	si.01	
Pillar	p.01	p.01	p.01	p.01	p.01	p.01	p.01	p.01	p.01	
Sub-pillar	sp.01	sp.01	sp.01	sp.01	sp.01	sp.01	sp.01	sp.01	sp.02	
Direction	1	1	1	1	1	1	1	1	1	
Name	Logistics Performance Index	International flights passenger capacity	Liner Shipping Connectivity Index	Border crossings	Trade in electricity	Trade in gas	Average connection speed	Population covered by at least a 4G mobile network	Trade in goods	
Name	Indicator	ind.01	ind.02	ind.03	ind.04	ind.05	ind.06	ind.07	ind.08	ind.09
Logistics Performance Index	ind.01		0.99	0.43	0.33	0.13	0.22	0.45	0.58	0.02
International flights passenger capacity	ind.02	0.99		0.42	0.33	0.14	0.22	0.48	0.58	0.04
Liner Shipping Connectivity Index	ind.03	0.43	0.42		-0.17	-0.40	0.07	-0.05	0.06	-0.24
Border crossings	ind.04	0.33	0.33	-0.17		0.55	0.34	0.17	0.37	0.51
Trade in electricity	ind.05	0.13	0.14	-0.40	0.55		-0.08	0.14	0.43	0.47
Trade in gas	ind.06	0.22	0.22	0.07	0.34	-0.08		0.26	0.05	0.29
Average connection speed	ind.07	0.45	0.48	-0.05	0.17	0.14	0.26		0.50	0.10
Population covered by at least a 4G mobile network	ind.08	0.58	0.58	0.06	0.37	0.43	0.05	0.50		0.17
Trade in goods	ind.09	0.02	0.04	-0.24	0.51	0.47	0.29	0.10	0.17	
Trade in services	ind.10	0.08	0.08	-0.06	0.41	0.41	0.00	-0.07	0.26	0.28
Foreign direct investment	ind.11	-0.29	-0.29	-0.28	0.02	-0.14	0.15	-0.10	-0.44	0.25
Personal remittances (received and sent)	ind.12	-0.21	-0.21	-0.41	0.33	0.20	0.17	-0.20	0.03	0.45
Foreign portfolio investment liabilities	ind.13	0.60	0.59	0.10	0.41	0.23	0.39	0.41	0.52	0.10
Embassies network	ind.14	0.41	0.39	0.46	-0.13	-0.32	-0.04	0.08	0.08	-0.33
Participation in international trade	ind.15	0.63	0.59	0.40	0.08	0.18	-0.10	0.26	0.53	-0.16
UN voting alignment	ind.16	0.45	0.46	-0.08	0.36	0.57	-0.10	0.42	0.73	0.26
Cost to export/import	ind.17	0.46	0.44	0.09	0.38	0.49	0.07	0.31	0.71	0.37
Mean tariff rate	ind.18	0.36	0.36	-0.16	0.44	0.36	0.35	0.29	0.54	0.25
Technical barriers to trade	ind.19	-0.47	-0.44	-0.18	-0.26	-0.42	0.17	-0.13	-0.60	-0.22
Signatory of TIR Convention	ind.20	0.26	0.25	-0.04	0.17	0.43	-0.20	0.10	0.41	0.01
Regional trade agreements	ind.21	0.48	0.48	0.12	0.33	0.49	0.00	0.43	0.52	0.27

The information in the **IndCorrel** tab should be combined with the information in the following **Rebalancing** tab, which looks at correlations between indicators and aggregation levels. This combined information may lead to adjustments in weights, removal/addition of indicators, and should be weighed up against conceptual considerations.

Note that statistical significance is not taken into account.

5.2 Rebalancing

LITE FULL

Objective	To illustrate the correlations between each indicator, sub-pillar, pillar, and sub index, and aggregation levels above it. To give the user the opportunity to adjust weights based on this information.
User input	Optional: new weights for each indicator and aggregation level. Adjust which correlations are highlighted with a low-correlation parameter.

While the **IndCorrel** tab shows the correlations between indicators, the **Rebalancing** tab shows correlations between each indicator, sub-pillar, pillar, and sub index, and aggregation levels above it. For example, the INDICATOR table shows the correlation of each indicator with its sub-pillar, pillar, sub-index and index (see Figure 9).

Each table also shows the initial indicator weights, and has a row of “adjusted weights” which can be entered by the user. It then shows the correlations based on the initial weights, as well as those based on the adjusted weights.

The objective of this tab is to let you adjust the weights to achieve a balance of correlations within aggregation groups. For more details on why this is important, see Box 4.

Figure 9: Re-weight based on correlations in the Rebalancing tab

Rebalancing of weights Low correlation threshold 0.5

CORRELATIONS WITH SUPRA-DIMENSIONS - WEIGHTED ARITHMETIC AVERAGES

INDICATOR	ind.01	ind.02	ind.03	ind.04	ind.05	ind.06	ind.07	ind.08
Sub-pillar	sp.01	sp.01	sp.01	sp.01	sp.01	sp.01	sp.01	sp.01
Initial weights	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Initial correlation with sub-pillar	0.855	0.858	0.336	0.616	0.417	0.441	0.593	0.736
Adjusted weights	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
New correlation with sub-pillar	0.855	0.858	0.336	0.616	0.417	0.441	0.593	0.736
Pillar	p.01	p.01	p.01	p.01	p.01	p.01	p.01	p.01
Initial correlation with pillar	0.776	0.767	0.217	0.597	0.483	0.276	0.527	0.737
New correlation with pillar	0.666	0.659	0.093	0.675	0.525	0.328	0.419	0.664
Sub-index	si.01	si.01	si.01	si.01	si.01	si.01	si.01	si.01
Initial correlation with sub-index	0.644	0.637	0.048	0.590	0.599	0.212	0.433	0.771
New correlation with sub-index	0.644	0.637	0.048	0.590	0.599	0.212	0.433	0.771
Index	Index	Index	Index	Index	Index	Index	Index	Index
Initial correlation with index	0.644	0.637	0.048	0.590	0.599	0.212	0.433	0.771
New correlation with index	0.608	0.602	0.003	0.664	0.610	0.271	0.373	0.725

SUB-PILLAR	sp.01	sp.02	sp.03	sp.04	sp.05
Pillar	p.01	p.01	p.01	p.02	p.02
Initial weights	1.000	1.000	1.000	1.000	1.000
Initial correlation with pillar	0.985	0.885	0.969	0.986	0.961
Adjusted weights	1.000	2.000	1.000	1.000	3.000
New correlation with pillar	0.977	0.924	0.946	0.959	0.988
Sub-index	si.01	si.01	si.01	si.01	si.01
Initial correlation with sub-index	0.975	0.888	0.959	0.990	0.939
New correlation with sub-index	0.973	0.917	0.941	0.980	0.946
Index					
Initial correlation with index	0.975	0.888	0.959	0.990	0.939
New correlation with index	0.973	0.917	0.941	0.980	0.946

PILLAR	p.01	p.02
Sub-index	si.01	si.01
Initial weights	1.000	1.000
Initial correlation with sub-index	0.992	0.994
Adjusted weights	2.000	1.000
New correlation with sub-index	0.994	0.980
Index		
Initial correlation with index	0.992	0.994
New correlation with index	0.994	0.980

SUB-INDEX	si.01
Index	Index
Initial weights	1.000
Initial correlation with index	1.000
Adjusted weights	1.000
New correlation with index	1.000

Notes: Negative correlations are highlighted in red and low positive correlations are highlighted in light orange.

A suggested way to use this tab is as follows.

1. Start at the INDICATOR table. Copy the row of initial weights into the adjusted weights row. The correlations should now be the same for both sets of weights.

2. Inspect the correlation of each indicator with its sub-pillar, pillar, sub-index and index. The idea is that correlations, within the same aggregation group, should be roughly the same. If one indicator has a much lower correlation than the other indicators, the aggregate value will be un-representative of that indicator.
3. For indicators which have very different correlations from the others in their aggregation group, adjust the weight in the "adjusted weights" row. A higher weight will increase the correlation, whereas a lower weight will reduce it. You may wish to try values such as 0.5, 1 and 2, since these are easier to communicate than seemingly arbitrary values such as 0.397. Weights are relative and do not need to sum to 1. It may also be easier to focus on balancing the indicator correlations with just one aggregation level, e.g. with the sub-pillar.
4. Repeat for each sub-pillar. Remember to press F9 to re-calculate the correlation values.
5. Once you are satisfied with the indicator correlations, move on to the SUB-PILLAR table. Steps 1-4 should be repeated, again adjusting the weights to provide satisfactory correlations.
6. Repeat for the PILLAR and SUB-INDEX tables.

Note that the adjusted weights will be used in subsequent calculations, although comparisons with initial weights are also given in later tabs.

