European Centre for the Development of Vocational Training

2020 European Skills Index

Technical report

Unedited Proof Copy

Note: This is not an official Cedefop publication. For any further information please contact Cedefop

(esi@cedefop.europa.eu)

Note

The technical report was drafted during the update of the European Skills Index 2020.

List of abbreviations

EU-27+4	EU-27 member states plus Iceland, Norway, Switzerland and the UK
ESI	European Skills Index
ET2020	Education and Training 2020
EU	European Union
HCI	Human Capital Index
JRC	Joint Research Centre
NEET	Not in Education, Employment or Training
OECD	Organisation for Economic Co-operation and Development
PISA	Programme for International Student Assessment
VET	Vocational education and training
WEF	World Economic Forum
Cedefop	European Centre for the Development of Vocational Training
EU LFS	European Union Labour Force Survey
ISCED	International Standard Classification of Education
PCA	principal component analysis

Part One: Constructing the Index

1. Introduction

This technical report accompanies the release of the 2020 version of the European Skills Index (ESI) developed for Cedefop.

The methodological decisions made in constructing the Index have implications for the subsequent interpretation and understanding of the results. The first part of this report outlines the scope, structure and results of the Index. The second part of the report discusses the analysis motivating some of the methodological decisions made in constructing the Index.

The 2020 European Skills Index updates the work undertaken for the 2018 European Skills Index, published in 2018 (Cedefop, 2019). The new Index builds on the methodology described in the 2018 European Skills Index Technical Report (Cedefop, 2018) and the JRC Statistical Audit performed by the European Commission's Competence Centre on Composite Indicators and Scoreboards (Norlén & Saisana, 2018). The changes made compared to the previous version are explained in Part 2 of this report; briefly, they include adding two years of data and three new countries, extending its geographical scope to include three members of the European Free Trade Association (Iceland, Norway and Switzerland). In the text, we use EU-27+3 to make reference to the EU-27 member states plus Iceland, Norway, Switzerland and the UK.

2. Theoretical framework

2.1. Developing a framework to conceptualise a country's skills system

The ESI is intended to measure the performance of EU-27+4 countries' skills formation and matching systems to enable a comparative assessment across EU-27+4 countries. The concept of a *skills system* is a multifaceted and complex one, and there is no single all-encompassing measure of the system's performance.

2.2. Defining a skills system

A country's skills system delivers enhanced skills to its population through compulsory education, and post-compulsory education and training. The skills system includes a variety of formal and informal training and education, secondary, further (continuing) and higher education, and both academic and vocational education and training (VET). It also includes lifelong learning, including on-the-job training and the acquisition of competences accrued through years working in a job. It also includes the activation of skills of different groups into the labour force to increase the skills base of the economy. The skills system's role is to ensure, as far as is feasible, that skills demand is met by skills supply in a way that optimises the use of the skills available in the labour force.

A country's skills system can be seen to fulfil several different roles, including:

(a) delivering the skills the country needs and/ or is anticipated to need in the future (including re-skilling and up-skilling);
(b) activating the skills in the labour market, by providing enough job opportunities to different groups in the population;
(a) matching, as far as possible, individuals' aspirations, interests, and abilities to the needs of the labour market.

The capacity of a skills system to realise these ends has traditionally been measured with respect to individuals' propensity to avoid unemployment, obtain relatively high-wage work, and secure progression in the labour market. Accordingly, indicators have concentrated on measures of employment status and wages. The role that a skills system has in matching interests, aspirations, and abilities to labour market demand points to a wider range of outcomes that focus, more or less, on non-pecuniary measures relating to the quality of employment and working life.

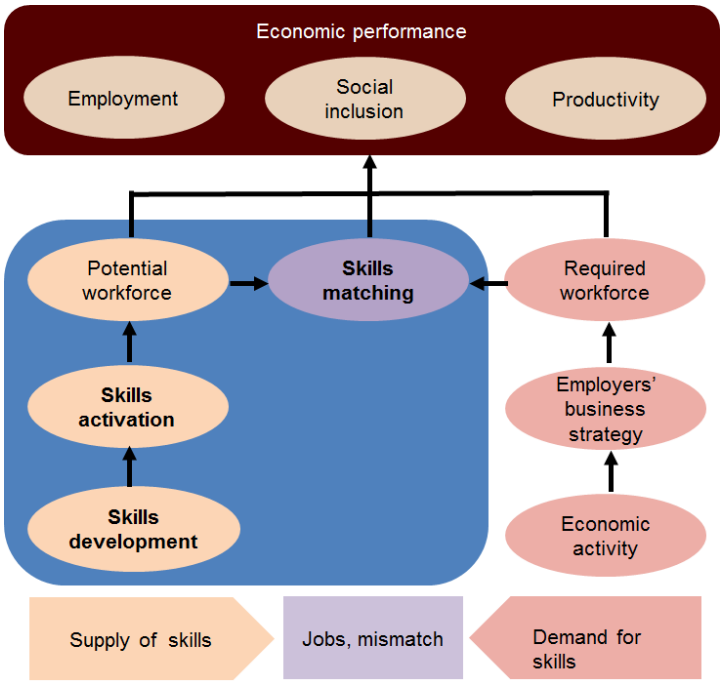
These have driven the design of the ESI.

2.3. Our theoretical framework

In Figure 2.1 the theoretical framework to characterise a country's skills system is presented. The framework developed for the ESI is based on a human capital approach in which both the individual and society derive economic benefits from investing in skills. The framework identifies the various dimensions of skills that can be acquired by an individual through both formal and informal learning. The starting point is that these skills drive economic performance through employment, social inclusion and productivity. Within the framework, social inclusion stands as a desired outcome because success in improving employment and productivity

outcomes will depend on the latter being shared across the population as a whole. In other words, outcomes are socially as well as economically optimal.

Figure 2.1 Theoretical framework for the skills system



Source: European Skills Index (2020), Cedefop.

The role of the skills system is to bring together and match a suitably skilled **potential workforce** (supply) with the needs of employers (the **required workforce**, demand). The required workforce and the skills needed are determined by the nature and scale of **economic activity** and by **employers' business strategies**. The potential workforce is determined by **skills development** (education and training, and lifelong learning) and by the **activation** (or participation) of workers in the labour market. It is through the interplay between skills supply and demand that the degree of successful **matching** of skills is observed.

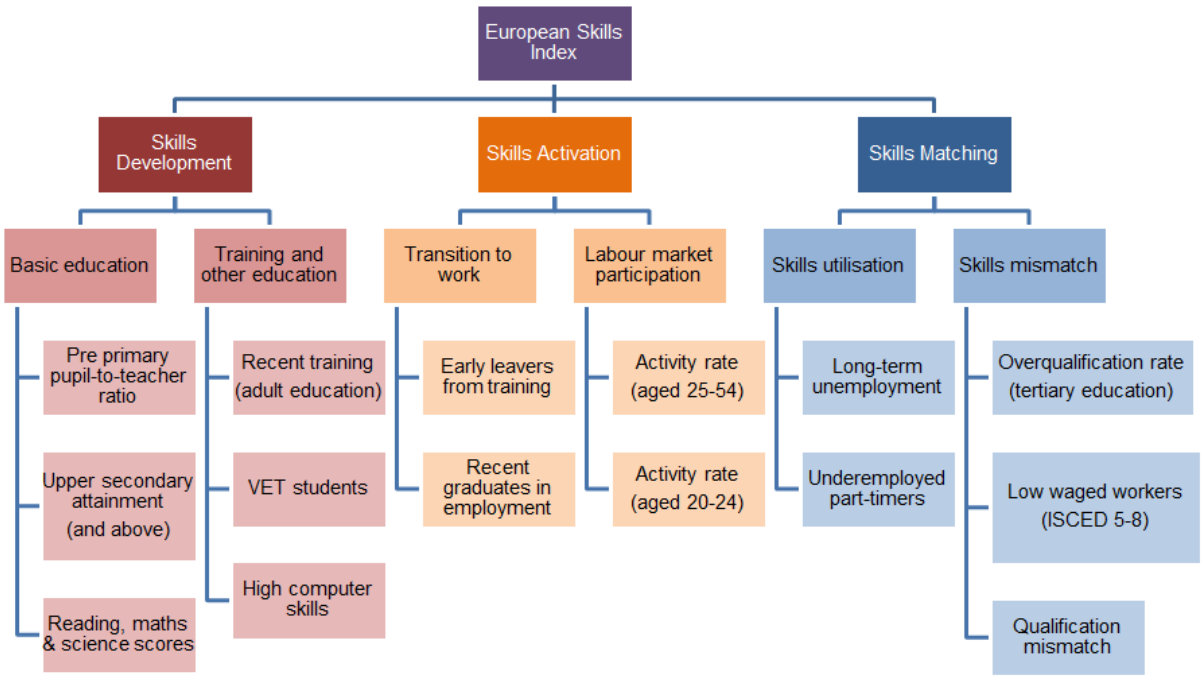
3. Scope of the European Skills Index (ESI)

3.1. Structure of the Index

In Figure 2.1 above, the area highlighted in the blue box indicates the aspects of the skills system that are included in the ESI. The ESI has three pillars (highlighted in bold in Figure 2.1 above) to assess how well the skills formation and matching systems of EU-27+4 countries are performing in relation to the degree to which they are **developing**, **activating** and **matching** skills reserves within their economies. The ESI focuses on these supply and matching aspects of the skills system. Within the ESI, the demand for skills is captured most clearly in the matching of skills, and in the extent to which it influences decisions to invest in training and to activate skills.

Each pillar is broken down further into sub-pillars, to further organise the indicators into related groups. In total, the ESI has three pillars, six sub-pillars, and 15 indicators. The rationale and definition of each indicator are outlined in Table 3.2 below (Section 3.4). The structure of the Index is represented in Figure 3.1.

Figure 3.1 European Skills Index structure



Source: European Skills Index (2020), Cedefop.

3.1.1. Skills development

This pillar represents the training and education activities of the country and the immediate outputs of that system in terms of the skills developed and attained. This pillar has two sub-pillars:

- basic education; and
- training and other education.

3.1.2. Skills activation

The potential workforce of a country is determined not only by the development of skills in the population, but also by the activation (or participation) of skills in the labour market. This pillar includes indicators of the transition from education to employment, together with labour market activity rates for different groups of the population. This pillar has two sub-pillars:

- transition to work; and
- labour market participation.

