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Towards a set of composite indicators on Flexicurity - The dimension of Lifelong Learning

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Abstract

A composite indicator on Lifelong Learning is developed. This represents the first step of a project that aims to cover the four main dimensions of flexicurity[1]: i) modern labour laws; ii) effective active labour market policies; iii) modern social security systems; and iv) comprehensive lifelong learning policies. A composite indicator is calculated for EU Member States followed by sensitivity analysis to check their robustness. Results suggest a high degree of heterogeneity across Europe

1. Introduction

This paper presents a composite indicator on Lifelong Learning using 9 indicators based on the European Labour Force Survey (LFS) and the Continuing Vocational Training Survey (CVTS). The paper is organised as follows. Section 2 lists the indicators and presents their characteristics. Section 3 discusses the computation of a composite indicator. Section 4 presents the results. Section 5 carries out sensitivity analysis of their robustness. Finally, section 6 presents results on a country-by-country basis.

2. The List of Indicators

Based on the recommendations formulated within the LIME project and the suggestions provided in the compendium of indicators compiled by the Employment Committee (Compendium), and following a consultation with the Flexicurity team of DG Employment, a set of 9 indicators has been selected for the construction of the Life Long Learning Composite Indicator. These indicators have been extracted from two institutional data sources: the Eurostat's Labour Force Survey (LFS) and the Eurostat's Continuing Vocational Training (CVTs). For this reason the overall quality of the data and country coverage of the set of indicators is overall satisfactory. In particular, the two indicators extracted from the Eurostat'Labour Force Survey cover all Member States, while the CVTS covers 23 Member States. The quality of the data has been assessed through commonly used statistical criteria, ranging from a maximum (++) to a minimum (--).
Table 1 below contains the list of indicators used:

[1] `Towards common principles of flexicurity: More and better jobs through flexibility and security´, COM(2007) 359.

Table 1 - The full list of basic indicators of the LLL Composite Indicator

Indicators and Dimensions	short name	Source	Also in..
Percentage of firms providing CVT			
Percentage of enterprises providing CVT courses	trng_cvts3_06	CVTs 3	
Participation in CVT			
Percentage of employees (all enterprises) participating in CVT courses - Male	trng_cvts3_42_M	CVTs 3	LIME and EMCO
Percentage of employees (all enterprises) participating in CVT courses - Female	trng_cvts3_42_F	CVTs 3	LIME and EMCO
Hours in CVT courses per employee (all enterprises)	trng_cvts3_71	CVTs 3	
Investment in CVT			
Cost of CVT courses as % of total labour cost (all enterprises)	trng_cvts3_54	CVTs 3	LIME and EMCO
Cost of CVT courses per employee (all enterprises) - Corrected Direct Cost	trng_cvts3_61_1	CVTs 3	
Cost of CVT courses per employee (all enterprises) - Direct Cost	trng_cvts3_61_2	CVTs 3	
Cost of CVT courses per employee (all enterprises) - Labour Cost of Participants	trng_cvts3_61_3	CVTs 3	
LifeLong Learning			
Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey); Male.	part_25-64_M	LFS	LIME and EMCO
Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey); Female.	part_25-64_F	LFS	LIME and EMCO

The **time coverage** of the Life Long Learning composite indicator is 2005. In fact, the indicators extracted from Labour Force Survey are available from 2000 to 2006 but CVTs data only refer to 2005 as not all indicators were monitored in the previous survey carried out in 1999. Using the LIME statistical standards, the time coverage for the composite indicator on Life Long Learning can be rated with a "+".

The **geographical coverage** is rated "++" by using the LIME standard. In fact, data for at least 23 member states are available for all the indicators. In table 2, the set of countries with available data are shown.

Table 2 - Geographical coverage with availability of indicators

Available	**Missing**
Belgium *(10/10)*	Italy *(2/10)*
Bulgaria *(10/10)*	Ireland *(2/10)*
Czech Republic *(10/10)*	Slovenia *(2/10)*
Denmark *(10/10)*	Finland *(2/10)*
Germany *(10/10)*	
Estonia *(10/10)*	
Greece *(10/10)*	
Spain *(10/10)*	
France *(10/10)*	
Cyprus *(10/10)*	
Latvia *(10/10)*	
Lithuania *(10/10)*	
Luxembourg *(10/10)*	
Hungary *(10/10)*	
Malta *(10/10)*	
Netherlands *(10/10)*	
Austria *(10/10)*	
Poland *(10/10)*	
Portugal *(10/10)*	
Romania *(10/10)*	
Slovakia *(10/10)*	
Sweden *(10/10)*	
United Kingdom *(10/10)*	

Data for the countries marked as “missing” are available just for the indicators extracted from the Labour Force Survey. All the indicators extracted from the CVTs are missing either because the country did not participate to the survey or the data has not yet been released.

The **direction of the indicator** has been assumed to be positive for all the indicators, i.e. the higher the score recorded, the better is the performance. This decision is not trivial. In fact for some indicator the opposite decision can be considered valid as well. This is the case for example of the indicators measuring the cost of CVT per courses. A higher cost could mean a better course whereas a lower cost could imply a more efficient use of funds.

The **correlations among indicators** are probably the major issue within the process of constructing a composite indicator. Although the identification and removal of redundant indicators is still a controversial topic among researchers, correlation analysis remains a useful tool to that purpose. However, as highlighted in the literature, the mechanical application of correlation analysis is not sufficient to identify redundant indicators; and researchers tend to agree that two indicators can be considered as redundant when they are highly correlated *and* their meaning is similar. The case of the Lifelong Learning Composite Indicator is peculiar because some indicators are strongly correlated with each other despite having very different meaning.
In table 3 the correlation analysis matrix is presented .

Focusing on correlation coefficients greater than 0.8, problems arise with the following pairs of indicators:

- *cvts3_06* with *cvts3_61_1*
- *cvts3_06* with *cvts3_61_2*

in this case the higher is the share of enterprises providing CVTs courses the higher are the direct costs (corrected or not). The meaning of the two indicators is different and so both have been kept in the analysis.

- *cvts3_71* with *cvts3_42*_M and *cvts3_42_F*

In this case the higher the amount of hours per employee, the higher is the percentage of employees participating in continuing vocational training. Although the correlation coefficient is considerably high, the two indicators have not been considered redundant and, hence, they have been kept in the analysis.

- *cvts3_71* with *cvts3_61_3*

In this case, the higher is the amount of hours per employees, the higher is the cost (Labour cost per participants). The two indicators have been maintained in the analysis.

cvts3~_1 with *cvts3_61_2*
cvts3~_3 with *cvts3_61_2*

In this case, on the one hand, the higher is the direct cost the higher is the corrected direct cost and, on the other hand, the higher is the Labour Cost per participants the higher is the direct cost. Within the two pairs, the two indicators measure a very similar concept and for this reason the indicator cvts3_61_2 is deleted from the analysis.

Other pairs of indicators with high correlation coefficient are those providing gender breakdown for the same aspect. This high correlation was in some sense expected leading to these indicators be maintained in the analysis.