Note also that correlations in the **Rebalancing** tab *are* dependent on the choice of normalisation and aggregation methods.

Box 6: Weights and importance

A common misconception in composite indicators is that by assigning equal weights to indicators, you are assigning equal importance to each indicator.

In fact (and depending on the definition of "importance") this is not usually the case. The final effect of each indicator is dependent not only on its weight, but on its correlation with other indicators, and their weights.

One way of measuring importance is to use the correlation coefficient of the indicator with the index. Recently, this has been shown to be a proxy for the mutual information between the indicator and the index². In other words, a high correlation means that the index contains much of the information in the indicator, whereas a low correlation means the opposite.

Ideally, the index should contain a balanced contribution of information from each indicator. This implies that correlation values (between indicator and index) should be roughly similar. Otherwise, the index is much more representative of some indicators than others.

The same argument applies for weighting sub-pillars, pillars, and sub-indexes. The Rebalancing tab illustrates these correlations, and gives the opportunity to adjust weights accordingly.

Of course, balancing correlations should be put in perspective against other objectives of the index. In order to achieve a good balance, sometimes the weights may have to be very different from each other, and this may be difficult to communicate to users of the index. It may be preferable to strike a compromise between statistical balance and a simple weighting scheme. For the interested reader detailed explorations into tuning the weights of composite indicators are available³.

² Lindén, D., Cinelli, M., Spada, M., Becker, W., Gasser, P., Burgherr, P. (2019), Information transfer in composite indicators. *Ecological Indicators* (under review, preprint available on request)

³ Becker, W., Saisana, M., Paruolo, P., & Vandecasteele, I. (2017). Weights and importance in composite indicators: Closing the gap. *Ecological indicators*, 80, 12-22.

6 Index scores and ranks

The **Scores**, **Heatmap** and **Rankings** tabs present the index scores and ranks based on the data provided and the methodological choices selected.

6.1 Heatmap

LITE **FULL**

Objective	To report and visualise scores and overall ranks.
User input	None.

The Heatmap tab gives a first overview of the scores at each aggregation level, and the ranks of the overall index - see Figure 10. Units are sorted according to index scores, from highest to lowest. The score values are also reported at the index, sub-index, pillar, and sub-pillar level, and colour-coded such that the highest scores are in green and the lowest in red.

This illustrates at a glance which units perform well in particular dimensions. The ranking can be used to confirm (or otherwise) which units perform overall well and which do not.

Figure 10: Visualise scores and ranks in the Heatmap tab

Heatmap of scores		Connectivity	Connectivity	P1	P2	Physical	Econ/Fin	Political	Institutional	P2P
Rank	Unit									
1	LU	68.92	68.92	67.97	70.81	62.55	79.09	51.17	74.26	69.66
2	SG	62.22	62.22	61.56	63.55	81.53	66.20	32.30	69.13	61.69
3	BE	59.31	59.31	61.58	54.79	81.48	41.99	80.84	72.28	48.96
4	NL	57.17	57.17	59.94	51.62	78.11	38.55	84.55	68.42	46.02
5	CH	56.55	56.55	51.97	65.71	72.48	30.32	74.78	82.73	60.03
6	MT	55.66	55.66	50.86	65.26	50.60	55.27	42.29	73.07	62.66
7	SI	53.23	53.23	52.60	54.47	64.72	45.14	55.42	73.01	48.29
8	SK	52.87	52.87	57.43	43.77	52.92	56.02	64.75	73.61	33.82
9	DK	52.13	52.13	46.98	62.43	56.42	26.68	78.13	72.06	59.22
10	HR	49.80	49.80	47.67	54.06	54.97	36.53	62.64	73.48	47.59
11	EE	49.59	49.59	42.46	63.83	50.95	31.75	55.41	73.93	60.46
12	NO	49.33	49.33	48.44	51.11	63.68	25.02	80.03	86.63	39.28
13	IE	48.61	48.61	47.79	50.23	51.39	36.07	67.63	67.09	44.61
14	CZ	47.27	47.27	46.22	49.39	52.15	30.85	71.01	71.05	42.16
15	SE	47.18	47.18	46.62	48.30	62.33	21.59	80.98	70.43	40.92
16	CY	47.14	47.14	36.42	68.59	27.56	34.73	48.66	69.29	68.36
17	PL	46.93	46.93	50.02	40.74	46.16	37.47	79.00	73.99	29.65
18	AT	46.81	46.81	37.82	64.79	27.30	22.88	78.23	74.22	61.65
19	HU	46.81	46.81	45.80	48.82	41.36	35.15	71.56	73.74	40.51

6.2 Scores

LITE **FULL**

Objective	To report scores in more detail, also at the index level. To compare ranks from initial weights against adjusted weights.
User input	None.

The **Scores** tab shows again the scores of each unit, but additionally adds the scores at the indicator level. Units are sorted by rank according to the adjusted weights (i.e. those input in the **Rebalancing** tab), but the rank using the initial weights is also reported, and the rank difference.

The difference in rank may be used as a metric to judge the impact of adjusting weights. Typically, some units are more sensitive than others to adjustments in weights.

Figure 11: Detailed score information in the Scores tab

Scores and Rankings										
Minmax [0, 100]										
Name	Name Unit/Indicator	Adjusted weights		Difference Rank	Connectivity Index	Connectivity si.01	P1 p.01	P2 p.02	Physical sp.01	
		Rank	Initial weights Rank							
LU	unit.018	1	1	0	68.92	68.92	67.97	70.81	62.55	
SG	unit.049	2	4	2	62.22	62.22	61.56	63.55	81.53	
BE	unit.002	3	3	0	59.31	59.31	61.58	54.79	81.48	
NL	unit.020	4	5	1	57.17	57.17	59.94	51.62	78.11	
CH	unit.029	5	2	-3	56.55	56.55	51.97	65.71	72.48	
MT	unit.019	6	8	2	55.66	55.66	50.86	65.26	50.60	
SI	unit.026	7	9	2	53.23	53.23	52.60	54.47	64.72	
SK	unit.025	8	12	4	52.87	52.87	57.43	43.77	52.92	
DK	unit.007	9	6	-3	52.13	52.13	46.98	62.43	56.42	
HR	unit.004	10	11	1	49.80	49.80	47.67	54.06	54.97	
EE	unit.008	11	10	-1	49.59	49.59	42.46	63.83	50.95	
NO	unit.021	12	7	-5	49.33	49.33	48.44	51.11	63.68	
IE	unit.014	13	18	5	48.61	48.61	47.79	50.23	51.39	
CZ	unit.006	14	17	3	47.27	47.27	46.22	49.39	52.15	
SE	unit.028	15	16	1	47.18	47.18	46.62	48.30	62.33	
CY	unit.005	16	22	6	47.14	47.14	36.42	68.59	27.56	
PL	unit.022	17	21	4	46.93	46.93	50.02	40.74	46.16	
AT	unit.001	18	15	-3	46.81	46.81	37.82	64.79	27.30	
HU	unit.013	19	20	1	46.81	46.81	45.80	48.82	41.36	
GB	unit.030	20	14	-6	46.72	46.72	45.43	49.30	63.60	
DE	unit.011	21	13	-8	46.39	46.39	48.86	41.45	65.36	
ES	unit.027	22	23	1	46.14	46.14	52.07	34.26	50.23	
FI	unit.009	23	19	-4	45.85	45.85	44.25	49.05	52.77	
FR	unit.010	24	24	0	43.71	43.71	44.30	42.52	50.55	

6.3 Rankings

LITE FULL

Objective	To report the ranks of units at indicator, sub-pillar, pillar, sub-index and index level.
User input	None.

The **Rankings** tab gives the ranks of each unit at every level, from indicator to index level. This tab simply gives additional information on how units compare to each another in all dimensions of the index.