3.1.3. Skills matching

Finally, the skills matching pillar represents the degree of successful utilisation of skills, the extent to which skills are effectively matched in the labour market. This can be observed in the form of jobs and mismatches which include unemployment, skills shortages, and skills surpluses or underutilisation of skills in the labour market. This pillar has two sub-pillars:

- skills utilisation; and
- skills mismatch.

3.1.4. Interpretation of the pillars

The pillars represent different aspects of the skills system and they organise our understanding of the system and the indicators that will be used to measure it. In reality, inter-relationships exist between the different pillars of the ESI. This is evident in all composite indices, for example, other composite indices (in a similar domain to the ESI) also include pillars that are inter-related: the WEF's Human Capital Index (World Economic Forum, 2017) (pillars - education; health and wellness; workforce and employment; and enabling environment); and the European Commission's Social Scoreboard for the European Pillar of Social Rights (Joint Research Centre, 2018) (pillars - education, skills and lifelong learning; gender equality in the labour market; inequality and upward mobility; living conditions and poverty; and youth).

In our framework, the pillars can be interpreted as a process: the development of an individual's skills influences their activation in the labour market and consequently their matching to employment. However, as in other composite indices, there are also inter-relationships that run in the opposite direction: for example, an individual's decision to invest in training may be influenced by the likelihood of training improving their employment opportunities (matching).

3.2. Country coverage

The Index covers the 31 Member States of the EU-27+4, at the country level. The specific countries covered within the ESI are outlined in Table 3.1 below.

Table 3.1 Country coverage

Countries (country code)			
Belgium (BE)	Greece (EL)	Lithuania (LT)	Portugal (PT)
Bulgaria (BG)	Spain (ES)	Luxembourg (LU)	Romania (RO)
Czech Republic (CZ)	France (FR)	Hungary (HU)	Slovenia (SI)
Denmark (DK)	Croatia (HR)	Malta (MT)	Slovakia (SK)
Germany (DE)	Italy (IT)	Netherlands (NL)	Finland (FI)
Estonia (EE)	Cyprus (CY)	Austria (AT)	Sweden (SE)
Ireland (IE)	Latvia (LV)	Poland (PL)	United Kingdom (UK)
Iceland (IS)	Norway (NO)	Switzerland (CH)	

Source: European Skills Index (2020), Cedefop.

3.3. Time coverage

The 2020 European Skills Index draws on annual data, up to 2018. The Index is back-cast over 2016-2017 data to gauge how countries have performed over recent history (see Section 6.2 below).

3.4. Indicators in the Index

The details of each indicator in the Index are summarised in Table 3.2 below.

Table 3.2 Details of the indicators

Indicator (unit of measurement)	Description	Relevance of indicator (direction of effect)	Source of data (and dataset code, if applicable)	Country coverage	Time coverage
Development					
Pre-primary pupil-to-teacher ratio (students per teacher)	Ratio of pupils and students to teachers and academic staff at the pre-primary education level (ISCED11 level 0, 3 years to the start of primary education.)	Proxy for the quality of teaching at pre-primary education level. (-)	Eurostat, Collected by the UNESCO, OECD, Eurostat joint data collection (Eurostat code educ_uoe_perp04)	EU 28 plus Iceland, Liechtenstein, Norway, Switzerland, North Macedonia, Serbia, Turkey,	2013-2017
Upper secondary education (and above) (%)	Share of population aged 15-64 with at least upper secondary education (ISCED11 level 3-8)	Proxy for the education attainment level of the country (+)	Eurostat - Labour Force Survey (Eurostat code edat_lfse_03)	EU 28 plus Iceland, Norway, Switzerland, North Macedonia, Turkey	1992 - 2018
Reading, maths & science scores (PISA score)	Average PISA scores (15-year olds) for reading, maths and science.	Proper levels of basic competences are key outcomes of initial education because they build the foundation for long-term economic growth of societies and social inclusion of individuals. Average across three separate indicators. (+)	OECD PISA programme	OECD plus other partner countries for a total of 72 countries	6 rounds, every three years, starting in 2000, last one being in 2015
Recent training (%)	Share of population aged 25-64 who stated that they received formal or non-formal education or training in the four weeks preceding the survey.	Continued learning after initial education is crucial for raising productivity levels of the working-age population and tackling skill mismatches and bottlenecks on the labour market. Matches EC E&T Monitor Target 6. (+)	Eurostat - Labour Force Survey, (Eurostat code edat_lfse_03)	EU 28 plus Iceland, Norway, Switzerland, North Macedonia, Turkey	1992 - 2018
VET students (%)	Share of the population at ISCED11 level 3 attending vocational training	Evidence shows that within the group of graduates from upper secondary education, graduates from vocational education and training (VET) programmes have better employment prospects, particularly in countries where work-based learning is a strong component of VET programmes. EC E&T Monitor Target 13. (+)	Eurostat, Collected by the UNESCO, OECD, Eurostat joint data collection (Eurostat code educ_uoe_enra13)	EU 28 plus Iceland, Liechtenstein, Norway, Switzerland, North Macedonia, Turkey, with a further breakdown at NUTS 2 level	2013 - 2017
High computer skills (%)	Share of 16-74-year olds able to carry out 5 or 6 out of the 6 tasks described in the survey	Digital competences are required for employability and active participation in society. (+)	Eurostat self-assessment survey (Eurostat code tsdsc460)	EU 28 plus Iceland, Norway, Switzerland, Montenegro, North Macedonia, Serbia, Turkey,	2005-2007, 2009, 2011, 2012, 2014
Activation					
Early leavers from training (%)	Early leavers from education and training (work status 'not in employment') as a share of the population, aged 18-24 having attained ISCED11 level 0, 1, 2 or 3c short and not receiving any formal or non-formal education or training in the four weeks preceding the survey.	Early leavers experience reduced lifetime earnings and longer and more frequent unemployment spells; early leaving also brings large public and social costs.	Eurostat - Labour Force Survey (Eurostat code edat_lfse_14)	EU 28 plus Iceland, Norway, Switzerland, North Macedonia, Turkey	1992-2018
Recent graduates in employment (%)	Share of employed people aged 20-34 having successfully completed upper secondary or tertiary education 1 to 3 years before the reference year of the survey and who are no longer in education or training.	Although education and training cannot compensate for the economic downturn, the quality and relevance of education can be strengthened to better meet the needs of the modern labour market. Matches EC E&T Monitor Target 5 (+)	Eurostat - Labour Force Survey (Eurostat code edat_lfse_24)	EU 28 plus Iceland, Norway, Switzerland, North Macedonia, Turkey	2000-2018

Activity rate (aged 25-54) (%)	Employed/active persons as a share of same age total population	The supply of skills can be increased through higher activation. (+)	Eurostat - Labour Force Survey (Eurostat code lfsa_argaed)	EU 28 plus Iceland, Norway, Switzerland, North Macedonia, Turkey	1983-2018
Activity rate (aged 20-24) (%)	Employed/active persons as a share of same age total population	Integrating under-represented groups into the labour force can increase the skills base in an economy. (+)	Eurostat - Labour Force Survey (Eurostat code lfsa_argaed)	EU 28 plus Iceland, Norway, Switzerland, North Macedonia, Turkey	1983-2018
Matching					
Long-term unemployment (%)	Share of unemployed persons since 12 months or more in the total number of active persons in the labour market	Gives some indication of structural mismatch and of the effectiveness of a skills system in responding to skill obsolescence. (-)	Eurostat - Labour Force Survey (Eurostat code une_ltu_a)	EU 28 plus Iceland, Norway, Switzerland, North Macedonia, Turkey	1996-2018
Underemployed part-timers (%)	Underemployed part-time workers aged 15-74 as share of active population. Persons working on an involuntary part-time basis are those who declare that they work part-time because they are unable to find full-time work	Ineffective use of skills - labour is underutilised among persons already employed and willing to work more hours. (-)	Eurostat - Labour Force Survey (Eurostat code lfsa_sup_age)	EU 28 plus Iceland, Norway, Switzerland, North Macedonia, Turkey	2008-2018
Overqualification rate (tertiary education) (%)	Share of employed people aged 25-34 with ISCED11 level 5 and 6 that occupy jobs NOT corresponding to ISCO 1, 2 or 3	Gives an indication of ineffective use of skills – highly-educated employees working in lower skilled jobs (-)	Skills Panorama, from Eurostat – Labour Force Survey	EU 28	2011-2017
Low waged workers (ISCED 5-8) (%)	This is defined as the proportion of low wage earners out of all employees of ISCED11 level 5-8 qualification level, where low wage is defined as “those employees (excluding apprentices) earning two-thirds or less of the national median gross hourly earnings in that particular country”	Gives an indication of the ineffective use of skills - high-educated employees in low wage employment (-)	Eurostat - Structure of Earnings Survey (Eurostat code earn_ses_pub1i)	EU 28	2006, 2010, 2014
Qualification mismatch (%)	The measure is calculated by taking the modal education attainment level for each occupation in each industry and assessing whether each employee’s education attainment level matches it	Measures incidences of both underqualification and overqualification, which provides an indication of ineffective use of skills, or the need for upskilling. (-)	OECD WISE database	EU 28 plus Iceland, South Africa	2015-2016

Source: European Skills Index (2019), Cedefop.

4. Treatment of indicators

4.1. Missing data and imputation methods

4.1.1. Method for data imputation in our dataset

For the ESI, a complete dataset for the latest year would mean 31 observations per indicator and 15 observations per country. Since the dataset is not complete, cold deck imputation is used, i.e. replacing missing values with values from a previous year. After that, by indicator, the lowest data availability is 93% for qualification mismatch indicator (Croatia and Malta have missing data).

For back-casting the Index, in addition to cold-deck imputation, linear interpolation is used to fill in missing data for which data are available in preceding and subsequent years in the same indicator.

4.1.2. Practical rules

In determining whether additional imputation methods are necessary, some practical rules are followed:

- a requirement for at least 60-65% indicator, pillar and sub-pillar coverage per country. This can be relaxed or made stricter depending on the degree of correlation between indicators within a dimension; for example, for each country, if there are more than 20% missing values in one dimension, then the country may be removed.
- there is a requirement for at least 75-80% data coverage per indicator.

Once cold deck imputation is applied, **no imputation** approach is adopted thereafter (see Table 4.1 below). This is conceptually equivalent to imputing the missing value with the weighted mean of the values observed for that unit on the other indicators included in the same lower dimension (mean-row). This applies even if the indicators are assigned different weights. When using an arithmetic average at pillar level, the available data (indicators) in the incomplete pillar may dominate, sometimes biasing the ranks of countries up or down.