Table 3 - Correlation Matrix

	3_06	3_42_M	3_42_M	3_71	3_54	61_1	61_2	61_3	part_2~m	part_2~f
cvts3_06	1									
cvts3_42_M	0,70	1								
cvts3_42_F	0,74	**0,94**	1							
cvts3_71	0,69	**0,93**	**0,92**	1						
cvts3_54	0,60	0,56	0,64	0,71	1					
cvts3_61_1	**0,81**	0,50	0,62	0,60	0,75	1				
cvts3_61_2	**0,84**	0,60	0,70	0,74	0,69	**0,88**	1			
cvts3_61_3	0,70	0,71	0,78	**0,85**	0,57	0,74	**0,85**	1		
part_2564_m	0,76	0,39	0,50	0,45	0,44	0,64	0,70	0,56	1	
part_2564_f	0,69	0,29	0,41	0,33	0,36	0,56	0,58	0,44	**0,98**	1

3. Methodological assumptions.

Nardo et al. (2005) define a composite indicator as "a mathematical combination of individual indicators that represent different dimensions of a concept whose description is the objective of the analysis" (p.7). Following this logic, we summarise the concept of Lifelong Learning into one number that encompasses all its different dimensions. To create this composite indicator the methodological guidelines of Nardo et al. (2005) were thoroughly followed.

Given that a composite indicator is ultimately the sum of all its parts, the methodological assumptions made during its construction must be clear and well justified. In general, if supported by a theoretical framework, any methodological decision can be taken but it should be discussed and evaluated based on its effectiveness. In this case the decision we should take refers to:

a) the structure of the composite indicator
b) the aggregation rule
c) the standardization formula
d) the weighting system

Based on the theoretical framework developed in cooperation with the flexicurity team of DG Employment, the composite indicator has been constructed following the methodological assumptions specified below:

The structure of the composite indicator.

The structure of the composite indicator is very simple. It was decided not to include different levels of aggregation of the indicators. The composite indicator is computed putting all input indicators at the same level. Figure 1 shows the structure of the composite indicator (the reader should refer to table 1 for full indicator names).

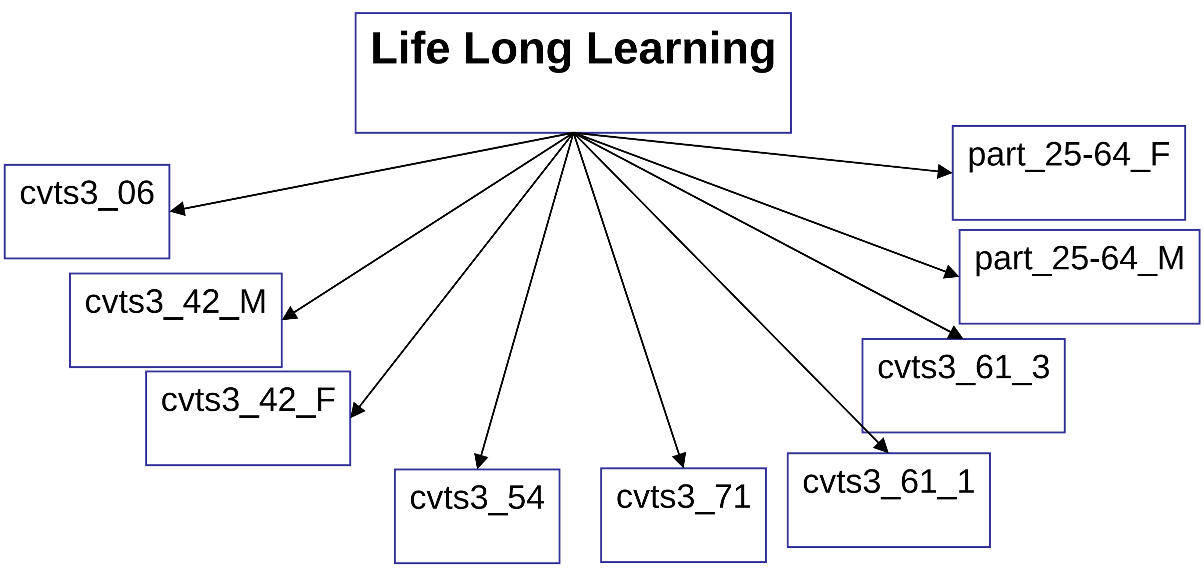

Figure 1 – The structure of the LLL composite Indicator

Different structure will be discussed and tested in the sensitivity analysis section by changing the weighing scheme.

The aggregation rule

The issue of aggregation of the information conveyed by the different dimensions into a composite index comes together with the weighting. Different aggregation rules are possible.
Sub-indicators could be summed up (e.g. linear aggregation), multiplied (geometric aggregation) or aggregated using non linear techniques (e.g. multi-criteria analysis). Each technique implies different assumptions and has specific consequences.

In this paper we use a simple linear aggregation rule where the basic indicators are aggregated using the following formula:

$$Y_c = \sum_{i=1}^{n} w_i I_{ic}$$

Where *w* are the weights, *I* the basic indicators, *c* the country index and *n* the total number of indicators. Different aggregation rules have been tested within the sensitivity analysis.

The standardization scheme

Because the 9 basic indicators are expressed on different scales, a standardization process is needed before the data for the different indicators can be aggregated. Different standardization techniques are available (Nardo et al., 2005). The basic standardization technique that will be applied is the Min-Max approach. For q indicators each indicator will be standardized based on the following rule

$$I_{qc} = \frac{x_{qc} - \min_c(x_{qc})}{\max_c(x_{qc}) - \min_c(x_{qc})} \cdot 1000 .$$

Using this method, all indicators have been rescaled and the standardized values lie between 0 (laggard $x_{qc}=\min_c(x_q)$) and 1000 (leader, $x_{qc}=\max_c(x_q)$). In order to assess the robustness of the composite indicator alternative standardization methods are applied in the context of the uncertainty and sensitivity analysis.

The weighting scheme.

After the standardization process, data were checked in order to ensure that for every indicator a higher score would point to a better performance of the country. This step was clearly necessary to make a meaningful aggregation of the different indicators but in our case no transformation was needed.

The weighting scheme adopted for the construction of the Life Long Learning Composite Indicator strictly follows the suggestion addressed in the LIME project. All the indicators were assigned the same weights (100). Indicators referred to gender (Male and Female) were given the weight of 50. All the weights have been then rescaled to sum 1.

In table 4 the list of the weights are presented.

Table 4 - Weighting scheme of the LLL composite indicator

Indicators and Dimensions	short name	weight
Percentage of firms providing CVT		
Percentage of enterprises providing CVT courses	trng_cvts3_06	100
Participation in CVT		
Percentage of employees (all enterprises) participating in CVT courses - Male	trng_cvts3_42_M	50
Percentage of employees (all enterprises) participating in CVT courses - Female	trng_cvts3_42_F	50
Hours in CVT courses per employee (all enterprises)	trng_cvts3_71	100
Investment in CVT		
Cost of CVT courses as % of total labour cost (all enterprises)	trng_cvts3_54	100
Cost of CVT courses per employee (all enterprises) - Corrected Direct Cost	trng_cvts3_61_1	100
Cost of CVT courses per employee (all enterprises) - Labour Cost of Participants	trng_cvts3_61_3	100
LifeLong Learning		
Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey); Male.	part_25-64_M	50
Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey); Female.	part_25-64_F	50

4. Results

Having defined the structure, the weighting scheme and the standardization procedure, the computation of the Life Long Learning Composite indicator can be performed. In this section the results of the LLL composite indicator are presented – first - examining the results of each dimension and then presenting the results of the combined index.