Figure 12: Ranks of units at every level in the Rankings tab

Rankings Minmax													
Weights			1.000	0.667	0.333	0.250	0.500	0.250	0.250	0.750	0.125	0.125	0.125
Direction			1	1	1	1	1	1	1	1	1	1	1
Unit code	Unit/indicator	Connectivity	Connectivity	P1	P2	Physical	Econ/Fin	Political	Institutional	P2P	Logistics Performance Index	International flights passenger capacity	Liner Shipping Connectivity Index
AT	unit.001	19	19	31	5	40	31	10	5	5	50	50	43
BE	unit.002	3	3	2	9	2	8	7	21	9	6	5	3
BG	unit.003	32	32	35	30	37	34	23	25	31	43	43	40
HR	unit.004	10	10	14	11	14	14	25	13	11	34	34	27
CY	unit.005	16	16	33	2	39	20	35	29	2	36	36	30
CZ	unit.006	14	14	17	16	18	23	20	26	16	19	18	43
DK	unit.007	9	9	15	8	12	27	11	24	8	12	11	23
EE	unit.008	11	11	23	6	21	21	28	9	6	28	27	38
FI	unit.009	23	23	22	18	17	30	12	28	17	10	10	33
FR	unit.010	24	24	21	27	23	36	4	22	28	11	30	9
DE	unit.011	22	22	11	29	5	38	1	20	30	1	1	6
GR	unit.012	33	33	38	22	36	46	16	17	23	32	32	18
HU	unit.013	20	20	18	19	32	18	19	11	21	22	21	43
IE	unit.014	13	13	13	14	20	17	22	32	15	13	12	32
IT	unit.015	31	31	27	35	26	42	2	6	36	15	14	11
LV	unit.016	26	26	25	24	25	22	31	23	25	30	29	41
LT	unit.017	25	25	26	23	15	25	26	19	24	21	20	36
LU	unit.018	1	1	1	1	9	1	34	3	1	2	6	43
MT	unit.019	6	6	9	4	22	4	40	15	3	35	35	13
NL	unit.020	4	4	4	12	3	10	5	31	13	4	3	5
NO	unit.021	12	12	12	13	7	28	8	1	22	16	15	35
PL	unit.022	17	17	10	31	28	12	9	8	32	24	23	21
PT	unit.023	28	28	28	26	29	33	17	4	29	26	25	16
RO	unit.024	27	27	19	34	35	11	21	14	35	37	37	26
SK	unit.025	8	8	5	25	16	3	24	12	27	29	28	43
SI	unit.026	7	7	6	10	6	6	27	16	10	33	33	25
ES	unit.027	18	18	7	33	24	19	3	10	33	17	16	10
SE	unit.028	15	15	16	20	10	32	6	27	20	3	2	19
CH	unit.029	5	5	8	3	4	24	15	2	7	8	8	43
GB	unit.030	21	21	20	17	8	35	13	18	18	7	7	2

7.2 RankCorrel: Rank correlations

FULL

Objective	To illustrate the rank correlations (Spearman rank correlation) between indicators and each level of aggregation.
User input	None, although highlighting thresholds can be adjusted in the IndCorrel tab.

The **RankCorrel** tab has the same format and appearance as the **ScoreCorrel** tab, but it uses Spearman rank correlation rather than Pearson correlation coefficients.

The Pearson correlation coefficient is a measure of *linear* dependence between two variables. Therefore, it will effectively capture the relationship between two variables only when the relationship is linear, or close to linear. In practice, however, the relationship between indicators is often nonlinear, to some extent.

The Spearman rank correlation is a simple but effective measure of nonlinear dependence. It is simply defined as the Pearson correlation coefficient between the *ranks* of the two variables, rather than the scores. By using the ranks, the Spearman rank correlation measures how well the dependence between two variables can be captured using a monotonic function, which does not necessarily need to be linear.

Figure 14: Full rank correlation matrix in the ScoreCorrel tab

Rank Correlations										
High and negative correlation	-0.5									
High and positive correlation	0.3									
Highly collinear	0.92									
Indicator/agg. Name	Indicator/agg. Name	Connectivity	Connectivity	P1	P2	Physical	Econ/Fin	Political	Institutional	P2P
Indicator/agg. Name	Indicator/agg. Name	Index.r	si.01.r	p.01.r	p.02.r	sp.01.r	sp.02.r	sp.03.r	sp.04.r	sp.05.r
Connectivity	Index.r			0.94	0.89	0.79	0.62	0.49	0.69	0.85
Connectivity	si.01.r			0.94	0.89	0.79	0.62	0.49	0.69	0.85
P1	p.01.r	0.94	0.94		0.70	0.82	0.64	0.55	0.67	0.65
P2	p.02.r	0.89	0.89	0.70		0.64	0.45	0.34	0.64	0.98
Physical	sp.01.r	0.79	0.79	0.82	0.64		0.27	0.58	0.55	0.60
Econ/Fin	sp.02.r	0.62	0.62	0.64	0.45	0.27		-0.15	0.23	0.47
Political	sp.03.r	0.49	0.49	0.55	0.34	0.58	-0.15		0.64	0.25
Institutional	sp.04.r	0.69	0.69	0.67	0.64	0.55	0.23	0.64		0.54
P2P	sp.05.r	0.85	0.85	0.65	0.98	0.60	0.47	0.25	0.54	
Logistics Performance Index	ind.01.r	0.57	0.57	0.65	0.42	0.83	0.02	0.65	0.38	0.39
International flights passenger capac	ind.02.r	0.57	0.57	0.64	0.42	0.83	0.03	0.63	0.38	0.39
Liner Shipping Connectivity Index	ind.03.r	0.02	0.02	0.16	-0.14	0.32	-0.23	0.36	-0.04	-0.13
Border crossings	ind.04.r	0.64	0.64	0.64	0.53	0.50	0.54	0.28	0.48	0.50
Trade in electricity	ind.05.r	0.71	0.71	0.64	0.62	0.44	0.47	0.41	0.63	0.55
Trade in gas	ind.06.r	0.42	0.42	0.48	0.27	0.58	0.36	0.10	0.18	0.24
Average connection speed	ind.07.r	0.40	0.40	0.48	0.28	0.62	0.17	0.42	0.24	0.23
Population covered by at least a 4G n	ind.08.r	0.74	0.74	0.70	0.67	0.76	0.24	0.57	0.61	0.63
Trade in goods	ind.09.r	0.55	0.55	0.55	0.41	0.26	0.81	-0.07	0.27	0.42
Trade in services	ind.10.r	0.80	0.80	0.79	0.64	0.45	0.76	0.26	0.58	0.61
Foreign direct investment	ind.11.r	-0.06	-0.06	-0.05	-0.11	-0.27	0.44	-0.50	-0.27	-0.07
Personal remittances (received and p	ind.12.r	0.17	0.17	0.15	0.16	-0.10	0.60	-0.41	0.07	0.19
Foreign portfolio investment liabilitie	ind.13.r	0.74	0.74	0.67	0.76	0.71	0.31	0.47	0.47	0.74
Embassies network	ind.14.r	-0.07	-0.07	0.06	-0.20	0.20	-0.52	0.67	0.11	-0.25
Participation in international intergo	ind.15.r	0.44	0.44	0.50	0.30	0.53	-0.20	0.96	0.61	0.22
UN voting alignment	ind.16.r	0.72	0.72	0.70	0.62	0.61	0.30	0.65	0.78	0.54

In practice, you may find that the rank correlations are very similar to the Pearson correlations. This is due to the fact that although relationships between indicators are often nonlinear, they are rarely *strongly* nonlinear. On the other hand, there may exist particular cases with very skewed distributions where the rank correlation provides a more accurate measure of dependence, and therefore a better picture of "importance" in the context of composite indicators.

The **RankCorrel** tab can be used as complimentary information to the **ScoreCorrel** tab: if strong negative, or collinear correlations exist in the **ScoreCorrel** tab, check that they are also present in the **RankCorrel** tab. If there are big differences, it may be worth investigating further outside of the COIN Tool, by plotting histograms, scatterplots, and considering other measures of nonlinear dependence⁴.

7.3 IndWeights: Effective weighting

FULL

Objective	To show the final weight that each indicator and aggregation level has in the overall index.
User input	None.

Composite indicators have a hierarchical structure with weights at different levels. Each indicator has an indicator weight, which is used to aggregate the indicators into a sub-pillar. The sub-pillars also have their own weights which are used to aggregate them into pillars, and so on. The implication is that the weight of each indicator in the final index is a combination of its indicator weight, its sub-pillar weight, its pillar weight, and its sub-index weight.

The **IndWeights** tab explicitly calculates these “effective” weights of each indicator in the final index, as well as each aggregation (sub-pillars, pillars, etc). This can help to give an idea of the overall influence of each indicator on the final index, complementary to the correlation information in the **Rebalancing**, **ScoreCorrel** and **RankCorrel** tabs.

Figure 15: Effective indicator weights in the IndWeights tab

Final index weights							
Indicator	Indicator weight in index	Sub-pillar	Sub-pillar weight in index	Pillar	Pillar weight in index	Sub-index	Sub-index weight in index
ind.01	0.021	sp.01	0.167	p.01	0.667	si.01	1.000
ind.02	0.021						
ind.03	0.021						
ind.04	0.021						
ind.05	0.021						
ind.06	0.021						
ind.07	0.021						
ind.08	0.021						
ind.09	0.067	sp.02	0.333				
ind.10	0.067						
ind.11	0.067						
ind.12	0.067						
ind.13	0.067						
ind.14	0.056	sp.03	0.167				
ind.15	0.056						
ind.16	0.056						
ind.17	0.014	sp.04	0.083	p.02	0.333		
ind.18	0.014						
ind.19	0.014						

⁴ Becker, W., Saisana, M., Paruolo, P., & Vandecasteele, I. (2017). Weights and importance in composite indicators: Closing the gap. *Ecological indicators*, 80, 12-22.