Table 4.1: Data coverage (most recent year, 2018)

Indicator (unit)	Missing data after imputation	Year of data for the Index
Pre-primary pupil-to-teacher ratio (students per teacher)	IE	2017 except: EE - 2015; DK, CH - 2014
Upper secondary education (and above) (%)	0	2018
Reading, maths & science scores (PISA score)	0	2015
Recent training (%)	0	2018
VET students (%)	0	2017 except IS - 2015; IE - 2013
High computer skills (%)	CH	2014
Early leavers from training (%)	0	2018
Recent graduates in employment (%)	0	2018
Activity rate (aged 25-54) (%)	0	2018
Activity rate (aged 20-24) (%)	0	2018
Long-term unemployment (%)	0	2018
Underemployed part-timers (%)	0	2018
Overqualification rate (tertiary education) (%)	0	2017
Low waged workers (ISCED 5-8) (%)	0	2014
Qualification mismatch (%)	HR, MT	2016

Source: European Skills Index (2020), Cedefop.

4.2. Outliers

Table 4.2 below presents the main summary statistics for the indicators for the latest year of data([1]).

Table 4.2: Summary statistics

Indicator (unit)	Range	Median	Mean	Standard deviation	Skewness	Kurtosis
Pre-primary pupil-to-teacher ratio (students per teacher)	[5.3, 24.8]	12.3	12.9	4.1	1.0	2.2
Upper secondary education (and above) (%)	[50.2, 88.3]	78.5	76.4	9.3	-1.3	1.5
Reading, maths & science scores (PISA score)	[437.5, 524.3]	492.2	487.9	23.1	-0.8	0.1
Recent training (%)	[0.9, 31.6]	10.5	12.7	8.3	0.7	-0.3
VET students (%)	[1.5, 72.4]	46.6	46.9	18.3	-0.4	-0.3
High computer skills (%)	[7, 46]	30.0	29.9	8.3	-0.5	0.9
Early leavers from training (%)	[2.1, 9.6]	4.0	4.5	2.1	1.3	0.9
Recent graduates in employment (%)	[55.3, 94.8]	84.2	82.9	9.1	-1.7	3.6
Activity rate (aged 25-54) (%)	[77.9, 92]	87.0	87.1	2.9	-0.8	2.1
Activity rate (aged 20-24) (%)	[40.9, 84.3]	63.6	62.6	11.8	-0.2	-1.1
Long-term unemployment (%)	[0.3, 13.6]	1.7	2.6	2.5	3.2(*)	12.6 (*)
Underemployed part-timers (%)	[0.4, 7]	2.7	2.9	1.7	0.5	-0.4
Overqualification rate (tertiary education) (%)	[5.4, 44.5]	21.5	24.0	8.0	0.6	1.0
Low waged workers (ISCED 5-8) (%)	[0.2, 13.8]	3.6	5.2	3.9	0.9	-0.3
Qualification mismatch (%)	[17.1, 44]	35.0	33.6	7.0	-0.7	-0.1

(*) Instances where skewness is greater than 2 or kurtosis greater than 3.5.
Source: European Skills Index (2020), Cedefop.

Outliers can polarise the scores and bias the rankings. All variables are checked for absolute skewness greater than 2, and kurtosis greater than 3.5. Winsorising is used for Greece for “Long-term unemployment” to stop this value from becoming an unintended benchmark and introducing bias in the aggregation with other indicators.

The JRC Statistical Audit of the ESI (Norlén & Saisana, 2018) recommends simplification of the ESI development by removing the winsorisation step, which is not required because adopting the goalposts during the normalisation step means that the lower bound (worst case) for that indicator is set at 10%, which is higher than the value in Greece. However, JRC recommends removing this step only if the normalised (with the use of goalposts) indicator values satisfy the double criterion for skewness and kurtosis. Since the normalised values did not meet this criterion, the winsorisation step was not removed.

4.3. Normalisation – Distance to frontier

The distance to frontier normalisation method is a special case of min-max normalisation method with bounds, where a country's performance in a variable is compared with the value of a logical “best case” as well as that of a logical “worst case”. As a result, the country's relative position can be captured by the generated distance-to-frontier scores. If the upper and lower bounds are time-invariant, then this approach enables easier comparison of Index

([1]) The latest year of data in this instance refers to figures for 2018, including imputed values.

scores over time. A country's distance-to-frontier score for each indicator is calculated using the formula:

$$\frac{I_{ij} - lower\ bound}{Upper\ bound - lower\ bound}$$

where I_{ij} is the raw value of country i in indicator j.

The normalised scores for every indicator calculated using the formula above range from zero to one.

4.4. Bounds for the indicators

During 2018 ESI update, the fixed bounds, i.e. best case and worse case, adopted for each indicator were derived from statistical considerations. Some bounds could have been aligned with targets identified in policy papers at the EU level, in instances where they exist and can provide a target that countries can aspire to. However, it was decided not to use policy targets because of statistical coherence issues and it would not reward improvement of performance on either side of the bound. Regarding the first problem, many policy bounds are expressed as "at least" and they are average targets for the EU as a whole (e.g. at least 40% of people aged 30-34 should have completed some form of higher education). If such as target is used as a maximum bound, countries score full marks as soon as they achieve that bound, but no more if they exceed it – we do not reward the country performing better than the (EU-wide) target. If such a target is used as a minimum bound, countries score no points until they achieve that bound – we do not reward the country for making progress towards that (EU-wide) target. Regarding the second point, using policy bounds as described above causes a lack of variation in the scores of some indicators and this might be an issue for the index calculation. Statistical bounds are close to the maximum and minimum values observed at indicator level, across EU-28 countries, and observed over 2010-2016, in instances where data are available.

Table 4.3 below presents the bounds used for each Indicator in the Index and the rationale behind the choice of bounds, which are statistically computed bounds. The bounds were specified during the 2018 ESI update.

Table 4.3: Upper and lower bounds

Indicator (unit)	Rationale for bounds	Lower bound	Upper bound
Pre-primary pupil-to-teacher ratio (students per teacher)	There is no clear evidence on worst nor optimal student-to-teacher ratios. Bounds are the minimum and maximum across the years as the worst and best-case frontiers.	22	6
Upper secondary education (and above) (%)	Best outcome bound close to the maximum across the years. The Education and Training 2020 target is 40% attainment for tertiary education (of 30-34-year-olds), so in the long-term we would expect that the share of population with at least upper secondary education should be at least higher than this target. It was rounded up to the nearest 10%, based on the 5th percentile of the last seven years.	50	90

Indicator (unit)	Rationale for bounds	Lower bound	Upper bound
Reading, maths & science scores (PISA score)	Bounds close to the (EU) minimum and maximum, in particular, and the 5th and 95th percentile scores rounded to the nearest 10.	440	550
Recent training (%)	This indicator corresponds to the Education and Training target 6. Bounds as the seven-year minimum for worst outcome, and a number close to the seven-year maximum for the frontier.	1	30
VET students (%)	This indicator is monitored in the Strategic framework – Education and Training 2020. Bounds close to the minimum and maximum across the seven years.	10	75
High computer skills (%)	Bounds close to the minimum and maximum across the seven years.	7	46
Early leavers from training (%)	This indicator corresponds to the Education and Training target 1. It was decided for a number close to the maximum as the worst frontier across the years, and for the best frontier a figure close to the minimum scored across the years.	10	2
Recent graduates in employment (%)	This indicator corresponds to the Education and Training target 5. The best and worst frontiers are figures close to the minimum and maximum across the years.	55	95
Activity rate (aged 25-54) (%)	Bounds close to the minimum and maximum across the seven years.	80	90
Activity rate (aged 20-24) (%)	Bounds close to the minimum and maximum across the seven years.	40	78
Long-term unemployment (%)	Bounds close to the minimum and maximum across the seven years.	10	1
Underemployed part-timers (%)	Bounds close to the minimum and maximum across the seven years.	7	1
Overqualification rate (tertiary graduates) (%)	Bounds close to the minimum and maximum across the seven years.	40	10
Low waged workers (ISCED 5-8) (%)	Bounds close to the minimum and maximum across the seven years.	14	0
Qualification mismatch (%)	Bounds close to the minimum and maximum across the seven years.	44	16

Source: 2018 European Skills Index Technical Report, Cedefop.

The bounds in Table 4.3 have not been modified for the 2020 ESI update. As explained above, the main reason for the decision to use fixed bounds during the 2018 update was the need to benchmark performance over time. Keeping the same lower and upper bounds for the ESI indicators allows us to see how the EU-27 member states plus the UK have progressed since the last update (i.e. 2018). Three new countries were added in ESI during this update, which

affects the statistical maximums/minimums of the sample of countries. It is preferred to keep the benchmark based on the EU-28 to ensure that targets (bounds) are more consistent with the best/ worst performance in the EU.

With the addition of two years of data, the improvement over time in the countries' performance would be the basis of changes in the bounds. Since no methodological changes are envisaged during the 2020 update, keeping the bounds unchanged makes it easier to communicate new results and the improvement or deterioration of countries' skills systems. Methodologically, there is limited scope for bounds adjustments alone to improve the statistical coherence of the index, as bounds, aggregations methods, and weights need to be used together to ensure statistical coherence.

4.5. Transformation

No transformations are applied to the normalised scores. Although some of the normalised indicators present left or right skewness, it is considered that a sample of 31 countries is prone to such types of distribution. Some of the indicators exhibit a median greater than or equal to 0.7 (after normalisation) and lower than or equal to 0.3 (after normalisation). However, since the mean was above 0.3 or below 0.7, it was decided not to transform the scores, which would make interpretation of individual indicator scores more difficult for policy makers. One indicator stands out: "Long-time unemployment" has both a high median and mean. A log transformation would ensure a more uniform distribution, but would also make an evaluation by country across time less clear.

5. Aggregation

5.1. Aggregation method

The aggregation method is not changed for the 2020 ESI update. A mixture of weighted arithmetic and geometric means is used at different levels of the Index.

The Index score is computed as the weighted geometric average of three pillar scores. Pillar scores are derived from calculating the weighted arithmetic average of the sub-pillar scores. Sub-pillar scores are calculated as the weighted arithmetic average of the Indicator scores.

The weighted arithmetic average method is easy to interpret, but makes a key assumption of perfect compensability between indicators as it assumes that the score in one indicator/sub-pillar can fully offset the score in another. At the indicator and the sub-pillar level, the interpretation of perfect compensability of scores is considered reasonable and adequate. The use of weighted arithmetic average also has precedence in the creation of other composite indices in which a distance-to-frontier normalisation approach is chosen ([2]).