The overall performance of the Life Long Learning Composite Indicator

Using the Dashboard software, the results of the aggregation of the indicators are shown in figure 2 and 3.

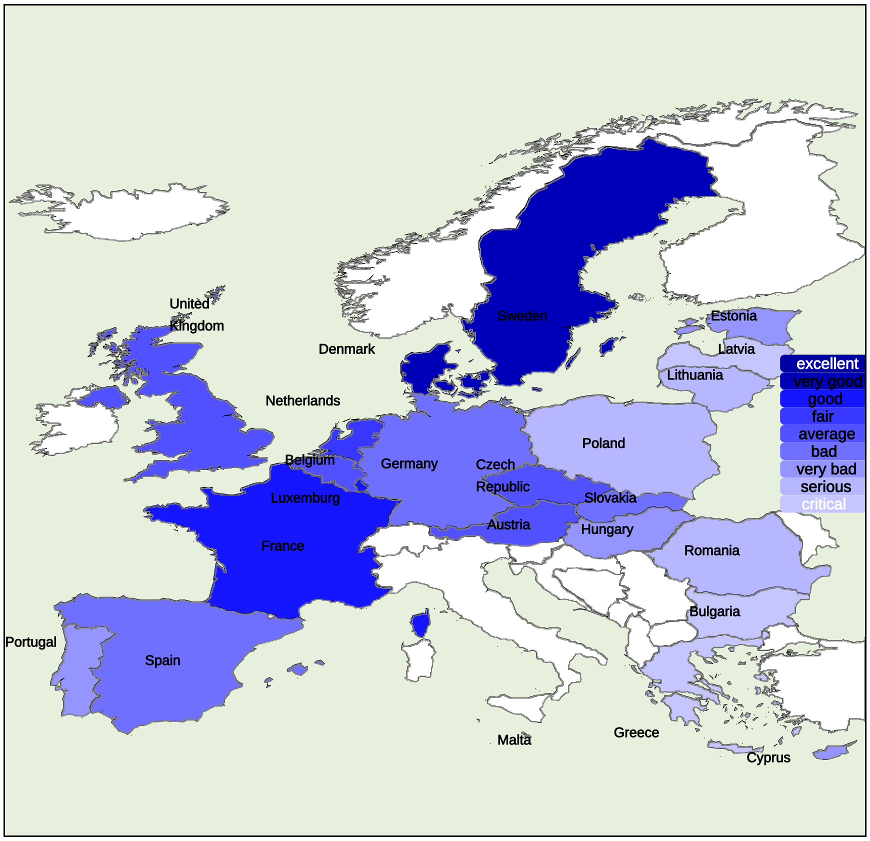

Figure 2 - Map of the LLL composite indicator (Green: good performance, Red: poor performance).

The map represents the overall index distribution. Red colour means an overall bad performance of the country. On the other hand, green colour is assigned for top performance countries. As we see, Nordic Countries such as Denmark and Sweden rank at the top of the league, followed by France, Luxembourg and the Netherlands. Then, Czech Republic over-performs the rest of Eastern Europe achieving an overall good performance, followed by Belgium, Austria and the United Kingdom. On the other hand Germany exhibits a worse performance than the rest of Central Europe, whereas Spain performs better than the rest of Mediterranean countries. Finally, Eastern and Southern European Member States fall at the bottom of the ranking.

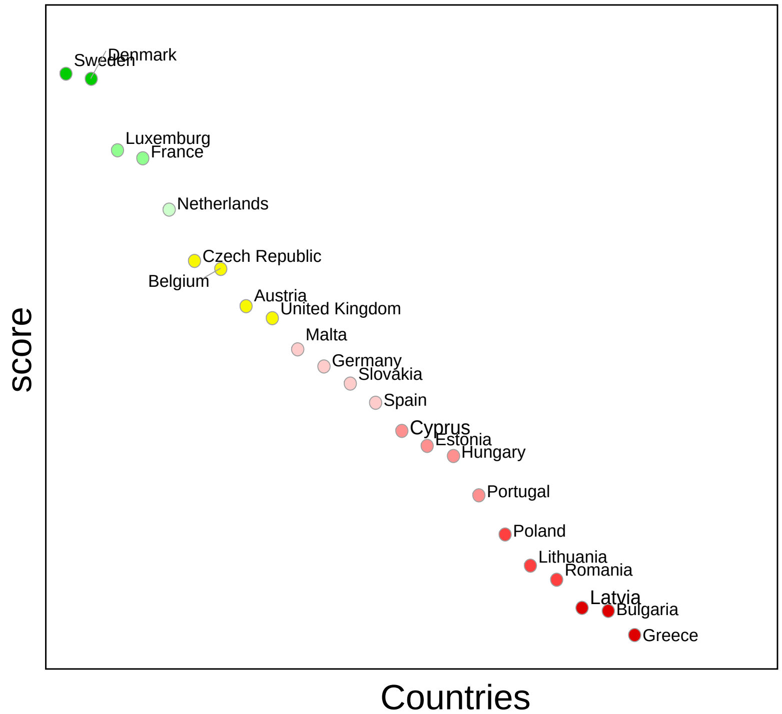

Figure 3 – Distribution of the score of the LLL composite Indicator.

Table 5 - Country ranking of the LLL composite Indicator.

Rank	Points	Country
1	808	Sweden
2	801	Denmark
3	703	Luxemburg
4	692	France
5	621	Netherlands
6	551	Czech Republic
7	539	Belgium
8	488	Austria
9	472	United Kingdom
10	429	Malta
11	405	Germany
12	382	Slovakia
13	356	Spain
14	317	Cyprus
15	296	Estonia
16	282	Hungary
17	228	Portugal
18	175	Poland
19	131	Lithuania
20	113	Romania
21	74	Latvia
22	69	Bulgaria
23	37	Greece

The distribution of the scores is presented in figure 3 and table 5. Both highlight the overall good performance of Nordic Countries, which achieve a very high score compared with the other countries, together with France, Luxembourg and the Netherlands. All remaining countries tend to be closer to each other in terms of score values. The sensitivity analysis will show the robustness of the composite indicator.

5. The Life Long Learning Composite Indicator Uncertainty and Sensitivity analysis

The robustness of the LLL cannot be fully assessed without evaluation of uncertainties underlying the index and an evaluation of the sensitivity of the country scores and rankings to the methodological approaches utilized. A summary of the uncertainty analysis follows. The more detailed version is included in the Annex.