8 Alternative aggregations

The previous tabs have focused on obtaining index scores by aggregating indicators using arithmetic or geometric means of indicators and aggregations. In this section, some alternatives are presented which are automatically calculated by the COIN Tool. They can either be used as an alternative final index, or as a comparison to help gauge robustness to methodological choices - see the [Scenaria](#) tab for a summary of different rankings.

8.1 Borda

FULL

Objective	To show the unit ranks obtained by the alternative Borda method
User input	None.

The Borda method is a simple alternative way of aggregating indicators, based on ranks rather than scores, which does not take the structure of the index into account: indicators are directly aggregated to an index without any intermediate aggregation.

For an index with N units, each indicator is examined separately. The top-ranked unit in that indicator gets $N-1$ points; the second ranked unit gets $N-2$ points and so on; the last ranked unit gets 0 points.

This results in a column of scores for each indicator - see Figure 16. For each unit, the scores are aggregated into a single score by taking the weighted average of the Borda points, where the weights are taken as either the indicator weights from the [Rebalancing](#) tab (normalised to sum to 1 - see "Adjusted weights" row in Figure 16), or as equal weights.

Figure 16: Borda scores and ranks in the Borda tab

Borda Scores and Ranks															
Equal weights		Adjusted weights		Name	Unit/Indicator	0.125 ind.01	0.125 ind.02	0.125 ind.03	0.125 ind.04	0.125 ind.05	0.125 ind.06	0.125 ind.07	0.125 ind.08	0.200 ind.09	0.200 ind.10
Ranks	Points	Ranks	Points												
16	31.2	13	26.5	AT	unit.001	0	0	8	41	38	7	20	37	34	31
1	37.6	1	31.5	BE	unit.002	45	46	48	48	31	46	29	43	45	39
29	26.6	28	22.9	BG	unit.003	8	8	11	33	36	17	26	10	36	25
22	30.0	24	24.7	HR	unit.004	17	17	24	44	46	25	6	37	27	50
27	27.9	30	22.5	CY	unit.005	15	15	21	5	21	12	2	11	19	40
13	31.9	14	26.3	CZ	unit.006	32	33	8	42	42	29	32	38	49	22
6	35.3	5	29.2	DK	unit.007	39	40	28	22	41	18	35	46	23	36
7	33.6	10	27.2	EE	unit.008	23	24	13	32	47	16	13	50	43	37
19	30.4	21	25.6	FI	unit.009	41	41	18	18	34	10	38	44	18	24
25	29.4	23	25.3	FR	unit.010	40	21	42	30	29	36	10	18	11	18
12	31.9	8	27.2	DE	unit.011	50	50	45	37	28	38	24	30	27	15
31	25.2	31	21.5	GR	unit.012	19	19	33	27	18	5	5	19	10	20
18	30.9	15	26.2	HU	unit.013	29	30	8	38	35	13	23	32	47	35
17	31.1	22	25.4	IE	unit.014	38	39	19	34	22	37	27	24	21	42
28	27.3	25	24.3	IT	unit.015	36	37	40	25	26	20	8	27	12	9
26	28.6	27	23.4	LV	unit.016	21	22	10	36	40	28	30	24	40	29
24	29.7	26	24.2	LT	unit.017	30	31	15	39	37	35	21	25	38	32
3	36.7	3	29.5	LU	unit.018	49	45	8	50	44	31	13	31	25	44
10	32.8	19	25.8	MT	unit.019	16	16	38	5	45	33	16	50	43	43
2	36.8	2	30.7	NL	unit.020	47	48	46	45	32	42	34	42	39	38
8	33.5	6	28.2	NO	unit.021	35	36	16	21	33	48	41	42	14	23
20	30.3	17	26.1	PL	unit.022	27	28	30	35	25	24	15	50	35	50
21	30.0	20	25.7	PT	unit.023	25	26	35	31	30	19	17	29	24	21
30	26.1	29	22.7	RO	unit.024	14	14	25	28	23	11	33	15	30	50
15	31.4	12	27.0	SK	unit.025	22	23	8	43	43	43	18	16	50	50
13	31.9	18	26.1	SI	unit.026	18	18	26	46	49	27	19	33	44	50
22	30.0	16	26.1	ES	unit.027	34	35	41	17	20	21	26	26	13	50

Units can then be ranked according to their overall scores. This provides two alternative rankings: one using equal weights, and one using the indicator weights. Both are displayed in the **Borda** tab.

Note that missing data distort results, because for indicators with low unit-coverage, Borda points will be lower, since N is taken as the total number of units with no missing data.

8.2 Outranking Matrix

FULL

Objective	To show the outranking matrix, which is a summary of how each unit compares to every other, by comparing pillar scores. This matrix is used to compute Copeland scores (see Copeland tab)
User input	None.

The Outranking matrix is a pairwise comparison of units, which is used to compute rankings based on the Copeland method - see the **Copeland** tab. However, the outranking matrix is also interesting in its own right.

Figure 17 shows the **OutrankingMatrix** tab. Each cell in the matrix corresponds to a pair of units, say unit A and unit B. The score in the cell is calculated by comparing the pillar scores of A and B.

Take for example a cell which is in the row of unit A, and the column of unit B. The score is calculated as the sum of the weights of the pillars where A has a higher value than B. Taking now the cell in the row of unit B and the column of unit A (which is the cell opposite on the other side of the diagonal), the score is calculated as the sum of the weights of the pillars where B has a higher value than A.

These two scores sum to 1 by definition, since the pillar weights sum to 1. The outranking matrix effectively summarises to what extent A scores better than B in all pillars, for all unit pairs.

In some cases, one unit may score higher than the other in all pillars. This is called a dominance pair, and corresponds to any pair scores equal to one (equivalent to any pair scores equal to zero).

The percentage of dominance pairs (reported in the top left of the **OutrankingMatrix** tab - see Figure 17), is an indication of robustness. Under dominance, there is no way methodological choices (weighting, normalisation, etc.) can affect their relative standing in the ranking. Unit A will always be ranked higher than unit B. The greater the number of dominance (or robust) pairs in a classification, the less sensitive country ranks will be to methodological assumptions.

It is worth pointing out, however, that this robustness only applies at the pillar-level. The outranking matrix is still affected by the methodological choices at indicator and sub-pillar level.

Figure 17: Pairwise comparison of units in the OutrankingMatrix tab

Outranking Matrix (pillar level)												
Dominance %:		76.6%										
Dominance pairs:		977										
Total pairs:		1275										
Weights		2		1								
Relative weights		0.67		0.33								
		p.01		37.82	61.58	35.67	47.67	36.42	46.22	46.98	42.46	44.25
		p.02		64.79	54.79	40.85	54.06	68.59	49.39	62.43	63.83	49.05
		Name		AT	BE	BG	HR	CY	CZ	DK	EE	FI
		Unit		unit.001	unit.002	unit.003	unit.004	unit.005	unit.006	unit.007	unit.008	unit.009
p.01	p.02	Name	Unit	unit.001	unit.002	unit.003	unit.004	unit.005	unit.006	unit.007	unit.008	unit.009
37.8	64.8	AT	unit.001	-	0.33	1.00	0.33	0.67	0.33	0.33	0.33	0.33
61.6	54.8	BE	unit.002	0.67	-	1.00	1.00	0.67	1.00	0.67	0.67	1.00
35.7	40.9	BG	unit.003	-	-	-	-	-	-	-	-	-
47.7	54.1	HR	unit.004	0.67	-	1.00	-	0.67	1.00	0.67	0.67	1.00
36.4	68.6	CY	unit.005	0.33	0.33	1.00	0.33	-	0.33	0.33	0.33	0.33
46.2	49.4	CZ	unit.006	0.67	-	1.00	-	0.67	-	-	0.67	1.00
47.0	62.4	DK	unit.007	0.67	0.33	1.00	0.33	0.67	1.00	-	0.67	1.00
42.5	63.8	EE	unit.008	0.67	0.33	1.00	0.33	0.67	0.33	0.33	-	0.33
44.3	49.1	FI	unit.009	0.67	-	1.00	-	0.67	-	-	0.67	-
44.3	42.5	FR	unit.010	0.67	-	1.00	-	0.67	-	-	0.67	0.67
48.9	41.5	DE	unit.011	0.67	-	1.00	0.67	0.67	0.67	0.67	0.67	0.67
31.6	46.0	GR	unit.012	-	-	0.33	-	-	-	-	-	-
45.8	48.8	HU	unit.013	0.67	-	1.00	-	0.67	-	-	0.67	0.67
47.8	50.2	IE	unit.014	0.67	-	1.00	0.67	0.67	1.00	0.67	0.67	1.00
40.8	33.7	IT	unit.015	0.67	-	0.67	-	0.67	-	-	-	-
41.1	44.6	LV	unit.016	0.67	-	1.00	-	0.67	-	-	-	-
41.0	45.2	LT	unit.017	0.67	-	1.00	-	0.67	-	-	-	-
68.0	70.8	LU	unit.018	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
50.9	65.3	MT	unit.019	1.00	0.33	1.00	1.00	0.67	1.00	1.00	1.00	1.00
59.9	51.6	NL	unit.020	0.67	-	1.00	0.67	0.67	1.00	0.67	0.67	1.00
48.4	51.1	NO	unit.021	0.67	-	1.00	0.67	0.67	1.00	0.67	0.67	1.00
50.0	40.7	PL	unit.022	0.67	-	0.67	0.67	0.67	0.67	0.67	0.67	0.67
40.6	42.9	PT	unit.023	0.67	-	1.00	-	0.67	-	-	-	-

8.3 Copeland

FULL

Objective	To provide a ranking of units based on the Copeland rule. The Copeland rule uses the scores in the outranking matrix.
User input	None.