The choice to use the weighted geometric average to combine the three pillar scores into an Index score stems from the consideration that perfect compensability at this level is more problematic. By using weighted geometric average, unbalanced profiles are penalised - that is, with pillar scores of two and eight, the weighted geometric average would be four, whereas pillar scores of five and five would score higher (five). Moreover, the geometric average gives more incentive for policymakers to improve those pillars with low values.

5.2. Weights

The weights are not changed for the 2020 ESI update. The choice of the ESI weights (see Table 5.1) is explained in the technical report that accompanied the release of the 2018 version of the ESI (Cedefop, 2018).

The ESI has also been back-cast (see Section 6.2). The variation of each indicator over time has been reviewed; any indicators that are particularly volatile might cause low correlations and so warrant an adjustment to the corresponding weight. No such adjustments to weights were made because none of the indicators were judged to show problematic volatility.

The final weights for each indicator and pillar are given in Table 5.1 below.

Table 5.1 Pillar, sub-pillar and indicator weights

Pillar/ *sub-pillar*/ indicator	Weights
Skills Development	**0.3**
Basic education	*0.5*
Pre-primary pupil-to-teacher ratio	0.4
Upper secondary education (and above)	0.3
Reading, maths & science scores (aged 15)	0.3
Training and other education	*0.5*
Recent training	0.3
VET students	0.35
High computer skills	0.35
Skills Activation	**0.3**

([2]) See for instance Doing Business from World Bank (World Bank, 2016) and the Legatum Prosperity Index 2016 (Legatum Institute, 2016). The Human Development Index (United Nations, 2016) uses simple arithmetic average at sub-pillar level and then simple geometric average at pillar level.

Transition to work	*0.5*
Early leavers from training	0.7
Recent graduates in employment	0.3
Labour market participation	*0.5*
Activity rate (aged 25-54)	0.5
Activity rate (aged 15-24)	0.5
Skills Matching	**0.4**
Skills utilisation	*0.4*
Long-term unemployment	0.4
Underemployed part-timers	0.6
Skills mismatch	*0.6*
Overqualification rate	0.4
Low waged workers (ISCED 5-8)	0.1
Qualification mismatch	0.5

Source: 2018 European Skills Index (Technical Report)

All ESI sub-pillars correlate strongly with their respective pillars (correlation coefficients close to 0.85 or greater) and all three ESI pillars correlate strongly and in a balanced way with the ESI (correlations ranging between 0.71 and 0.77) – see Figure 8.2 in Section 8.3. The correlation analysis confirms the choice to use uneven weights for the three pillars (0.3, 0.3 and 0.4) in order to ensure that all three pillars are placed on equal footing when it comes to calculating a summary measure for the performance of a country's skills system.

Sensitivity analysis was undertaken to test the potential change in ranks and scores of countries given alternative aggregation and weighting procedures than the one used above (see Sections 9.2 and 9.3 below).

6. Results

6.1. The 2020 Index

The rankings of the Index for 2020 are presented in **Figure 6.1** below. At the Index level, Czech Republic is ranked highest, and Italy is ranked lowest. At the pillar level, Finland is ranked highest and Romania lowest in terms of Skills Development, Switzerland is ranked highest and Italy lowest in Skills Activation, and Czech Republic highest and Greece lowest in Skills Matching.

The dispersion of ranks at the pillar level indicate that there is not one single country far outperforming other countries. For example, Iceland is ranked second in Skills Activation, but ranks 10th at the Index level. Similarly, Malta ranks second in Skills Matching, but ranks 13th at the Index level.

Figure 6.1 Index, pillar and sub-pillar rankings (*)

	Index	Skills Development	Skills Activation	Skills Matching	Basic education	Training and other education	Transition to work	Labour market participation	Skills utilisation	Skills mismatch
Czech Republic	1	10	13	1	12	12	7	19	1	1
Finland	2	1	15	10	2	1	23	9	20	6
Slovenia	3	5	6	9	3	9	4	11	12	8
Luxembourg	4	11	18	3	22	3	5	21	7	3
Estonia	5	3	9	11	1	10	17	4	3	19
Sweden	6	4	3	16	4	6	11	3	14	17
Norway	7	7	10	14	16	4	6	16	11	14
Denmark	8	6	16	12	8	8	18	14	13	11
Switzerland	9	2	1	24	13	2	1	1	29	16
Iceland	10	9	2	20	9	11	10	1	19	22
Poland	11	18	20	5	11	23	9	24	2	9
Latvia	12	14	8	15	7	22	13	6	17	15
Malta	13	29	11	2	29	25	12	13	6	2
Austria	14	8	5	22	14	5	8	5	18	25
Germany	15	12	14	18	5	20	21	10	16	18
Lithuania	16	17	7	17	10	24	3	12	5	24
Netherlands	17	13	4	21	20	7	2	8	24	21
Croatia	18	16	23	6	15	19	15	27	10	4
Slovakia	19	15	24	7	17	15	26	25	15	5
Hungary	20	25	26	4	18	29	27	23	4	7
Belgium	21	19	25	19	19	18	22	26	22	12
United Kingdom	22	21	12	27	26	14	19	7	23	27
Portugal	23	27	17	23	31	16	20	15	21	23
France	24	22	22	26	28	13	25	17	28	20
Ireland	25	20	21	29	6	28	14	20	26	30
Bulgaria	26	28	30	8	24	27	29	30	8	10
Romania	27	31	29	13	30	30	28	29	9	13
Cyprus	28	30	19	28	27	31	16	18	27	28
Spain	29	24	28	30	25	21	30	22	31	29
Greece	30	26	27	31	21	26	24	28	30	31
Italy	31	23	31	25	23	17	31	31	25	26

(*) Sorted from highest Index score to lowest.
Source: European Skills Index (2020), Cedefop.

Table 6.1 and Figure 6.3 displays the distribution of Index, pillar and sub-pillar scores. Figure 6.2 shows the index ranking and scores.

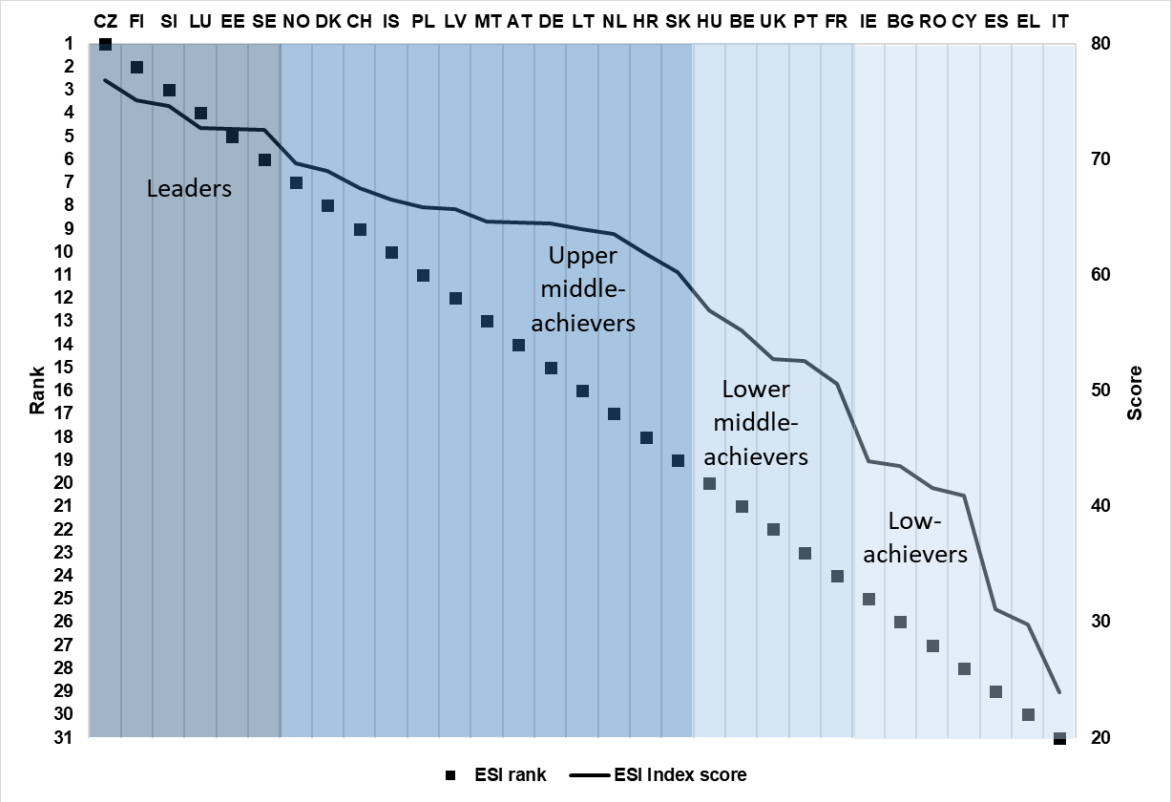
Table 6.1 Index, pillar and sub-pillar scores, 2020(*)

	Index	Skills Development	Skills Activation	Skills Matching	Basic education	Training and other education	Transition to work	Labour market participation	Skills utilisation	Skills mismatch
Czech Republic	77	64	74	91	68	59	85	63	100	84
Finland	75	90	73	67	84	97	66	79	70	65
Slovenia	75	74	83	70	82	65	88	78	84	60
Luxembourg	73	64	72	81	51	77	87	57	92	73
Estonia	73	75	79	66	88	63	72	87	99	44
Sweden	73	75	87	62	81	70	81	93	81	48
Norway	70	67	79	66	61	72	86	72	84	53
Denmark	69	69	73	66	71	68	71	74	83	55
Switzerland	68	77	97	46	64	91	94	100	37	53
Iceland	67	66	91	53	70	61	82	100	73	40
Poland	66	54	68	74	69	40	84	53	99	57
Latvia	66	57	81	62	72	42	80	82	77	53
Malta	65	37	78	86	37	36	81	75	95	81
Austria	65	66	85	51	62	70	85	85	75	35
Germany	64	63	74	59	78	47	71	78	80	45
Lithuania	64	54	82	60	69	39	89	75	96	36
Netherlands	64	62	86	52	56	68	91	80	66	42
Croatia	62	55	55	73	62	48	78	33	84	66
Slovakia	60	55	52	71	60	51	55	49	81	65
Hungary	57	43	51	76	59	27	50	53	98	61
Belgium	55	53	52	59	58	49	69	35	68	54
United Kingdom	53	50	76	41	44	57	71	81	67	25
Portugal	53	42	72	49	33	50	71	73	68	37
France	51	48	63	44	39	58	56	70	47	43
Ireland	44	53	68	28	76	29	79	57	57	8
Bulgaria	43	38	26	70	46	31	30	23	91	56
Romania	42	30	31	66	35	25	34	28	84	54
Cyprus	41	33	71	32	41	24	73	69	48	21
Spain	31	45	37	21	44	47	20	54	30	14
Greece	30	43	45	17	52	34	61	29	34	5
Italy	24	48	5	45	47	49	5	6	61	34

(*) Sorted from highest Index score to lowest.
Source: European Skills Index (2020), Cedefop.