Every composite index, including the LLL, involves subjective judgments such as the selection of indicators, the choice of aggregation model, and the weights applied to the indicators. As the quality of an index depends on the soundness of its assumptions, good practice calls for evaluating confidence in the index and assessing the uncertainties associated with its development process. To ensure the validity of the policy conclusions drawn from the LLL, it is important to analyze the sensitivity of the index to alternative methodological assumptions.

While uncertainty analysis deals with the assessment of the uncertainty of a model by propagating the sources of uncertainty and providing an overview of the different sources of variability and their impact on the composite indicator, the aim of sensitivity analysis is to estimate the rate of change in the output of a model with respect to changes in model inputs. Such knowledge is important for (a) evaluating the applicability and the robustness of the model, (b) determining parameters for which it is important to have more accurate values, and (c) understanding the behavior of the system being modeled.

Sensitivity analysis also demonstrates how each indicator depends upon the information that composes it. It is thus closely related to uncertainty analysis, which aims to quantify the overall uncertainty in a country's score (or rank) as a result of the uncertainties in the index construction. A combination of uncertainty and sensitivity analyses can help to gauge the robustness of the LLL results, to increase the LLL's transparency and to help frame the debate around the use of the index.

The validity of the LLL scoring and respective ranking is assessed by evaluating how sensitive it is to the assumptions that have been made for the construction of the composite indicator. These four sources of uncertainty exist and their combined effect on country rankings needs to be tested for this reason we tried to tackle all possible sources of uncertainty, which arise from:

1) Data Normalization
2) Weighting Scheme
3) Composite Indicator Formula (Aggregation Rule)
4) Inclusion/Exclusion of Basic Indicators

The essential point of the methodology used for the uncertainty analysis is based on computer simulations. The four sources of uncertainty are turned into 4 input factors with uniform probabilities across the different alternatives, i.e. different approaches and methods see table 6, then all possible combinations of input factors are run, delivering in total 126 simulations with corresponding set of indicators values and country rankings.

Table 6 - uncertainty factors for the LLL composite indicator

X_1	Standardization
1	Z-Score
2	Min-Max
3	Ranking across countries

X_2	Weighting Scheme
1	Equal Weight
2	Predetermined set of Weights
3	PCA weights
4	DEA weights

X_3	Aggregation Rule
1	Linear
2	Geometric
3	No further Aggregation (for DEA)

X_4	Excluded Sub-Indicator
1	Indicator 1 omitted
2	Indicator 2 omitted
3	Indicator 3 omitted
4	Indicator 4 omitted
5	Indicator 5 omitted
6	Indicator 6 omitted
7	Indicator 7 omitted
8	Indicator 8 omitted
9	Indicator 9 omitted
10	No indicator omitted

Although the total number of the combinations of uncertainty factors is equal to 360, the number of combinations producing a valid scenario are equal to 126. So that, for every country the results of the distribution of their rankings achieved in the 126 simulations are presented. The variability of these distributions can be considered as the impact of the uncertainty in the composite indicator. We discuss ranks and not scores because non-parametric statistics are more appropriate in our case given the non-normal character of the data and the scores. The results of the simulations are organized in a frequency matrix and the overall LLL is calculated across the 126 scenarios. Besides the frequency matrix, the median rank per country was selected as benchmark to be compared with the rank recorded in the LLL composite indicator.

On figure 4 the frequency distribution of a country rank is presented. These frequencies are estimated over the 126 different scenarios. A colour code summarize s the frequencies as follows in table 7:

Table 7 - Colour Codes

(white)	Frequency lower than 15%
(light grey)	Frequency between 15% and 30%
(grey)	Frequency between 30% and 50%
(dark grey)	Frequency higher than 50%
bold	Position in the LLL composite indicator
Italic	median
orange	mode of the distribution

Moreover, **Bold**, *Italic* and Orange represent the country rank in the LLL composite indicator, the median and the mode of the 126 simulations respectively. For example Austria has a distribution encoded as follows, Table 8:

Table 8 - Austria performance in the 126 scenarios

	Rank 5	Rank 6	Rank 7	Rank 8	Rank 9	Rank 10	Rank 11	Rank 12	Rank 13
AUT	0	8	29	***56***	32	1	0	0	0

This means that the country is ranked in position 6th and 10th for 8 and 1 time respectively, with a frequency lower than 15%. Moreover the country is ranked in position 7th and 9th for 29 and 32 times respectively with a frequency between 15% and 30%. Finally Austria is ranked in position 8th for 56 times, which correspond to a frequency between 30% and 50% and position 8th is the mode, the median and position of the country in the LLL composite indicator. On figure 4 the results of the uncertainty analysis are shown.

	SWE	DNK	LUX	FRA	NLD	CZE	BEL	AUT	GBR	MLT	DEU	SVK	ESP	CYP	EST	HUN	PRT	POL	LTU	ROM	LVA	BGR	GRC
Rank 1	102	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rank 2	24	83	18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rank 3	0	15	62	40	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rank 4	0	4	41	69	9	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rank 5	0	0	5	15	93	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rank 6	0	0	0	1	14	35	59	8	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rank 7	0	0	0	0	0	37	47	29	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rank 8	0	0	0	0	0	27	15	56	24	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Rank 9	0	0	0	0	0	13	5	32	57	11	5	1	2	0	0	0	0	0	0	0	0	0	0
Rank 10	0	0	0	0	0	0	0	1	17	48	45	2	14	0	0	0	0	0	0	0	0	0	0
Rank 11	0	0	0	0	0	0	0	0	3	19	42	35	27	0	0	0	0	0	0	0	0	0	0
Rank 12	0	0	0	0	0	0	0	0	1	28	28	42	26	0	0	0	0	0	0	0	0	0	0
Rank 13	0	0	0	0	0	0	0	0	0	17	6	41	57	5	0	0	0	0	0	0	0	0	0
Rank 14	0	0	0	0	0	0	0	0	0	0	0	5	0	120	0	1	0	0	0	0	0	0	0
Rank 15	0	0	0	0	0	0	0	0	0	0	0	0	0	1	105	18	2	0	0	0	0	0	0
Rank 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	65	40	0	0	0	0	0	0
Rank 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	84	2	0	0	0	0	0
Rank 18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	124	0	0	0	0	0
Rank 19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	121	5	0	0	0
Rank 20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	110	11	0	0
Rank 21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	73	33	9
Rank 22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	53	36
Rank 23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	40	81
Total	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126

Figure 4 - Results of the Uncertainty Analysis, ranking distribution per country

A first consideration is that the overall ranking is quite stable; in fact considering the whole 126 simulations all countries clustered unambiguously. Sweden, Denmark, Luxembourg, France and the Netherlands stand out as top performers. Then, Czech Republic, Belgium, Austria, United Kingdom, Malta, Germany, Slovakia and Spain follow the leaders and they show the highest variability. All remaining countries exhibit a relatively bad performance and their ranking is very stable across all 126 scenarios.