The **Copeland** tab uses the outranking matrix in the previous tab to compute an overall ranking of units. This proceeds by generating a new matrix as follows (see Figure 18):

- Values greater than 0.5 are replaced with +1
- Values lower than 0.5 are replaced with -1
- Values of exactly 0.5 are replaced with 0.

The diagonal elements are set at 0 by definition. The Copeland score for each unit is simply the sum of the values in a given row, and effectively measures how often each unit, on average, performs better than other units. A final ranking is then calculated based on these scores.

Figure 18: Ranking of units in the Copeland tab

Outranking Matrix (pillar level)													
Dominance %:		76.6%											
Dominance pairs:		977											
Total pairs:		1275											
Weights		2 1											
Relative weights		0.67 0.33											
		p.01		37.82 61.58 35.67 47.67 36.42 46.22 46.98 42.46 44.25									
		p.02		64.79 54.79 40.85 54.06 68.59 49.39 62.43 63.83 49.05									
		Name		AT BE BG HR CY CZ DK EE FI									
		Unit		unit.001 unit.002 unit.003 unit.004 unit.005 unit.006 unit.007 unit.008 unit.009									
37.8	64.8	AT	unit.001	-	0.33	1.00	0.33	0.67	0.33	0.33	0.33	0.33	0.33
61.6	54.8	BE	unit.002	0.67	-	1.00	1.00	0.67	1.00	0.67	0.67	0.67	1.00
35.7	40.9	BG	unit.003	-	-	-	-	-	-	-	-	-	-
47.7	54.1	HR	unit.004	0.67	-	1.00	-	0.67	1.00	0.67	0.67	0.67	1.00
36.4	68.6	CY	unit.005	0.33	0.33	1.00	0.33	-	0.33	0.33	0.33	0.33	0.33
46.2	49.4	CZ	unit.006	0.67	-	1.00	-	0.67	-	-	-	0.67	1.00
47.0	62.4	DK	unit.007	0.67	0.33	1.00	0.33	0.67	1.00	-	-	0.67	1.00
42.5	63.8	EE	unit.008	0.67	0.33	1.00	0.33	0.67	0.33	0.33	-	-	0.33
44.3	49.1	FI	unit.009	0.67	-	1.00	-	0.67	-	-	-	0.67	-
44.3	42.5	FR	unit.010	0.67	-	1.00	-	0.67	-	-	-	0.67	0.67
48.9	41.5	DE	unit.011	0.67	-	1.00	0.67	0.67	0.67	0.67	0.67	0.67	0.67
31.6	46.0	GR	unit.012	-	-	0.33	-	-	-	-	-	-	-
45.8	48.8	HU	unit.013	0.67	-	1.00	-	0.67	-	-	-	0.67	0.67
47.8	50.2	IE	unit.014	0.67	-	1.00	0.67	0.67	1.00	0.67	0.67	0.67	1.00
40.8	33.7	IT	unit.015	0.67	-	0.67	-	0.67	-	-	-	-	-
41.1	44.6	LV	unit.016	0.67	-	1.00	-	0.67	-	-	-	-	-
41.0	45.2	LT	unit.017	0.67	-	1.00	-	0.67	-	-	-	-	-
68.0	70.8	LU	unit.018	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
50.9	65.3	MT	unit.019	1.00	0.33	1.00	1.00	0.67	1.00	1.00	1.00	1.00	1.00
59.9	51.6	NL	unit.020	0.67	-	1.00	0.67	0.67	1.00	0.67	0.67	0.67	1.00
48.4	51.1	NO	unit.021	0.67	-	1.00	0.67	0.67	1.00	0.67	0.67	0.67	1.00
50.0	40.7	PL	unit.022	0.67	-	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
40.6	42.9	PT	unit.023	0.67	-	1.00	-	0.67	-	-	-	-	-

8.4 Scenaria

FULL

Objective	To summarise the ranks obtained by different aggregation methods, and variations to methodology (e.g. normalisation method, weights, etc.) Ranks are summarised as median values and with intervals.
User input	None.

Composite indicators, like any model, involve subjective decisions in their construction. These decisions include:

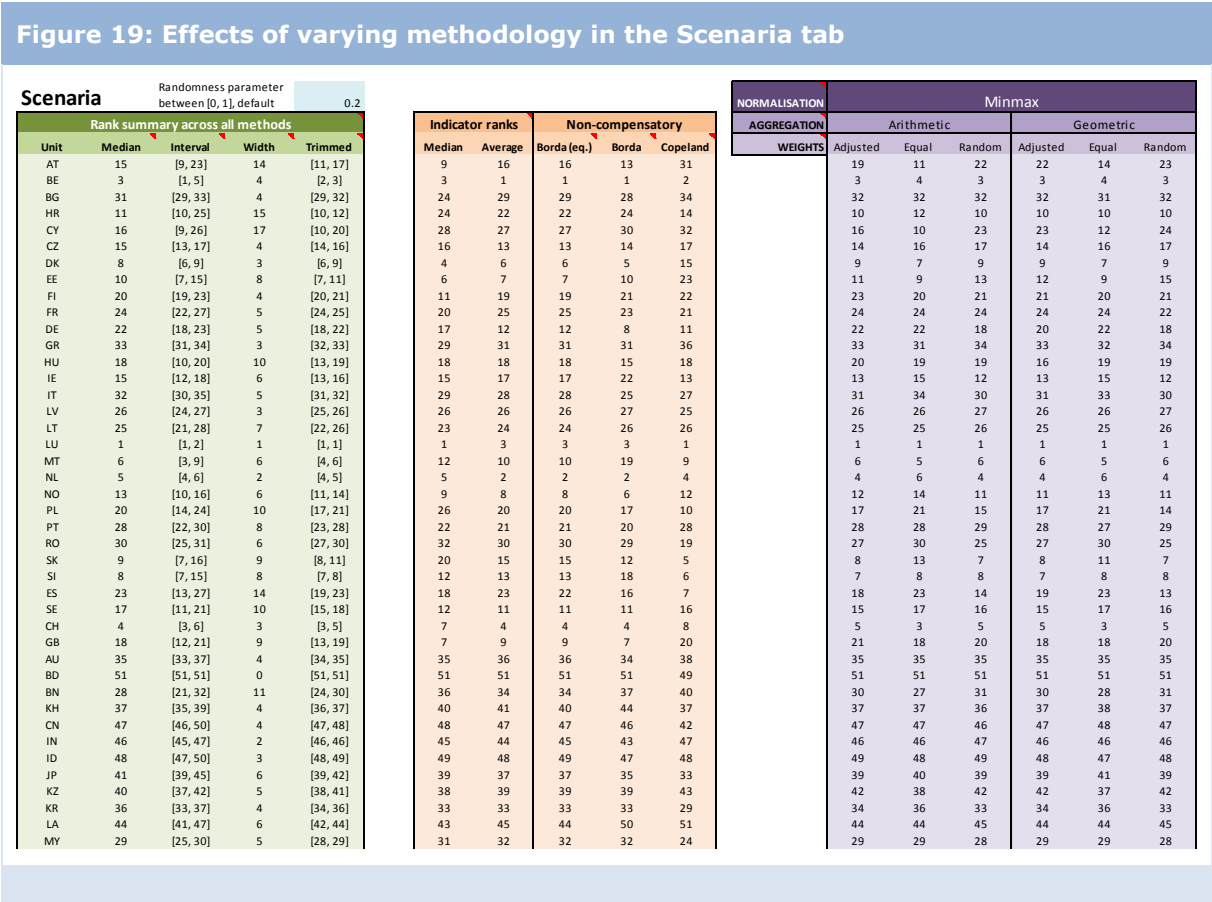
- The conceptual framework
- The selection of indicators
- How missing data are imputed, or not
- The normalisation method
- The aggregation method
- Weights assigned to indicators and aggregation levels

All of these steps introduce a degree of uncertainty into the results of the index. The Scenaria tab aims to acknowledge this uncertainty (to the extent possible) and to investigate how the ranks change with different methodological assumptions, by summarising the ranks from all different methodologies used in the COIN Tool.