It is possible to distinguish four groups of countries: around six top performers with scores above 70; a large group of upper middle performers with scores 60-70; a small group of five lower middle-performers with scores 51-57; and seven low performers, with scores below 45.

Figure 6.2 Index ranking and scores, 2018 (*)

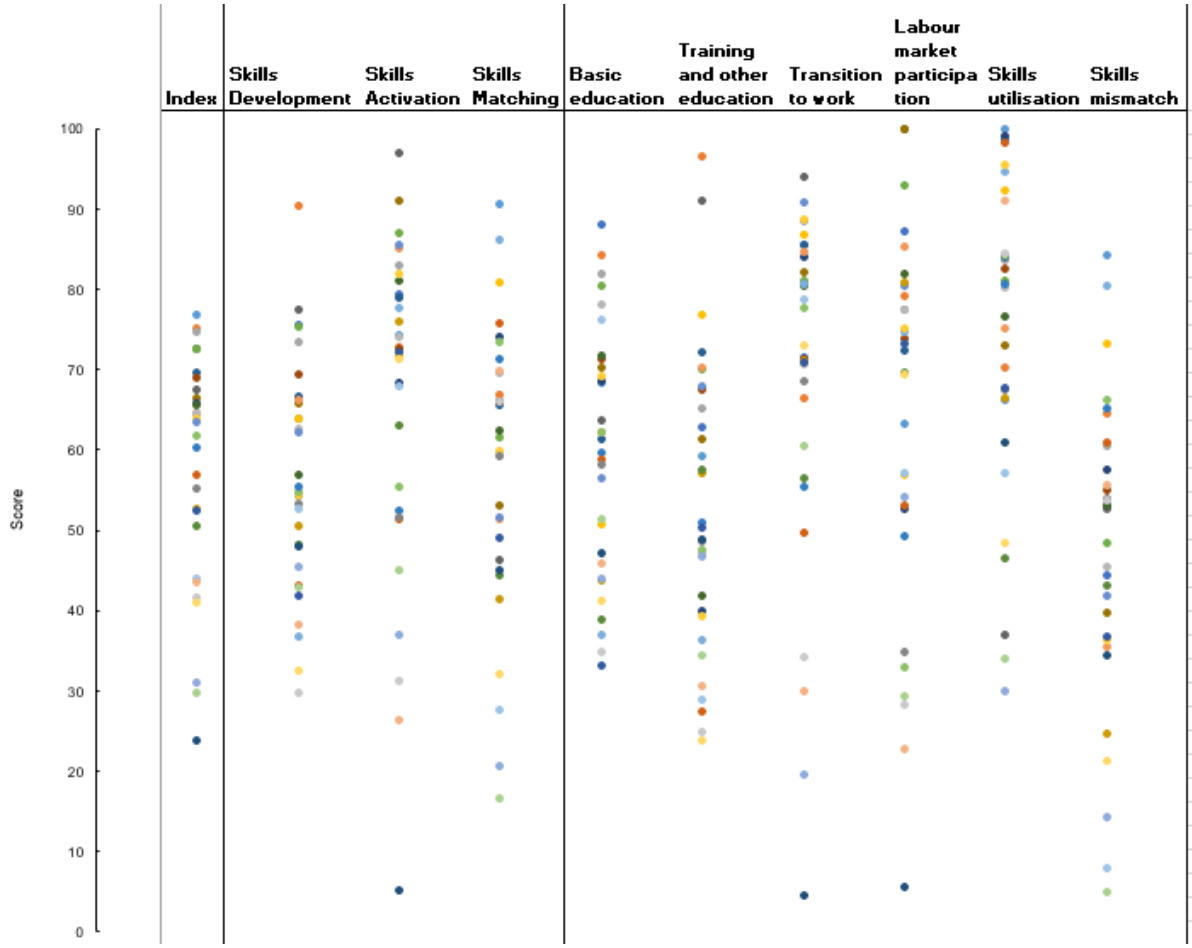


(*) Sorted from highest Index score to lowest.
Source: European Skills Index (2020), Cedefop.

There is a wider distribution of scores across EU-27+4 countries in the second and third pillars (Skills Activation and Matching), than in the first pillar (Skills Development).

At the sub-pillar level, there are some “lagging” countries with scores close to zero in “Transition to work”, “Labour market participation” and “Skills matching”. The scores in the “Skills utilisation” sub-pillar show the most significant improvement compared to the 2018 release; this result is to be expected given that Eurostat has reported in the last two years the highest employment rates in the EU-27 plus the UK in the last decades.

Figure 6.3 Distribution of index, pillars and sub-pillars scores, 2018



Source: European Skills Index (2020), Cedefop.

6.2. Back-casting the Index

Table 6.2 shows the changes in the ESI score, the ESI ranking and the ranking by pillar over the period 2016-2018. As can be observed in the first four columns below, not all increases in the ESI score translate to an increase in the position in the ranking. Belgium(21), Czech Republic (1), Greece (30), Croatia (18), Hungary (20), Poland (11) and United Kingdom (22) have not changed their position in the ranking during this period, although their scores change over time. In the pillar rankings, Greece, Spain and Poland maintain the same position in all three years.

Czech Republic kept the lead position throughout the three-year period. Finland was fourth in 2016 and became second in 2017 and 2018, at the expense of Sweden (now 6th), thanks to remaining a leader in skills activation. Slovenia ranks 3rd in 2017 and 2018, gaining three positions from 6th in 2016 because of improvements in both skills activation and matching.

The bottom of the ranking is occupied by Spain, Greece and Italy. Spain was the bottom ranked country in 2016, exchanging place with Italy in 2017, mainly because of an improvement in scores in the skills activation and matching pillars compared to Italy. Greece has improved in skills matching performance, but remains the lowest among the 31 countries. Instead, Italy is characterised by a very poor skills activation score, while has higher scores in the other two pillars compared to Greece and Spain.

Table 6.2 Back-cast Index, 2016-2018

	ESI				Skills development	Skills activation	Skills matching
	2016 score	2017 score	2018 score	2016-2018 rank change	2016-2018 rank change	2016-2018 rank change	2016-2018 rank change
Belgium	53	54	55				
Bulgaria	33	43	43				
Czech Republic	76	77	77				
Denmark	68	67	69				
Germany	62	63	64				
Estonia	67	72	73				
Ireland	40	43	44				
Greece	23	27	30				
Spain	23	28	31				
France	49	49	51				
Croatia	59	61	62				
Italy	25	23	24				
Cyprus	33	34	41				
Latvia	60	63	66				
Lithuania	61	62	64				
Luxembourg	71	70	73				
Hungary	54	56	57				
Malta	59	62	65				
Netherlands	59	61	64				
Austria	61	62	65				
Poland	62	64	66				
Portugal	45	49	53				
Romania	31	40	42				
Slovenia	68	73	75				
Slovakia	59	58	60				
Finland	70	73	75				
Sweden	72	72	73				
United Kingdom	50	52	53				
Iceland	68	67	67				
Norway	64	69	70				
Switzerland	68	67	68				

Source: European Skills Index (2020), Cedefop.

The highest-ranking member states in skills matching are: Czech Republic (1); Malta (2) and Luxembourg (3). Switzerland(1), Iceland (2) and Sweden (3) hold the top positions in skills activation, while Finland (1), Switzerland (2) and Estonia (3) hold the top three in skills development.

The low achievers remain the same in the first two pillars in each of the three years. In skills activation, Romania (29), Bulgaria (28) and Italy (31) are at the bottom. In skills development, the low achievers are Malta (29), Cyprus (30) and Romania (31). In 2016 and 2017, Cyprus (29), Spain (30) and Greece (31) occupy the bottom positions in skills matching, with Ireland becoming 29th in 2018 at the expense of Cyprus.

Despite being one of the low achievers (i.e. in the last three positions) in skills development and activation, Romania manages to stay among the first half ranked member states in skills matching and thus ranks 28/27 at ESI level. Malta holds the last positions in all three years in

skills development and middle range position in skills activation but is a top achiever in skills matching.

Part Two: Statistical coherence analysis

7. Considerations since the last Index update

The ESI builds on the work undertaken for the European Skills Index, published by Cedefop in 2018. The theoretical and methodological framework remain unchanged from the one described in the 2018 technical report that accompanied the release of the 2018 version of the ESI (Cedefop, 2018).

During this update, the developers found out that two indicators (“High computer skills” and “Low waged workers”) will no longer be updated by the data providers. To keep the relevance of ESI for policy makers, these indicators will need to be replaced during the next update.

8. Descriptive statistics

8.1. Summary statistics

Summary statistics on the unprocessed data for the 15 indicators can be found in Table 8.1 below.

Table 8.1 Summary statistics, 2012-2018

	Range	Mean	Median	Observations (2012-2018)	Skewness and kurtosis check (*)
Pre-primary pupil-to-teacher ratio	[5.3; 24.8]	13.1	12.9	136	-
Upper secondary attainment (and above)	[38.4; 88.3]	74.6	77.4	217	-
Reading, maths & science scores (aged 15)	[437.49; 529.4]	491.1	494.8	60	-
Recent training	[0.9; 31.9]	12.3	9.6	217	-
VET students	[1.5; 88.1]	48.8	49.2	147	-
High computer skills	[7; 46]	29.4	30.0	60	-
Early leavers from training	[2.1; 15.5]	5.2	4.5	217	-
Recent graduates in employment	[40; 96.2]	78.4	80.7	217	-
Activity rate (aged 25-54)	[76.8; 92.2]	86.5	87.2	217	-
Activity rate (aged 20-24)	[39.7; 86.3]	61.9	61.0	217	
Long-term unemployment	[0.3; 19.5]	4.1	3.0	216	2015, 2016, 2017, 2018
Underemployed part-time workers	[0.4; 7.8]	3.3	2.9	215	-
Overqualification rate (tertiary graduates)	[4.61; 44.5]	23.9	21.5	186	-
Low waged workers (ISCED 5-8)	[0.2; 13.84]	5.2	3.6	31	-
Qualification mismatch	[15.97; 44.09]	33.6	35.2	58	-

(*) Skewness and kurtosis checks relates to years where the absolute skewness is greater than 2 and absolute kurtosis is greater than 3.5.
Source: European Skills Index (2020), Cedefop.