In the relevant literature, the median rank is proposed as a summary measure of a rank distribution. The median rank of all combinations of assumptions indicates that for 20 out of 23 countries the LLL rank corresponds with the most likely (median) rank. For the remaining countries the difference between the LLL rank and the most likely (median) rank is less than 2 positions. So that, for all the countries studied, the very modest sensitivity of the LLL ranking to the four input factors (standardization, weighting scheme, aggregation rule and inclusion/exclusion of a single indicator) implies a considerably high degree of robustness of the index for all countries. In sum the overall performance of the LLL composite indicator appears to be very robust especially if compared with other indices presented in the literature.

7. Conclusions

As a first step in the process of construction of a set of composite indicators on flexicurity, this paper presents a Life Long Learning Composite Indicator. Life Long Learning is one of the main four dimensions of Flexicurity according to relevant Commission policy documents (see COM(2007) 359). Based on the recommendation addressed in the LIME project, 9 basic indicators have been selected for the construction of the composite indicator relying upon institutional data sources such as Eurostat LFS and Eurostat CVTS. Although the indicators appear to be affected by a considerable correlation, the standardization has been performed using the MinMax approach and the weighting scheme adopted follows the guideline addressed in the LIME project. Results show a heterogeneous Europe with an overall good performance of Nordic countries, while Eastern and Southern European countries have less favourable scores. Uncertainty and sensitivity analysis have been performed in order to test the robustness of the Composite Indicator. In sum, this index appears to be very robust if compared with average performance of similar indicators that have recently appeared in the literature. The results of the uncertainty analysis are based on 126 different simulated scenarios, generated by considering different options with respect to standardization methods, weighting scheme, aggregation rules and the inclusion/exclusion of basic indicators. The results show an overall robustness of the composite indicator, as for 20 countries out of 23, the variability of ranking does not exceed a range of three positions, corresponding to approximately 13% of the total number of countries. Countries showing a higher variability are Czech Republic, Germany and United Kingdom which lie in the middle of the ranking.

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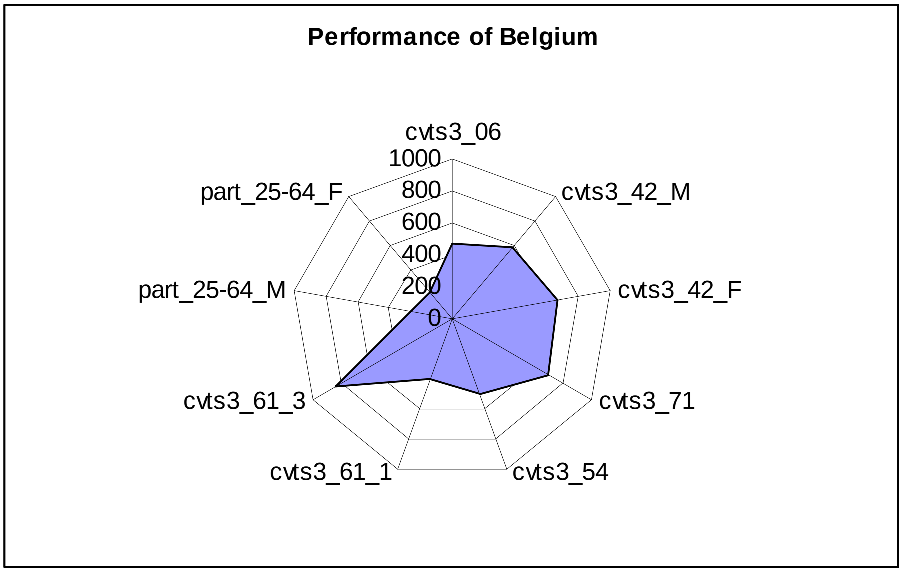
ANNEX 1
COUNTRY PROFILES

Country Profiles

In this section we analyse the country profiles for the 9 basic indicators of the Life Long Learning Composite Indicator and the robustness of the ranking achieved by the country. In order to ensure the comparability of the performances, the normalized values of the set of basic indicators is represented using a radar plot, where the higher is the value of the indicator, the best is the performance of the country in that indicator. The basic indicators are listed using their short name, for the complete name please see Table 1. In addition the robustness of the ranking performance of the country is presented with the results of the uncertainty and sensitivity analysis.

Belgium

Belgium is ranked in the 7th position of the overall ranking of the Life Long Learning Composite Indicator. Belgium performs quite well in the "*Cost of CVT courses per employee (all enterprises) - Labour Cost of Participants*" were the 3rd position is achieved. On other hands a bed performance for Belgium is recorded for the female participation in Life Long Learning.

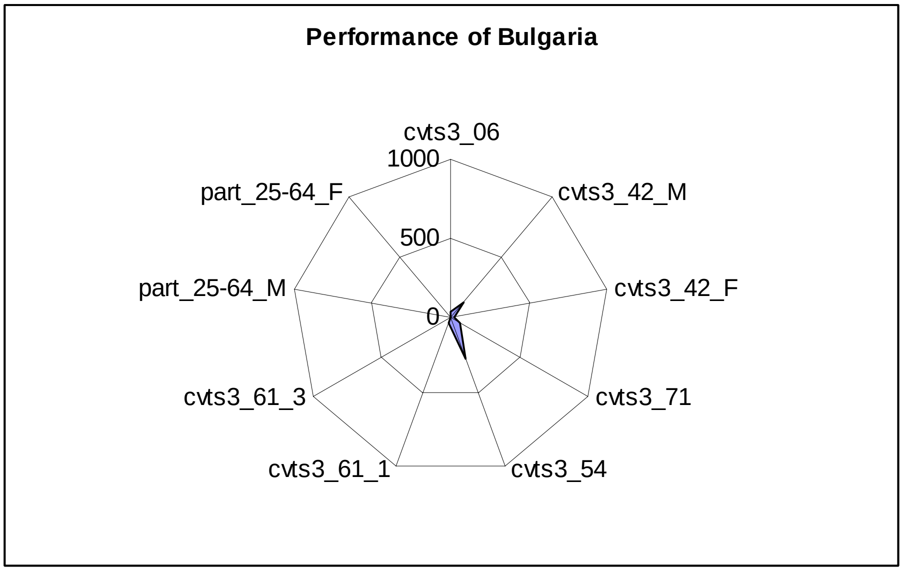


The ranking of Belgium is quite robust, the median of the distribution of the 126 simulations correspond to the position in the ranking of LLL composite indicator. On other hands the mode of the distribution is on position 6th. The rank of Belgium varies from the 6th position to the 9th position but most of the observations (84%) are focused on positions 6th and 7th.

Rank	5	6	7	8	9	10
Frequency N	0	59	47	15	5	0
Frequency %	0.00	46.83	37.30	11.90	3.97	0.00

Bulgaria

Bulgaria is ranked in the 22nd position of the overall ranking. Bulgaria performs not well in many of the basic indicators of the Life Long Learning Composite Indicator. The best result of Bulgaria is achieved for the basic indicator of *"Cost of CVT courses as % of total labour cost (all enterprises)"* and in the *"Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey); Male"* where the 19th position is achieved.