Figure 19 shows the **Scenaria** tab. All columns refer to overall index ranks. The purple table on the right side shows the ranks obtained by building the index in the "standard" way, by aggregating using the hierarchical structure defined in the **Framework** tab. However, each column in this table represents a variation of this methodology, using different combinations of:

- The normalisation method (min-max, datamax, goalposts, dataZ, dataranks)
- The aggregation method (arithmetic or geometric mean)
- The weights (adjusted, equal or random)

For the weights, the adjusted weights are those that were defined in the **Rebalancing** tab. Random weights are a single set of random weights which are drawn uniformly within the interval $[(1 - p)w, (1 + p)w]$, where w is a weight at either the pillar or sub-index level, and p is a parameter. If $p=0.2$, and $w=0.5$, for instance, weights will be randomly varied between 0.4 and 0.6 (by +/-20% of their nominal values).



Since the weights are randomly generated, every time the workbook is recalculated (press F9), the weights will change and the rankings under random weights will change.

The orange table gives further alternative rankings obtained from different approaches:

- The Borda ranks, with equal and adjusted weights (see **Borda** tab)
- The Copeland ranks (see **Copeland** tab)
- Mean and median indicator ranks (see **DataRanks** tab)

Finally, the green table on the left side summarises all the alternative ranks as follows:

- The median across all ranks

- An interval (similar to a confidence interval), showing the minimum and maximum ranks obtained for each unit
- The width of the interval
- A trimmed version of the interval specified above, consisting of the range of the middle five rank values

Clearly, the rank summaries should be taken with a degree of caution, in that this does not represent a formal sample across the distribution of alternative methodologies (for example, far more weight is given to ranks generated via the “standard” methodology in the purple table).

The robustness of results to modelling choices can be better assessed by computing rankings with a Monte Carlo simulation (uncertainty analysis), randomly varying all assumptions possible. This is better done in statistical software such as R, Matlab or Python. The **Scenaria** tab is a simple out-of-the-box investigation which gives a handle on the degree of uncertainty in the index ranks.

9 Methodological variations and further tabs

The **Scenaria** tab summarises the alternative rankings obtained from variations in methodology. The calculation of these ranks is done in the tabs towards the end of the COIN Tool. These tabs may be of interest if you wish to dig deeper into a particular scenario, and are described briefly here. Additionally, the imputation group of tabs shows how data are implicitly imputed by the COIN Tool.

9.1 Imputation

FULL

This group of tabs comprises the **MinmaxImp**, **DatamaxImp**, **GoalpostsImp**, **DatatzImp** and **DataprcranksImp** tabs.

Most composite indicators will face the issue of missing data. In these cases you can approach the problem in one of several ways:

- Exclude any units with missing data
- Exclude any indicators with missing data
- If a time series is available, use the latest available data point
- Formally impute (estimate) missing data points using statistical approaches
- Exclude the missing data point from aggregations, but retain all indicators and units

In most cases the first two options are too drastic, unless a unit or indicator has a very low data coverage (below 65% or so might be a threshold below which you could consider excluding). The option of using previous values in a time series is attractive, but in many cases a time series will not be available, or data is missing for all years for a particular unit.

There are a range of statistical approaches to imputation. Many are easily available in packages in open source software such as R and Python. However, within Excel the options are more limited. The COIN Tool opts for the last approach.

Let $x_{1,c}, x_{2,c}, x_{3,c}$ be three indicators comprising a sub-pillar s , for unit c . Assume that sub-pillar scores are calculated using the arithmetic mean and with equal weighting, for simplicity. Consider two examples:

1. Data is available for all three indicators. Then, the sub-pillar score is calculated as $s_c = \frac{1}{3}(x_{1,c} + x_{2,c} + x_{3,c})$
2. Data is available for $x_{1,c}$ and $x_{3,c}$ but not for $x_{2,c}$. In this case the COIN Tool calculates the sub-pillar score by taking the mean only over the indicators that have data, i.e. $s_c = \frac{1}{2}(x_{1,c} + x_{3,c})$.

This approach may seem at first glance to avoid the issue of imputation. However, implicitly in the second example, $x_{2,c}$ is being imputed with the sub-pillar score, i.e. the average of the other indicators. To show that this is the case we insert the pillar score in place of $x_{2,c}$ as follows, and take the average over the three values:

$$\begin{aligned} s_c &= \frac{1}{3} \left[x_{1,c} + x_{3,c} + \frac{1}{2}(x_{1,c} + x_{3,c}) \right] \\ &= \frac{1}{3} \left[\frac{3}{2}x_{1,c} + \frac{3}{2}x_{3,c} \right] \\ &= \frac{1}{2} [x_{1,c} + x_{3,c}] \end{aligned}$$

which is the same as the equation in example 2.

This “non-imputation” of missing data is therefore in fact equivalent to assigning the sub-pillar score value to the particular indicator (or the pillar score if the sub-pillar score is not available either). The imputation tabs serve two purposes: first, to calculate these implicitly-imputed values to calculate overall index scores; and second to clearly illustrate the values of the imputed data points.

Imputed data points are highlighted in green. You may wish to check that these values are realistic. In some cases, particularly with poorly-correlated indicators, values imputed in this way may be quite unrealistic. In these cases you should find an imputation approach outside of the COIN Tool.

Figure 20: Implicit imputation in the imputation tabs

Imputation: MinMax		p.01	p.01	p.01	p.01	p.01	p.01	p.01	p.01	p.01
		sp.01	sp.01	sp.01	sp.01	sp.01	sp.01	sp.01	sp.01	sp.01
		ind.01	ind.02	ind.03	ind.04	ind.05	ind.06	ind.07	ind.08	ind.09
AT	unit.001	-	-	-	42.30	39.17	1.73	37.23	98.00	40.56
BE	unit.002	94.56	94.56	97.14	100.00	18.96	100.00	46.75	99.89	80.42
BG	unit.003	34.30	34.30	37.40	16.46	33.85	5.90	43.29	56.73	46.85
HR	unit.004	50.66	50.66	58.76	73.43	83.29	11.57	13.42	98.00	29.37
CY	unit.005	43.16	43.16	55.21	-	9.19	3.72	6.06	60.00	21.68
CZ	unit.006	74.45	74.45	-	44.98	54.78	20.49	49.35	98.70	88.81
DK	unit.007	81.00	81.00	68.05	7.06	45.16	5.91	63.20	99.99	24.48
EE	unit.008	60.05	60.05	43.32	13.45	100.00	4.36	26.41	100.00	75.52
FI	unit.009	85.86	85.86	47.44	5.40	29.98	2.81	64.94	99.90	20.98
FR	unit.010	84.94	57.11	92.27	11.81	15.88	39.41	22.94	80.00	14.69
DE	unit.011	100.00	100.00	96.83	29.81	14.96	43.17	42.42	95.70	29.37
GR	unit.012	54.30	54.30	74.06	9.22	4.44	1.41	10.39	83.00	11.19
HU	unit.013	63.08	63.08	-	30.51	32.55	4.10	40.26	97.30	87.41
IE	unit.014	80.03	80.03	49.95	17.31	9.68	40.41	43.72	90.00	23.08
IT	unit.015	78.20	78.20	86.83	8.07	12.37	6.69	16.02	93.00	15.38
LV	unit.016	58.36	58.36	37.08	26.68	44.82	19.26	48.05	90.00	62.94
LT	unit.017	72.47	72.47	43.62	34.15	38.04	32.40	39.39	91.00	59.44
LU	unit.018	99.70	94.16	-	100.00	57.88	26.26	26.41	96.00	27.97
MT	unit.019	46.42	46.42	80.58	-	69.36	30.45	31.60	100.00	75.52
NL	unit.020	98.22	98.22	97.02	78.08	23.31	79.52	51.52	99.00	60.14
NO	unit.021	77.13	77.13	43.87	5.95	28.43	100.00	77.92	99.00	17.48
PL	unit.022	62.94	62.94	69.98	20.10	11.91	10.68	30.74	100.00	44.76
PT	unit.023	62.17	62.17	76.51	12.11	18.61	6.66	32.03	94.30	25.87
RO	unit.024	42.89	42.89	59.94	10.20	10.97	3.02	49.78	72.00	34.27
SK	unit.025	58.81	58.81	-	51.68	56.10	90.45	32.47	75.00	100.00
SI	unit.026	51.76	51.76	63.20	100.00	100.00	17.85	35.50	97.70	76.92
ES	unit.027	76.90	76.90	91.29	5.21	9.06	7.85	43.29	91.30	16.08
SE	unit.028	99.01	99.01	73.58	4.05	39.35	10.04	73.59	99.99	22.38
CH	unit.029	88.94	91.39	-	100.00	100.00	31.35	70.13	98.00	32.87
GB	unit.030	92.76	92.76	98.25	5.41	6.15	66.31	49.35	97.80	11.19
AU	unit.031	79.96	79.96	66.14	-	-	2.51	24.24	94.00	6.29
BD	unit.032	27.64	27.64	45.81	10.92	1.43	0.76	25.60	65.00	8.39
BN	unit.033	37.21	37.21	35.39	35.17	-	100.00	46.42	80.00	34.97
KH	unit.034	33.97	33.97	42.59	7.28	11.01	4.23	23.29	30.00	63.64
CN	unit.035	73.83	73.83	100.00	0.34	0.10	0.72	9.09	85.00	1.40
IN	unit.036	62.67	62.67	78.04	1.08	0.07	-	4.33	4.00	-
ID	unit.037	42.49	42.49	57.67	0.11	0.00	26.63	7.36	5.00	7.69
JP	unit.038	88.16	88.16	81.53	-	0.00	22.96	63.64	99.00	1.40
KZ	unit.039	31.72	31.72	-	1.71	2.40	64.60	28.24	65.50	19.58
KR	unit.040	76.43	76.43	96.48	1.02	0.00	13.81	100.00	99.00	18.88
LA	unit.041	-	-	-	8.56	2.71	2.71	2.71	5.00	30.77
MY	unit.042	62.96	62.96	97.07	2.77	0.04	100.00	14.72	71.00	56.64