8.2. Correlation analysis

Correlation analysis is used to assess to what extent the selected indicators support the ESI framework. From the analysis of the correlation matrix within an Index, an indicator should be more correlated to:

- indicators from its own dimension than to indicators from other dimensions;
- its own dimension than to other dimensions.

Figure 8.1 below displays the correlation matrix of the list of indicators. Directional adjustments were accounted for in the matrix figure below. That is, it controls for differences in direction of

impact, in instances where a lower value indicates a more positive outcome, by ensuring that the correlation calculation treats both indicators as if they are moving in the same direction for positive outcomes.

From the correlation analysis, it is evident that there are no indicators that are highly correlated with each other (i.e. correlation coefficient greater than 0.92), and that there are no indicators that are negatively and significantly correlated with each other.

Figure 8.1 Correlation matrix of the 15 ESI indicators (*)

15	Pre-primary pupil-to-teacher ratio	Upper secondary attainment (and above)	Reading, maths & science scores (aged 15)	Recent training	VET students	High computer skills	Early leavers from training	Recent graduates in employment	Activity rate (aged 25-54)	Activity rate (aged 20-24)	Long-term unemployment	Underemployed part-time workers	Over-qualification rate (tertiary graduates)	Low-wage workers (ISCED 5-8)	Qualification mismatch
Pre-primary pupil-to-teacher ratio	1.000														
Upper secondary attainment (and a	0.139	1.000													
Reading, maths & science scores (a	-0.007	0.142	1.000												
Recent training	0.077	0.023	0.619	1.000											
VET students	-0.123	0.245	0.206	0.094	1.000										
High computer skills	0.178	-0.034	0.621	0.804	-0.001	1.000									
Early leavers from training	0.104	0.396	0.341	0.317	0.080	0.361	1.000								
Recent graduates in employment	0.044	0.238	0.302	0.398	0.037	0.258	0.381	1.000							
Activity rate (aged 25-54)	0.195	0.275	0.292	0.478	0.060	0.518	0.522	0.593	1.000						
Activity rate (aged 20-24)	0.085	0.117	0.506	0.698	-0.179	0.528	0.464	0.654	0.504	1.000					
Long-term unemployment	0.097	0.380	0.284	0.401	0.078	0.194	0.478	0.846	0.456	0.606	1.000				
Underemployed part-time workers	0.336	0.244	-0.159	-0.400	0.198	-0.209	-0.059	0.160	-0.080	-0.321	0.306	1.000			
Over-qualification rate (tertiary gra	0.088	0.047	0.389	0.414	0.369	0.322	0.243	0.562	0.275	0.261	0.593	0.419	1.000		
Low-wage workers (ISCED 5-8)	0.088	-0.320	-0.060	0.225	0.346	0.147	-0.161	0.036	0.103	-0.200	0.000	0.008	0.281	1.000	
Qualification mismatch	0.118	0.551	-0.208	-0.264	0.546	-0.300	-0.026	0.208	0.094	-0.331	0.245	0.630	0.238	0.237	1.000

(*) The full names of each indicator are available in Figure 3.1 above. Green figures denote significant Pearson's correlation at 1% level.
Source: European Skills Index (2020), Cedefop.

8.3. Correlation analysis following normalisation

Correlation analysis is also performed on the normalised indicators.

Figure 8.2 below outlines the correlation results of the Index, based on the indicators, normalisation, weights and aggregation procedure outlined in Part 1 of the technical report. Given the lack of highly collinear (i.e. Pearson correlation coefficient greater than 0.92) pairs of indicators within the same sub-pillar, the correlation analysis of normalised indicators suggests that there is no redundancy of information in the ESI framework.

Figure 8.2: Correlation analysis of normalised scores (*)

	Index	Skills Development	Skills Activation	Skills Matching	Basic education	Training and other education	Transition to work	Labour market participation	Skills utilisation	Skills mismatch
Index	1.00									
Skills Development	**0.74**	1.00								
Skills Activation	**0.77**	0.59	1.00							
Skills Matching	**0.69**	0.23	0.16	1.00						
Basic education	**0.63**	**0.81**	**0.47**	0.24	1.00					
Training and other education	**0.61**	**0.87**	**0.51**	0.16	0.41	1.00				
Transition to work	**0.76**	**0.50**	**0.91**	0.26	0.45	0.39	1.00			
Labour market participation	**0.66**	**0.58**	**0.93**	0.03	0.42	**0.54**	**0.69**	1.00		
Skills utilisation	**0.59**	0.14	0.14	**0.89**	0.31	-0.05	0.25	0.03	1.00	
Skills mismatch	**0.66**	0.27	0.14	**0.95**	0.15	0.28	0.23	0.04	**0.69**	1.00
Pre-primary pupil-to-teacher ratio	0.30	0.39	0.13	0.24	**0.68**	0.04	0.11	0.13	0.32	0.15
Upper secondary attainment (and above)	**0.48**	0.43	0.33	0.29	**0.63**	0.14	0.41	0.21	0.33	0.22
Reading, maths & science scores (aged 15)	**0.49**	**0.75**	**0.48**	0.00	**0.60**	**0.66**	0.38	**0.50**	-0.02	0.01
Recent training	**0.49**	**0.75**	**0.59**	-0.05	0.39	**0.84**	0.39	**0.69**	-0.17	0.05
VET students	0.37	0.44	0.00	0.43	0.13	**0.57**	0.09	-0.09	0.19	**0.54**
High computer skills	**0.47**	**0.72**	**0.56**	-0.06	0.41	**0.78**	0.38	**0.63**	-0.08	-0.04
Early leavers from training	**0.63**	**0.46**	**0.82**	0.14	0.43	0.35	**0.96**	**0.56**	0.13	0.12
Recent graduates in employment	**0.73**	0.36	**0.74**	**0.46**	0.29	0.32	**0.63**	**0.72**	0.43	0.42
Activity rate (aged 25-54)	**0.64**	**0.49**	**0.78**	0.14	0.34	**0.48**	**0.60**	**0.83**	0.09	0.15
Activity rate (aged 20-24)	**0.52**	**0.51**	**0.82**	-0.06	0.39	**0.46**	**0.60**	**0.89**	-0.03	-0.07
Long-term unemployment	**0.77**	0.41	**0.69**	**0.57**	0.39	0.31	**0.67**	**0.60**	**0.62**	**0.46**
Underemployed part-time workers	0.38	-0.01	-0.12	**0.82**	0.21	-0.20	0.01	-0.23	**0.94**	**0.64**
Over-qualification rate (tertiary graduates)	**0.73**	**0.48**	0.39	**0.72**	0.27	**0.51**	0.39	0.34	**0.56**	**0.73**
Low-wage workers (ISCED 5-8)	0.13	0.13	-0.12	0.29	-0.18	0.34	-0.12	-0.10	-0.01	**0.46**
Qualification mismatch	0.41	0.10	-0.07	**0.79**	0.16	0.02	0.04	-0.17	**0.59**	**0.82**

(*) Figures in blue denote significant Pearson's correlation at 1% level.
Source: European Skills Index (2020), Cedefop.

Figure 8.2 indicates that the Index is not overly dominated by specific pillars, sub-pillars, or indicators. Moreover, Figure 8.2 confirms the expectation that most indicators are more associated with their own sub-pillar than to any of the other sub-pillars. However, three indicators are more correlated with other sub-pillars: "Reading, maths and science scores"; "Recent graduates in employment"; and "Long-term unemployment". Similarly, the sub-pillars are more associated within their respective pillar than across the three pillars. Therefore, the correlation analysis suggests that the allocation of ESI indicators to the specific sub-pillar, and allocation of sub-pillars to pillars, is consistent both from conceptual and statistical perspectives.

Ten out of 15 indicators are also positively and significantly correlated with the overall Index (see values in blue in Figure 8.2). Some indicators have low correlation at the Index level (e.g. "Low waged workers (ISCED 5-8)"), but some remain significantly correlated at both sub-pillar level and pillar level (e.g. "Underemployment part-time workers" and "Activity rate (aged 20-24)").

Underemployed part-time workers indicator is highly correlated with the Skills utilisation sub-pillar (i.e. Pearson correlation coefficient greater than 0.92) and Skills Matching pillar, but it is not significantly correlated with the overall index. This indicator was added to the sub-pillar of Skills utilisation as it measures the ineffective use of skills in countries where labour is underutilised among persons already employed and willing to work more hours. Even if its influence in the overall result is partially captured, its importance at pillar level is conceptually relevant.

Similarly, the indicator “Pre-primary pupil-to-teacher ratio” has a great importance on the development of skills and the labour market participation of women. Early childhood education and care is one of the ET2020 targets. The 2019 Employment and Social Development in Europe (ESDE) report (European Commission, 2019) emphasises the importance of investing in children and their families to create long-term positive effects for the whole society. As a measure of quality of the early childhood education and care, the indicator “Pre-primary pupil-to-teacher ratio” is conceptually relevant to the future skills development and activation in a country, although its effects might not be captured in the present.

8.4. Principal Component Analysis (PCA)

The correlation analysis is followed by a statistical procedure called Principal Component Analysis (PCA).

In this update, PCA is used to assess to what extent the conceptual framework is confirmed by statistical approaches. For each sub-pillar and pillar, loadings with eigenvalues greater than one were considered for the factor matrix, which is rotated using varimax rotation. Ideally, this rotation should result in one single latent component that captures more than 60% of the total variance and all the loadings in the same component have the same sign. In addition, the restriction is added that each individual component with eigenvalue greater than one. If eigenvalue less and equal to one then the component has to explain more than 10% of the variance (see OECD/EC JRC (2008)).

Although, in this update, the weights remain unchanged, the factor loadings are calculated to check the representativity of the current weights.

The PCA analysis shows the presence of a single statistical dimension between the three pillars that explains around 60% of the total variance, thus justifying the three-pillar structure and the aggregation of these three pillars into one number:

European Skills Index			
Factor	Eigenvalue	Proportion	Cumulative
Factor1	1.77	0.59	0.59
Factor2	0.90	0.30	0.89
Factor3	0.33	0.11	1.00

The factor loadings suggest that the third pillar should have the greatest weight among the three pillars to increase its influence on the Index:

Index	Factor 1
Pillar 1 Score	0.90
Pillar 2 Score	0.86
Pillar 3 Score	0.48

The sections below look at the unidimensionality at pillar and sub-pillar level.