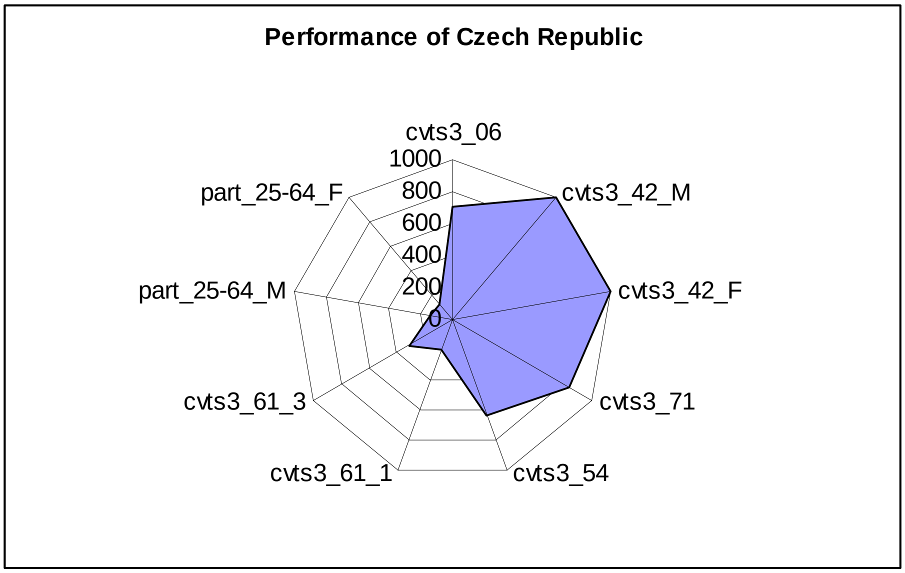


The performance of Bulgaria is robust in the uncertainty analysis and the position of the countries varies from position 21st to 23rd and the frequencies of the simulations are spread among these three values. The median and the mode of the distribution correspond to the position of the country achieved in the LLL composite indicator (22nd).

Rank	20	21	22	23
Frequency N	0	33	53	40
Frequency %	0.00	26.19	42.06	31.75

Czech Republic

Czech Republic is ranked in the 6th position of the overall ranking of the Life Long Learning Composite indicator. This good performance is driven by a top performance in the basic indicators of "*Percentage of employees (all enterprises) participating in CVT courses both* for male and female, and that of "*Percentage of enterprises providing CVT courses*" where the 7th position is achieved. On other hands, a bad performance is recorded for the indicators of "*Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey)*" both for male and female.

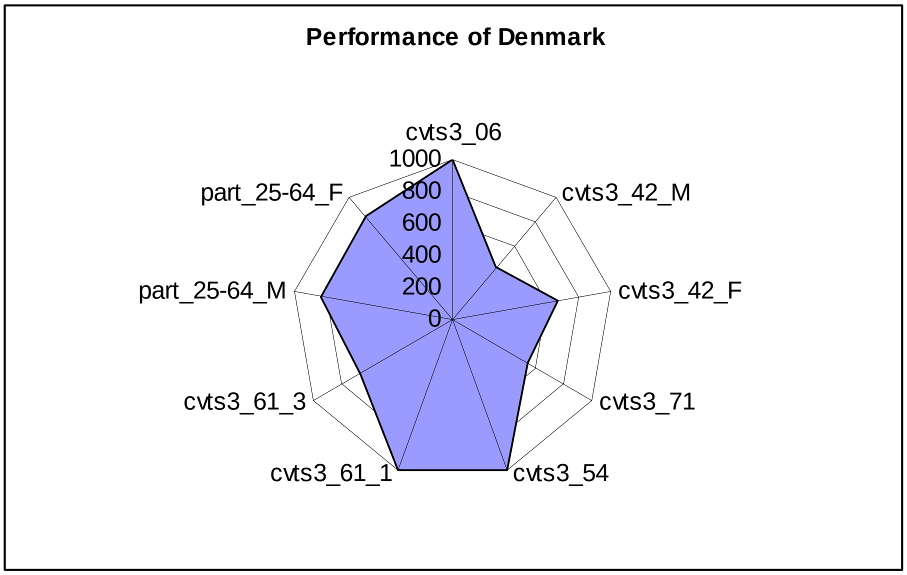


The performance of Czech Republic in the uncertainty analysis is not very robust and is one of the countries showing a consistent variability in ranking. The performance of Czech Republic varies from the 4th to the 9th position even if the frequencies of the simulations are concentrated among position 6th and 8th. For the Czech Republic the mean and the mode of the distribution fall in the 7th position when the country occupies the 6th position in the LLL composite indicator, this proved the consistent variability which affects the Czech Republic performance.

Rank	3	4	5	6	7	8	9	10
Frequency N	0	1	13	35	37.00	27	13	0
Frequency %	0.00	0.79	10.32	27.78	29.37	21.43	10.32	0.00

Denmark

Denmark is one of the top performers of the Life Long Learning Composite Indicator achieving the 2nd position in the ranking. This performance is mainly driven by a very good performance in the basic indicators which measure investments in CVT as the *"Cost of CVT courses per employee (all enterprises) - Direct Cost"* and *"Cost of CVT courses as % of total labour cost (all enterprises)"*. A very good performance is also recorded or the basic indicators monitoring *"Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey)"* both for male and female.

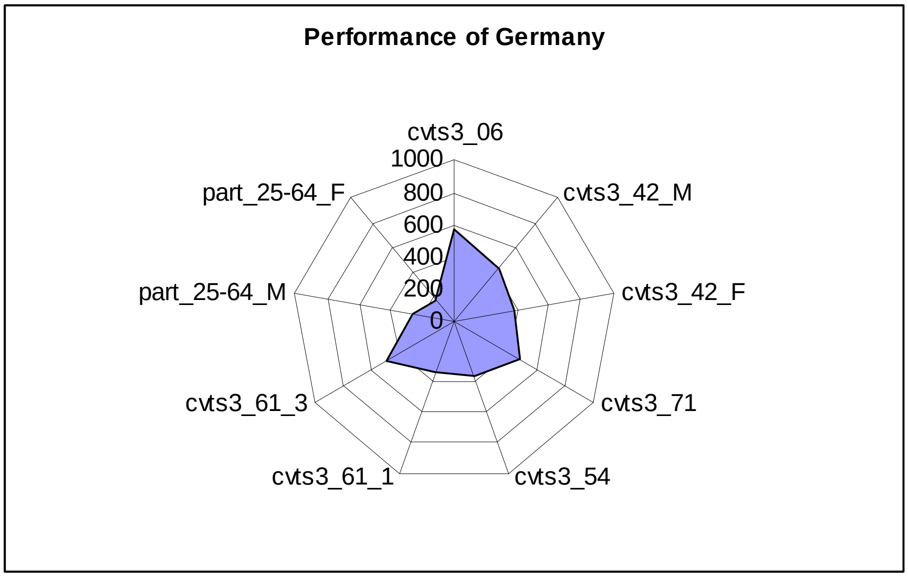


The performance of Denmark in the uncertainty analysis is quite robust and stable. The position of Denmark varies from the 1st to the 3rd with a high concentration on the 2nd (66%). The median and the mode of the distribution correspond with the position occupied by the country in the LLL composite indicator (2nd). In 24 simulations Denmark is the top of the ranking by swapping its position with Sweden.