Notes: imputed values are highlighted in green

9.2 Methodological variations

FULL

The group of tabs comprising **Minmax**, **Datamax**, **Goalposts**, **Dataz** and **Datapranks** are where alternative scores are calculated using the methodological variations described in the **Scenaria** tab. Each of these five tabs represents one of the normalisation approaches. Within each tab, scores are calculated using combinations of:

- Either geometric or arithmetic mean
- Adjusted, equal or random weights

The **Scenaria** tab in this manual gives more details on the implementation of these choices.

These tabs may be used to check the scores obtained with particular variations of methodology.

An additional tab, which is slightly different, is the **Dataranks** tab. It computes the ranks of individual indicators from the original dataset, and uses these to give alternative overall rankings for units. It may help in the interpretation of results when trying to understand why one unit is doing better than another within a given dimension. Specifically, for each unit it computes:

1. The average rank - simply the mean of the ranks of each indicator, taking into account the direction of the indicators.
2. The median rank - as above except taking the median.
3. The rank based on the average rank computed in (1), i.e. units are ranked according to their average ranks.
4. The rank based on the median rank computed in (1), i.e. units are ranked according to their median ranks.

The ranks from this tab also feed into the **Scenaria** tab.

Note that as with the Borda method, missing data distort results because for indicators with low unit-coverage, ranks will be lower (thus better).

9.3 Leaving out indicators

FULL

A final group of tabs, comprising the **LeaveOutScores** and **LeaveOutRanks** tabs, recalculates index scores that result from leaving out indicators and aggregations (sub-pillars, pillar, sub-indexes) one at a time.

The objective here is to see how sensitive the scores and the ranks are to the inclusion/exclusion of each indicator and aggregation. This may help for example, in cases where an indicator is problematic (low data or negative correlations). If the change in score and rank from removing this indicator is minimal, it can be safely removed without affecting the index.

In the **LeaveOutScores** tab, each column represents the index scores resulting from leaving out each component. For example, the sp.02 column is the index scores calculated after leaving out sp.02.

The **LeaveOutRanks** tab is exactly analogous, but displays the change in rank resulting from leaving out each component. Shifts of three rank places or more are highlighted - see Figure 21.

Figure 21: Rank changes from leaving out components in the LeaveOutRanks tab

Leave-out ranks			1.000	0.667	0.333	0.167	0.333	0.167	0.083	
Index weights			Connectivity	Connectivity	P1	P2	Physical	Econ/Fin	Political	Institutional
Indicator										
Unit name	Unit/Indicator	Index	si.01	p.01	p.02	sp.01	sp.02	sp.03	sp.04	
LU	unit.018	1	0	0	0	0	-4	0	0	0
SG	unit.049	2	0	-5	-1	0	-6	0	0	0
BE	unit.002	3	0	-6	1	-1	1	-1	0	0
NL	unit.020	4	0	-8	0	-2	1	-3	0	0
CH	unit.029	5	0	2	-3	0	4	0	0	0
MT	unit.019	6	0	2	-3	3	-10	3	0	0
SI	unit.026	7	0	-3	1	-3	-6	1	0	0
SK	unit.025	8	0	-16	3	1	-18	0	0	0
DK	unit.007	9	0	1	-6	1	5	-2	0	0
HR	unit.004	10	0	-1	-4	-3	-5	0	0	0
EE	unit.008	11	0	5	-12	-1	-1	2	0	0
NO	unit.021	12	0	-1	0	-5	6	-2	-1	0
IE	unit.014	13	0	-1	0	-1	-6	0	1	0
CZ	unit.006	14	0	-1	-3	-4	-4	-1	-1	0
SE	unit.028	15	0	-4	-1	-6	6	-6	-1	0
CY	unit.005	16	0	14	-16	7	-4	4	2	0
PL	unit.022	17	0	-14	7	1	-6	-2	0	0
AT	unit.001	18	0	13	-13	7	7	0	-2	0
HU	unit.013	19	0	1	1	4	-2	3	1	0
GB	unit.030	20	0	4	0	-2	10	3	1	0
DE	unit.011	21	0	-8	10	-3	14	-5	0	0
ES	unit.027	22	0	-12	15	3	0	-3	0	0
FI	unit.009	23	0	6	1	3	9	-1	0	0
FR	unit.010	24	0	-2	3	-1	7	-5	0	0

Notes: shifts of three rank places or more are highlighted in red

Glossary

Aggregation	A value that is obtained by taking an aggregate measure (e.g. the average or geometric mean) of a number of indicators or other aggregate measures.
Composite indicator	An aggregation of indicators that aims to measure a concept which is not directly measurable. For example, a composite indicator may involve a weighted average of a set of normalised indicator values, following an agreed framework of the concept.
Imputation	Estimation of missing data points. Imputation can involve simple methods (taking the most recent known value, or averaging over remaining indicators), or more complex approaches such as k-means clustering or expectation maximisation.
Index	The highest level of aggregation in a composite indicator framework - there should be only one index value per unit. The index is an aggregation of the underlying sub-indices (if they exist), or otherwise the underlying pillars.
Indicator	A measurable variable (e.g. life expectancy, literacy rate) which gives an <i>indication</i> of something that is not directly measurable (e.g. quality of life).
Normalisation	A mathematical operation which brings indicators onto a common scale. For example, the min-max approach brings all indicators onto a scale ranging from zero to 100. The unit with the lowest value is assigned a value of 0, and the unit with the highest value is assigned 100, and other units are proportionally scaled within that range.
Outlier	A data point that differs significantly from other observations. An outlier may be due to an error, but it may be also simply due to a skewed indicator distribution. To deal with outliers, one must first detect their presence, and then decide whether they should be treated or not.
Pillar	The third-highest level of aggregation in a composite indicator framework. Pillars are aggregated to a sub-index (if there is one), or to the final index if there is no sub-index. Pillars are aggregations of sub-pillars (if they exist) or direct aggregations of underlying indicators.
Scoreboard	A group of indicators that aims to measure or represent a concept which is not directly measurable. A scoreboard can be viewed as a composite indicator without any aggregations, and without normalisation. Composite indicators and scoreboards can be used in conjunction with one another.
Sensitivity analysis	Quantifying the relative impact of uncertainties on the results of the composite indicator. A full sensitivity analysis would show which uncertainties (e.g. weight values, imputation method) cause the most uncertainty in the final scores, and which cause the least.