8.4.1. Pillar 1 – Skills Development

For the two sub-pillars in Skills Development, the results of the PCA show one latent component in both sub-pillars using eigenvalues greater than 1 as a criterion:

Basic education			
Factor	Eigenvalue	Proportion	Cumulative
Factor1	1.29	0.43	0.43
Factor2	0.97	0.32	0.75
Factor3	0.74	0.25	1.00
Training and other education			
Factor	Eigenvalue	Proportion	Cumulative
Factor1	1.78	0.59	0.59
Factor2	1.00	0.33	0.93
Factor3	0.22	0.07	1.00

The factor loadings are presented in the table below:

Basic education		
Indicators	Variable	Factor1
Pre-primary pupil-to-teacher ratio	Ind01	0.56
Upper secondary attainment (and above)	Ind02	0.78
Reading, maths & science scores	Ind03	0.60
Training and other education		
Indicators	Variable	Factor1
Recent training	Ind04	0.94
VET students	Ind05	0.02
High computer skills	Ind06	0.94

As in the previous version of the ESI, the PCA factor loadings suggest a weak relationship between “VET students” and the other two indicators in this pillar.

PCA at the pillar level confirms unidimensionality of the first pillar: the single latent dimension captures 71% in Pillar 1 Skills Development of the total variance of the underlying sub-pillars:

Skills Development			
Factor	Eigenvalue	Proportion	Cumulative
Factor1	1.42	0.71	0.71
Factor2	0.58	0.29	1.00

Thus, the structure of the pillar is justified. Moreover, the loadings of the two sub-pillars would suggest that the use of equal weights for the two sub-pillars is appropriate:

Skills Development	Factor 1
Basic education Score	0.84
Training and other education Score	0.84

8.4.2. Pillar 2 – Skills Activation

The PCA confirms the unidimensionality in each of the sub-pillars: single latent dimension captures more than 60% of the variance of the underlying indicators:

Transition to work			
Factor	Eigenvalue	Proportion	Cumulative
Factor1	1.48	0.74	0.74
Factor2	0.52	0.26	1.00

Labour market participation			
Factor	Eigenvalue	Proportion	Cumulative
Factor1	1.35	0.67	0.67
Factor2	0.65	0.33	1.00

As expected, the loadings of each indicator of the two sub-pillars indicate equal weighting:

Transition to work	
Indicators	Factor1
Early leavers from training	0.86
Recent graduates in employment	0.86
Labour market participation	
Indicators	Factor1
Activity rate (aged 25-54)	0.82
Activity rate (aged 15-24)	0.82

The conceptual framework for this pillar is confirmed by the fact that almost 82% of the variance of the underlying sub-pillars is captured by a single latent component:

Skills Activation			
Factor	Eigenvalue	Proportion	Cumulative
Factor1	1.64	0.82	0.82
Factor2	0.36	0.18	1.00

And the loadings suggest equal weighting when the two sub-pillars are to be aggregated at pillar level:

Skills Activation	Factor 1
Transition to work Score	0.90
Labour market participation Score	0.90

8.4.3. Pillar 3 – Skills Matching

The PCA analysis confirms the unidimensionality in both sub-pillars capturing over 50% of the variation of the underlying indicators:

Skills Utilisation			
Factor	Eigenvalue	Proportion	Cumulative
Factor1	1.13	0.56	0.56
Factor2	0.87	0.44	1.00
Skills mismatch			
Factor	Eigenvalue	Proportion	Cumulative
Factor1	1.58	0.53	0.53
Factor2	0.78	0.26	0.79
Factor3	0.64	0.21	1.00

The factor loadings suggest that equal weights could be a used:

Skills Utilisation	
Indicators	Factor1
Long-term unemployment	0.75
Underemployed part-timers	0.75

Skills mismatch	
Indicators	Factor1
Overqualification rate	0.78
Low waged earners (ISCED 5-8)	0.72
Qualification mismatch	0.68

PCA analysis confirms the unidimensionality at the pillar level: the single latent dimension captures 82% in Pillar 3 Skills Matching of the total variance of the underlying sub-pillars:

Skills Matching			
Factor	Eigenvalue	Proportion	Cumulative
Factor1	1.64	0.82	0.82
Factor2	0.36	0.18	1.00

The loadings of the two sub-pillars would suggest the use of equal weights:

Skill Matching	Factor 1
Skills utilisation Score	0.91
Skills mismatch Score	0.91

9. Sensitivity analysis

The robustness of rankings and the manner in which a composite index is interpreted are greatly influenced by the many methodological choices that are made during its development, for example, the selection of pillars and indicators, the selection of weights and the method of aggregation. These choices require assumptions to be made that introduce uncertainty into the final results. As in any modelling exercise, it is good practice to assess the uncertainties associated with the modelling process and the methodological choices made.

The robustness of the composite index calculation is checked using different scenarios in which one step in the calculation is varied with respect to the original version. Our analysis focussed on varying the:

1. bounds used in normalisation;
2. aggregation method;
3. weights.

Each of these scenarios are explained in the sections below and the results are discussed in Section 9.4.

9.1. Bounds used in normalisation

There is a lot of flexibility on how to choose the “frontier”, i.e. the best and worst cases, and different ways of defining the frontier can be applied to different indicators.

As described in Section 4.4 above, the method used for the 2018 ESI version was to use statistical-defined bounds, i.e. close to the maximum and minimum values over 7 years (2010-2016) for EU-28.

In this scenario, the impact of using as bounds the actual (rather than close to) minimum and the maximum value over a 7 year period (2012-2018) for EU-27+4 countries, is tested.

9.2. Aggregation method

The Index is calculated using weighted arithmetic mean to calculate the score of the sub-pillar and then using weighted arithmetic mean of sub-pillar scores to obtain the score for each pillar. The pillar scores are then aggregated using weighted geometric mean to obtain the overall ESI score.

In this scenario, the impact on the composite index results of varying the method of aggregation only from pillar to index is tested; weighted arithmetic mean (rather than weighted geometric mean in the baseline) is used. In other words, the only change made is to allow full compensability between pillars.

9.3. Equal weights

Equal weights are applied when there is no clear reference in the literature about the importance of elements the composite indicator. Under the equal weighting scheme all indicators should be equally important in classifying countries with respect to the sub-dimension; sub-dimensions should be equally important in classifying countries with respect to the dimension etc.

In this scenario, the impact on the composite index of using equal weights at sub-pillar, pillar and index level is tested.

9.4. Findings

In this sensitivity analysis, different scenarios are considered to test the robustness of countries' ranking by varying different steps in the calculation of the composite index. In this section, the original composite index presented in Part 1 is referred to as the "baseline" index. Five other variations of this index were calculated with the changes to the calculation as explained in sections 9.1 - 9.4 above and summarised in the table below:

Table 9.1 Description of scenarios

Scenario	Short description
Baseline	Composite index calculated as presented in Part 1.
Scenario 1 (Section 9.1)	Baseline with normalisation bounds changed to the actual (rather than close to) minimum and maximum over 7 years.
Scenario 2 (Section 9.1 combined with 9.2)	Scenario 1 with weighted arithmetic mean at the index level.
Scenario 3 (Section 9.2)	Baseline plus weighted arithmetic mean at the index level.
Scenario 4 (Section 9.3)	Baseline with simple means (equal weights) at all levels of aggregation.
Scenario 5 (Section 9.3 combined with 9.2)	Scenario 4 with weighted arithmetic mean at the index level.

Source: European Skills Index (2020), Cedefop.

Table 9.2 shows the results of the sensitivity analysis. The "ranks" columns show the ranking of the index and the pillars in the baseline scenario, while the "range" columns display the best and worst rankings obtained by the country among the scenarios considered in the sensitivity analysis. This table shows to what degree a country's rank depends on the modelling choices.

In the baseline index, Czech Republic is the top performer, followed by a group of countries with a similar overall score until the 6th position. The last position in the baseline is occupied by Italy, preceded by Greece and Spain. Scenarios 2 and 5 produce higher scores than the baseline for almost all the countries, while Scenarios 4 and 5 produce the largest changes in rank positions compared to the baseline.

Table 9.2: Distribution of ranks and scores, sensitivity analysis (*)

	Composite index			Pillar 1			Pillar 2			Pillar 3		
Country	Rank	Range	Score	Rank	Range	Score	Rank	Range	Score	Rank	Range	Score
Czech Republic	1	[1,4]	77	10	[10,13]	64	13	[13,16]	74	1	[1,1]	91
Finland	2	[1,2]	75	1	[1,1]	90	15	[15,16]	73	10	[10,11]	67
Slovenia	3	[3,5]	75	5	[5,5]	74	6	[6,6]	83	9	[9,9]	70
Luxembourg	4	[4,9]	73	11	[10,11]	64	18	[17,20]	72	3	[3,3]	81
Estonia	5	[5,8]	73	3	[3,4]	75	9	[9,11]	79	11	[11,16]	66
Sweden	6	[2,6]	73	4	[3,4]	75	3	[3,3]	87	16	[12,16]	62
Norway	7	[6,8]	70	7	[7,7]	67	10	[10,10]	79	14	[8,14]	66
Denmark	8	[7,10]	69	6	[6,6]	69	16	[14,16]	73	12	[7,12]	66
Switzerland	9	[4,10]	68	2	[2,2]	77	1	[1,1]	97	24	[23,26]	46

Iceland	10	[6,11]	67	9	[8,9]	66	2	[2,2]	91	20	[18,20]	53
Poland	11	[11,15]	66	18	[15,18]	54	20	[20,21]	68	5	[5,6]	74
Latvia	12	[12,17]	66	14	[14,14]	57	8	[8,8]	81	15	[14,22]	62
Malta	13	[10,17]	65	29	[28,29]	37	11	[7,11]	78	2	[2,2]	86
Austria	14	[11,15]	65	8	[8,9]	66	5	[5,5]	85	22	[21,22]	51
Germany	15	[12,17]	64	12	[11,13]	63	14	[12,14]	74	18	[17,19]	59
Lithuania	16	[16,18]	64	17	[15,17]	54	7	[7,11]	82	17	[17,19]	60
Netherlands	17	[13,19]	64	13	[12,13]	62	4	[4,4]	86	21	[21,24]	52
Croatia	18	[16,20]	62	16	[16,19]	55	23	[23,26]	55	6	[5,7]	73
Slovakia	19	[17,19]	60	15	[15,16]	55	24	[24,24]	52	7	[5,13]	71
Hungary	20	[18,21]	57	25	[25,27]	43	26	[23,26]	51	4	[4,4]	76
Belgium	21	[21,23]	55	19	[17,19]	53	25	[25,26]	52	19	[15,19]	59
United Kingdom	22	[20,24]	53	21	[21,23]	50	12	[12,13]	76	27	[27,27]	41
Portugal	23	[22,23]	53	27	[25,27]	42	17	[17,19]	72	23	[20,23]	49
France	24	[23,24]	51	22	[21,22]	48	22	[22,22]	63	26	[25,26]	44
Ireland	25	[25,27]	44	20	[20,20]	53	21	[18,21]	68	29	[29,29]	28
Bulgaria	26	[25,27]	43	28	[28,29]	38	30	[30,30]	26	8	[8,10]	70
Romania	27	[26,28]	42	31	[31,31]	30	29	[29,29]	31	13	[11,14]	66
Cyprus	28	[26,28]	41	30	[30,30]	33	19	[17,19]	71	28	[28,28]	32
Spain	29	[29,31]	31	24	[24,24]	45	28	[27,28]	37	30	[30,30]	21
Greece	30	[30,31]	30	26	[26,27]	43	27	[27,28]	45	31	[31,31]	17
Italy	31	[29,31]	24	23	[22,23]	48	31	[31,31]	5	25	[24,25]	45

(*) Sorted from highest Index score to lowest.
Source: European Skills Index (2020), Cedefop.