Rank	1	2	3	4	5
Frequency N	24	83	15	4	0
Frequency %	19.05	65.87	11.90	3.17	0.00

Germany

The Germany performance is not very good compared with that of Nordic countries or of the other central European countries. In fact Germany achieved just the 11th position of the overall ranking Life Long Learning Composite Indicator. The performances of Germany are in some sense constant for each basic indicator. By the way, the best performance is achieved for the indicator of "*Percentage of enterprises providing CVT courses*" where is ranked at the 10th position, on other hands, in terms of score, the worse performance is recorder for the female *"Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey)"*.

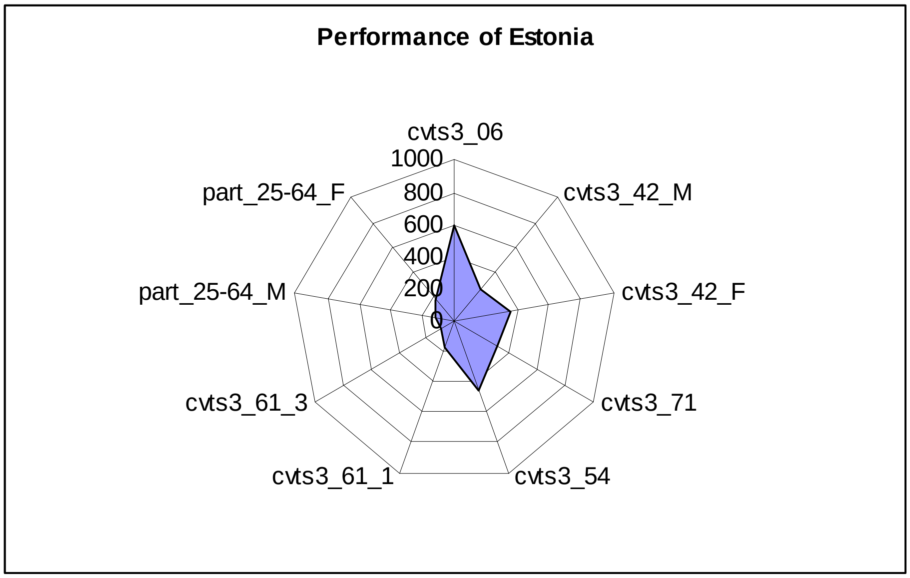


The performance of Germany in the uncertainty analysis shows a considerable variability in the ranking positions, which varies from the 9th to the 13th, even if the 90% of observations are recorded from the 10th to 12th position. For Germany the median of the distribution (11th) corresponds with the ranking recorded in the LLL composite indicator. On other hand, the mode falls in 10th position.

Rank	8	9	10	11	12	13	14
Frequency N	0	5	45	42	28	6	0
Frequency %	0.00	3.97	35.71	33.33	22.22	4.76	0.00

Estonia

The Estonia performance is quite good especially compared with the other performances of the Eastern European member states. Estonia is ranked at the 15 position of the overall ranking. The Estonia performance is driven by a remarkable results in the *"Percentage of enterprises providing CVT courses"* where the 9th position is achieved and in the *"Cost of CVT courses as % of total labour cost (all enterprises)"* where the country is ranked at the 11th position. On other hands, a not brilliant result is obtained for the indicators of *"Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey)"* both for male and female.

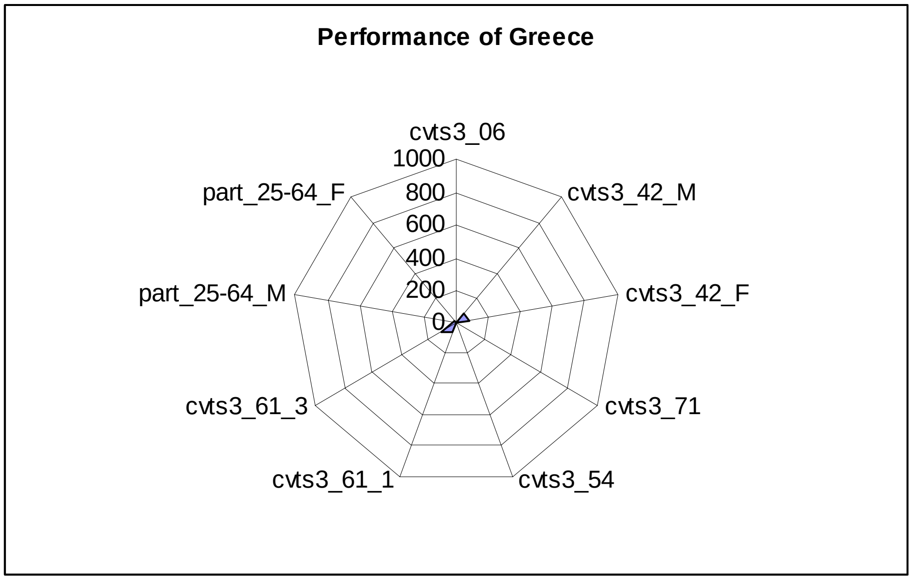


The performance of Estonia is indubitably very robust and stable. On 105 simulations out of 126, the position of Estonia is confirmed as the 15th position. The median and the mode of the distribution coincide with the 15th position which is the position recorded in the LLL composite indicator.

Rank	14	15	16	17
Frequency N	0	105	21	0
Frequency %	0.00	83.33	16.67	0.00

Greece

Greece is unfortunately the laggard of the overall ranking of the Life Long Learning Composite Indicator. The bad performance of Greece is driven by a poor performance in all the basic indicators. Anyway, the best performance of Greece is achieved for the dimensions of "*Cost of CVT courses per employee (all enterprises) - Labour Cost of Participants"* and "*Percentage of employees (all enterprises) participating in CVT courses*", both for male and female, where the 18th and 22nd positions are respectively achieved.

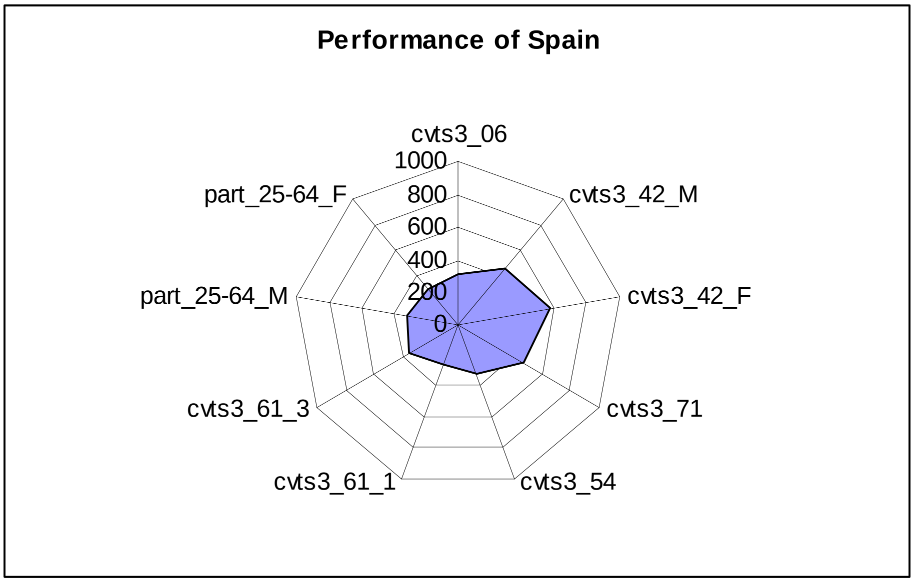


The performance of Greece is robust in the uncertainty analysis and the position of the countries varies from position 21st to 23rd. Although the frequencies are concentrated on position 23rd, 63%, the frequencies of the simulations are spread among these three values. The median and the mode of the distribution correspond to the position of the country achieved in the LLL composite indicator, 23rd.