Sub-index	The second-highest level of aggregation in a composite indicator. Sub-indices are aggregated to the final index value. A sub-index is usually an aggregation of underlying pillar scores.
Sub-pillar	The lowest level of aggregation. Sub-pillar scores are calculated by aggregating normalised indicator values. Sub-pillar scores are aggregated to give pillar scores.
Uncertainty analysis	Quantifying the uncertainty in the composite indicator scores and ranks, as a result of uncertainty in the methodology, data, and so on. Uncertainty may be quantified with confidence intervals on index ranks, for example.
Unit	One of the entities for which the composite indicator measures the concept. Typically a country or a region.
Weight	A coefficient which is attached to each indicator and controls the relative importance of the indicator in aggregations.
Winsorisation	A method to treat outliers, which involves replacing outliers with the closest non-outlying value.
Correlation	A statistical measure of the linear relationship between two variables (indicators). Correlation values can be anywhere between -1 and 1. A value close to 1 means that the two indicators are very strongly related, such that higher values of one imply higher values of the other (a value close to -1 means the reverse). A value close to zero means that the two indicators have very little (linear) relationship.
Skewness	A measure of asymmetry in the distribution of values of an indicator. A high positive skew means that the majority of indicator values are at the lower end of the scale, with some few outlying values at the high end of the scale. A high negative skew means the opposite. Skewness causes issues in composite indicators because it means that a large part of the normalised scale of the indicator may be empty, so the contribution of the indicator is dictated by small number of outliers.
Kurtosis	A measure of how long the "tails" of the indicator distribution are - a high kurtosis value implies that there are outliers in the distribution.
Scores	Indicator scores are the values of the indicators after normalisation. Aggregate scores refer to the values of the aggregation. For example, a sub-pillar score is the value resulting from taking the mean of the underlying indicator scores.
Denomination	Dividing one indicator by another to remove the "size" effect, in order to "fairly" compare units. For example, the number of patents of a country is clearly related to the size of the country. If it is divided by the population or GDP, this gives a fairer comparison measure which may be used as an indicator for innovation - respectively, patents per capita, or patents scaled by the size of the economy.

Troubleshooting and FAQs

Troubleshooting

I'm working on a laptop and the area where I can see my data is very small.

The COIN Tool is easier to use on a larger screen. It makes use of freezing some rows and columns to show the data in context. However, on a laptop this may leave only a small corner of the window available for inspecting the data.

To help this, either:

- Hide rows and columns by selecting a (range of) column(s)/row(s), right clicking and selecting "Hide". You can un-hide by selecting the range of rows/columns in which the hidden rows/columns are, right-clicking and selecting "Unhide".
- Shrink rows/columns by simply dragging them and making them smaller.

The COIN Tool is running very slow.

The COIN Tool is built in Excel in order to be accessible to the widest range of users, and also aims to provide maximum flexibility in accommodating many different possible composite indicator structures and methodological approaches. This combination results in a large Excel file, which can be slow to work with due to its size and the way that Excel works.

To make the COIN Tool experience as user-friendly as possible, we recommend that you **disable automatic workbook calculation**. This is done as follows:

- Go to the "File" menu
- Go to Options -> Formulas -> Workbook calculation and set to MANUAL

This will make the COIN Tool much faster to use, but remember to manually re-calculate formulas when needed by pressing F9, or the "Calculate" button in the bottom left of the screen.

Sub-indices/pillars/sub-pillars are missing from the Framework tab, even though I entered them in the Database tab.

Go back to the Database tab. Check that you have entered a code for every level (sub-pillar, pillar, sub-index, index), for every indicator. Any deviations (e.g. "p.1" instead of "p.01") will cause errors. See Section 3.1 and Box 1 for more details.

Also if you are copying in names from other spreadsheets, be extremely careful you are not copying in merged cells, as this may paste over hidden cells in the COIN Tool, and will cause the Framework tab to stop working.

I get #REF! errors in the Winsorisation tab

This is probably due to an encoding error in the Database tab. Check that:

- Missing data is denoted as "n/a" (without the inverted commas), and nothing else

- Data is formatted as numbers and not text
- Unit and indicator codes have not been altered from default values ("unit.xxx" and "ind.xxx")

The IndCorrel tab has no values

This is most likely due to an error in indicator definition - see previous point.

There are no results in the Rebalancing/Heatmap/Scores/Rankings tabs and further tabs

If the indicator tabs such as Winsorisation and IndCorrel work, but the tabs relating to aggregation (Rebalancing onwards) do not, this means you likely have an error in the specification of the indicator structure and/or weights. Check that:

- You have entered a code for every level (sub-pillar, pillar, sub-index, index), for every indicator. Any deviations (e.g. "p.1" instead of "p.01") will cause errors. See Section 3.1 and Box 1 for more details.
- The weights have been specified for each indicator (Database tab) and aggregation level (Framework tab)
- The direction has been specified for each indicator

Everything seems to be broken. Help.

The COIN Tool is "friendly-user" software: the user has to be friendly to the software, and careful to input values and parameters correctly, otherwise errors easily ensue.

If there are unfixable errors (after trying the solutions above), it is likely that you have either:

- Altered cells that are not meant to be altered (any cells *not* light blue or turquoise)
- Deleted or added the cells themselves rather than the contents
- Entered data or parameters in a way that does not follow the instructions of the manual (see previous points, and carefully re-read particularly the instructions in Section 3).

If you can't find your error, it may be easier to start again with a clean version of the COIN Tool. If errors persistently occur, there may also be a bug - please contact jrc-coin@ec.europa.eu if you think this is the case.

FAQs

Where can I download the COIN Tool?

The COIN Tool is available at <https://composite-indicators.jrc.ec.europa.eu/>.

What do COINs have to do with composite indicators anyway?

COIN is an abbreviation of "Composite Indicator". COIN is also the abbreviated name

of the European Commission's Competence Centre for Composite Indicators and Scoreboards, at the Joint Research Centre, which created the COIN Tool.

Which tabs do I absolutely need to survive a composite indicator?

See Section 1.3 for an example of some usage cases. At an absolute minimum, you need to specify your index in the Database and Framework tabs. We always recommend to check your data in the Statistics, Winsorisation and TreatedData tabs, and to check relationships in the IndCorrel tab. You may then see your scores in the Heatmap, Scores and Rankings tabs.

Which rules of thumb should I use for?

- **Data coverage:** A rule of thumb is at least 65% data for every unit and indicator. Anything less than that, and you should consider removing indicators or units, unless there are compelling reasons not to. Imputation is effectively informed guesswork, so more data coverage is always better.
- **How many indicators:** There is a balance between including many indicators to try to fully cover the concept, and having a streamlined framework with good data coverage and easy interpretation. Typically, a framework might include 30-40 indicators and still be easy to interpret. Consider that each indicator represents a chunk of information, and there is only so much information that can be packed into a single number (your index), so as the number of indicators increases, the amount of information retained in the final score from each indicator will decrease. This is why it is better not to build a very large framework, *unless* you do not intend to aggregate all indicators to a single index. On the other hand you should also be careful to include enough indicators to give a reasonable picture of the overall concept.
- **Number of aggregation levels:** This should be defined by breaking down the concept you are trying to measure into dimensions and sub-dimensions. Many frameworks simply consist of two aggregation levels: indicators -> pillars -> index. Complex frameworks may make use of all four aggregation levels of the COIN Tool. It is quite rare in practice that an index exceeds four aggregation levels.
- **Which aggregation and normalisation method to use:** The default methods here are the arithmetic average and the min-max normalisation method respectively. These are the easiest to understand and communicate. We would recommend to depart from these only if there is a good reason to do so.
- **Skewness and kurtosis thresholds:** The recommended thresholds are 2 and 3.5 respectively, which represent a roughly normal distribution. See Box 4 for more information.
- **How many points to Winsorise:** This should be taken in context of how many units you have. If you have 100 units and you Winsorise five, this is only 5% of the total and should have a small impact on the overall distribution. If you only have ten units and you Winsorise five, this has a much larger impact. Caution should be exercised in particular when Winsorising more than 10% of the total number of units.

Where can I find more guidance on constructing composite indicators?

Visit our website at composite-indicators.jrc.ec.europa.eu/ where you can find a number of

resources on methodology, including the JRC/OECD Handbook on Constructing Composite Indicators, many reports and audits, and academic papers.

We also organise the following events:

- An annual training course and community of practice on composite indicators ("JRC Week on Composite Indicators and Scoreboards") - see the Events page on our website
- COIN Open days (see COIN Open Days on our website), where organisations are able to come to the JRC in Ispra and receive feedback and assistance their composite indicator from the COIN team
- Ad-hoc training on request, subject to availability

Please contact jrc-coin@ec.europa.eu for further information.

I want to cite the COIN Tool. How do I do that?

Please cite the User Guide as: Becker, W., Benavente, D., Dominguez Torreiro, M., Moura, C., Neves, A., Saisana, M., Vertesy, D., COIN Tool User Guide, 2019, ISBN 978-92-76-12385-9, doi:10.2760/523877

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of the European Union

doi:10.2760/523877

ISBN 978-92-76-12385-9