Scenario 1 (using the winsorised minimum and maximum values across seven years for the bounds) does not lead to a change in the top three compared to the baseline. Ireland, Lithuania, the Netherlands and the United Kingdom lose the most in terms of ranking (two positions), while Greece exchanges places with Italy as bottom ranked country, and Italy gains two positions.

Scenario 2 (Scenario 1 with weighted arithmetic mean at the index level) looks like Scenario 1 ranking results at the top and the bottom of the ranking, but sees Switzerland and the Netherlands improving three positions compared to Scenario 1.

Scenario 3 (baseline with aggregation at the index level using the weighted arithmetic mean) does not show any changes at the top of the ranking, with the only sizeable movement being Malta gaining three positions. Spain exchanges places with Italy as the bottom ranked country, while Greece remains the second-from-bottom ranked country.

Scenario 4 (baseline with equal weights at all levels of aggregation) sees Finland exchanging places with Czech Republic at the top, with the latter becoming 4th, while Sweden becomes 2nd, followed by Slovenia. The bottom of the ranking remains the same as in the baseline. Luxembourg loses five positions (4 to 9), the Netherlands, Sweden and Switzerland each gain four positions compared to the baseline.

Scenario 5 (equal weights at all levels of aggregation and arithmetic mean at the index level) has again Finland as first and Czech Republic as third in the ranking. At the bottom of the ranking, Greece and Italy exchange positions. The Netherlands, Sweden and Iceland gain four positions while Latvia and Luxembourg lose five positions.

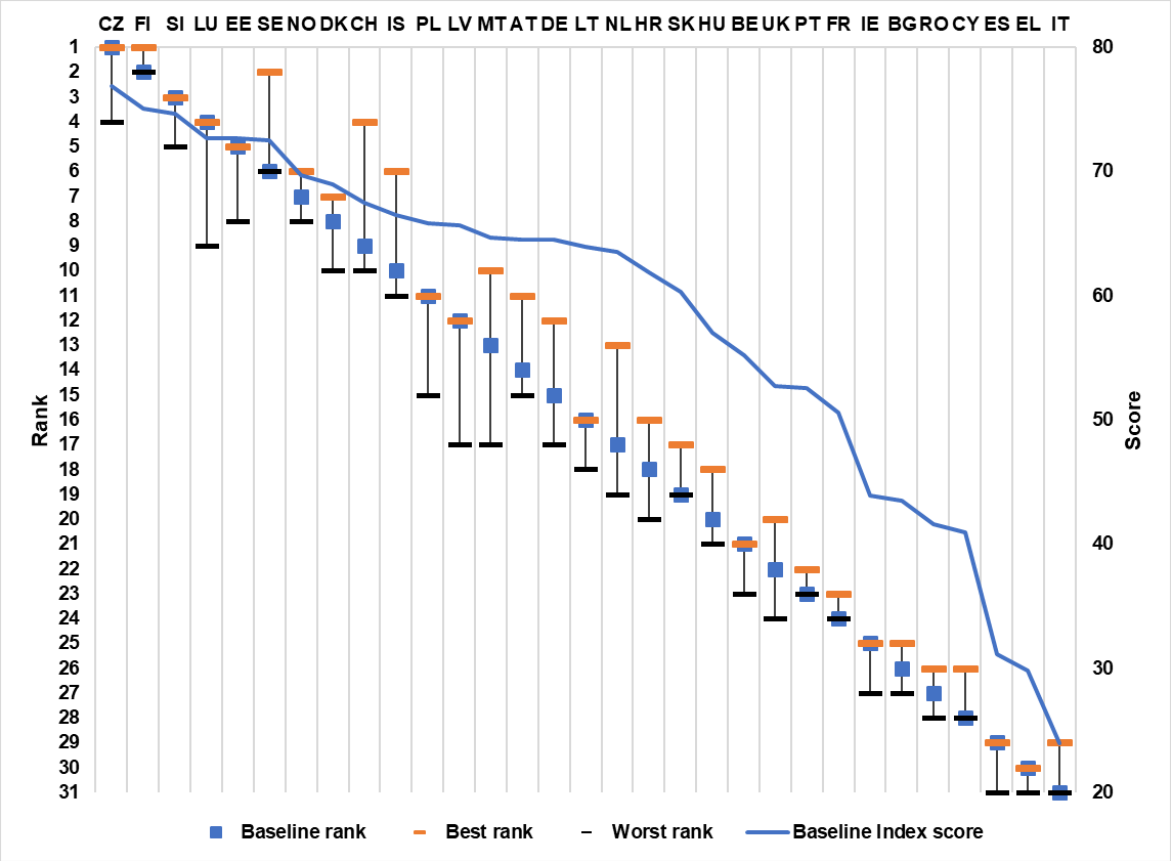
Table 9.3 Changes in ranking relative to baseline (negative is an improvement in ranking)

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Belgium	0	0	0	1	2
Bulgaria	-1	-1	-1	1	1
Czech Republic	0	0	0	3	2
Denmark	-1	1	1	2	2
Germany	-1	0	2	-3	-3
Estonia	1	1	1	2	3
Ireland	2	1	1	0	0
Greece	1	1	0	0	1
Spain	1	1	2	0	0
France	-1	0	0	0	0
Croatia	-2	0	0	1	2
Italy	-2	-2	-2	0	-1
Cyprus	0	0	0	-2	-2
Lithuania	2	1	0	0	0
Latvia	1	1	1	3	5
Luxembourg	0	0	1	5	5
Hungary	0	0	0	1	-2
Malta	-1	-2	-3	4	1
Netherlands	2	-1	-2	-4	-4
Austria	1	0	0	-3	-3
Poland	0	1	1	3	4
Portugal	-1	-1	0	0	-1
Romania	-1	0	0	1	1
Slovenia	0	0	0	0	2
Slovakia	-2	0	0	-1	0
Finland	0	0	0	-1	-1
Sweden	-1	-1	-2	-4	-4
United Kingdom	2	1	0	-2	-1
Iceland	-1	0	1	-2	-4
Norway	1	1	1	-1	0
Switzerland	1	-2	-2	-4	-5

Source: European Skills Index (2020), Cedefop.

Figure 9.1 shows the ranking variation of the composite index across different scenarios. The country experiencing the highest variation is Malta, ranging from 10th to 17th position (i.e. changing seven positions), followed by the Netherlands and Switzerland, both changing six positions. The average rank change is of 3.1 positions.

Figure 9.1: Index range (*)



(*) Sorted from highest Index score to lowest.
Source: European Skills Index (2020), Cedefop.

From this sensitivity analysis of ranks, it can be acknowledged that in some cases there are large variations in Member State (maximum being 7 positions) performance particularly in the middle of the distribution. This is due to Member States having particularly strong or weak performance in an individual indicator or pillar. This emphasises the need to look into the detail of the index to see which indicators are driving a Member State's performance. The rankings are most sensitive for those mid-ranking Member States that are clustered around a very similar baseline score so that *small changes in the score can have an exaggerated impact on the rankings*.

Notwithstanding some sizable variations, it is possible to distinguish five groups of countries: top performers varying within the top 6 positions (with scores above 70); a large group of upper-middle countries follows (with score 60-70); a small group of middle performers varying approximately between the 20th and the 24th positions (with scores 51-57); a group of lower-middle performers varying between the 25th and the 28th position (with scores 41-44); and finally a small group of lower performing countries (with scores 24-31).

In conclusion, the sensitivity analysis shows that the ESI ranks are reliable for the vast majority of EU Member States.

10. Bibliography

Cedefop, 2018. *2018 European Skills Index - Technical report,* Thessaloniki: Cedefop.

Cedefop, 2019. *2018 European skills index,* Luxembourg: Publications Office of the European Union.

Joint Research Centre, 2018. *A Social Scoreboard for the European Pillar of Social Rights.* [Online]
Available at: https://composite-indicators.jrc.ec.europa.eu/social-scoreboard/#

Legatum Institute, 2016. *The Legatum Prosperity Index 2016 - Methodology Report,* s.l.: Legatum Institute Foundation.

Norlén, H. & Saisana, M., 2018. *The JRC Statistical Audit of the European Skills Index (ESI),* Ispra: European Commission, Joint Research Centre.

OECD/EC JRC, 2008. *Handbook on constructing composite indicators: methodology and user guide: Methodology and user guide,* Paris: OECD Publications.

Saisana, M., 2012. *A do-it-yourself guide in Excel for composite indicator development,* Italy: European Commission, Joint Research Centre, http://composite-indicators.jrc.ec.europa.eu.

United Nations, 2016. *HUMAN DEVELOPMENT REPORT 2016: Technical Notes,* s.l.: http://dev-hdr.pantheonsite.io/sites/default/files/hdr2016_technical_notes_0.pdf.

World Bank, 2016. *Doing Business 2016: Measuring Regulatory Quality and Efficiency,* Washington, DC: World Bank Group. DOI:10.1596/978-1-4648-0667-4. License: Creative Commons Attribution CC BY 3.0 IGO.

World Economic Forum, 2016. *The Future of Jobs,* Geneva: The World Economic Forum.

World Economic Forum, 2017. *The Global Human Capital Report 2017: Preparing people for the future of work,* Geneva: World Economic Forum.