Rank	20	21	22	23
Frequency N	0	9	36	81
Frequency %	0.00	7.14	28.57	64.29

Spain

Spain is ranked at the 13th position of the overall ranking and its performance is the best among the Southern European countries. The good performance of Spain is mainly due by a good performance in the female *"Percentage of employees (all enterprises) participating in CVT courses"* and in the *"Hours in CVT courses per employee (all enterprises)"* where the 8th and 10th position are respectively achieved. In terms of ranking, the performance of Spain is also very good for the dimension of "*Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey)"* both for male and female where the 6th position is achieved.

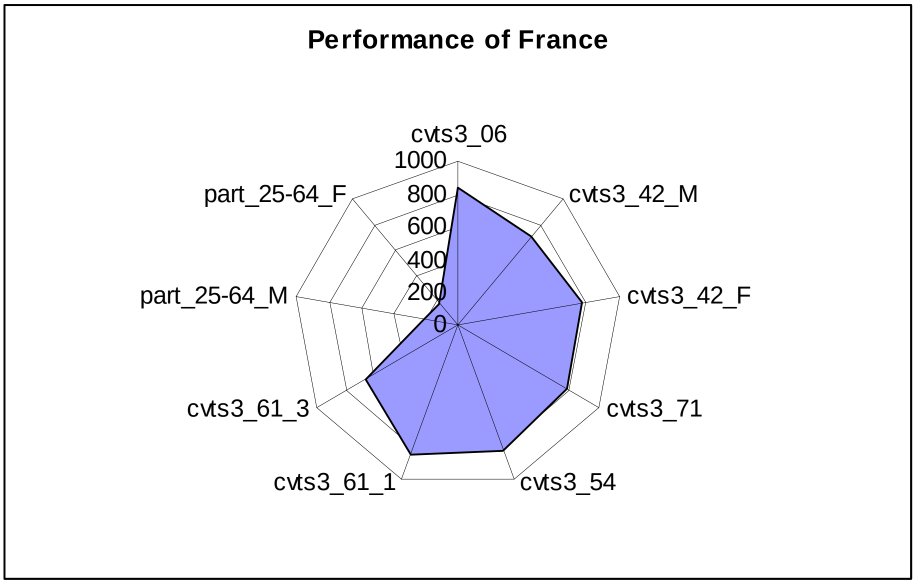


The performance of Spain in the uncertainty analysis shows a consistent variability in the ranking positions, which varies from the 9th to the 13th. By the way, the 86% of observations are recorded from the 11th to 13th position. For Spain the median of the distribution of the simulation (12th) does not correspond with the ranking recorded in the LLL composite indicator (13th) which is the mode of the distribution of the 126 simulations.

Rank	8	9	10	11	12	13	14
Frequency N	0	2	14	27	26	57	0
Frequency %	0.00	1.59	11.11	21.43	20.63	45.24	0.00

France

France shows a very good performance and is ranked at the 4th position of the overall ranking of Life Long Learning composite indicator. This good performance is driven by excellent results most of the dimensions, especially in that of "*Cost of CVT courses as % of total labour cost (all enterprises)*", "*Cost of CVT courses per employee (all enterprises) - Corrected Direct Cost*" and "*Percentage of enterprises providing CVT courses*" where the 3rd position is achieved. On other hands, a not good performance is recorded by France for the dimension of "*Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey);*" both for male and female.

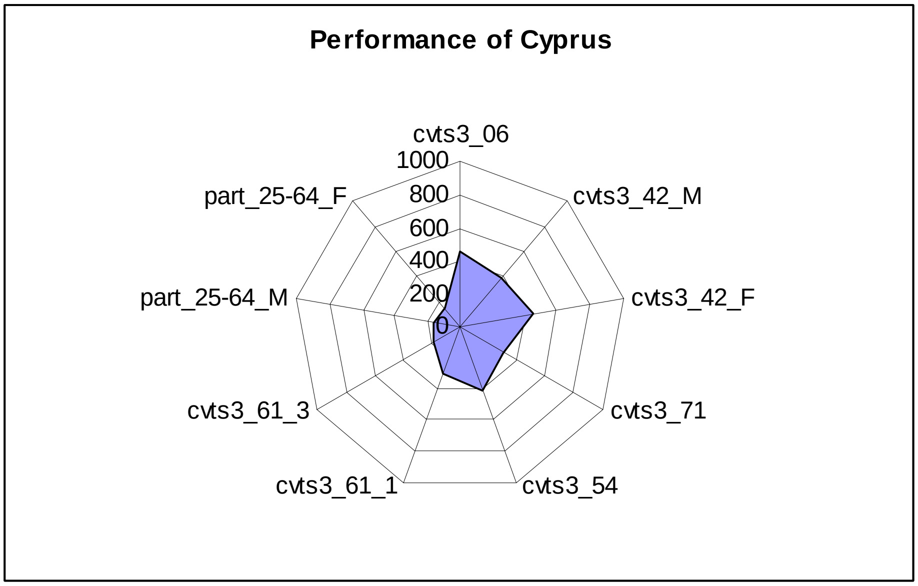


The performance of France is quite stable. Although the position of the country varies from the 2nd to the 6th position, it is worth noticing that the 85% of the simulations fall between the 3rd and the 4th position. The median and the mode of the distribution of the 126 simulations fall in the 4th position which is the position recorded in the LLL composite indicator.

Rank	1	2	3	4	5	6	7
Frequency N	0	1	40	69	15	1	0
Frequency %	0.00	0.79	31.75	54.76	11.90	0.79	0.00

Cyprus

Cyprus is ranked at the 14th position, just after Spain, of the overall ranking. Compared with the performances of other Mediterranean countries the performance of Cyprus can be considered as very good. The best performance of this country is achieved in the indicator of "*Percentage of enterprises providing CVT courses*" and in the female "*Percentage of employees (all enterprises) participating in CVT courses*" where it is ranked at the 12th position. On other hands, in terms of ranking, Cyprus worst performance is recorded for the dimension of "*Hours in CVT courses per employee (all enterprises)*" where the 17th position is achieved.

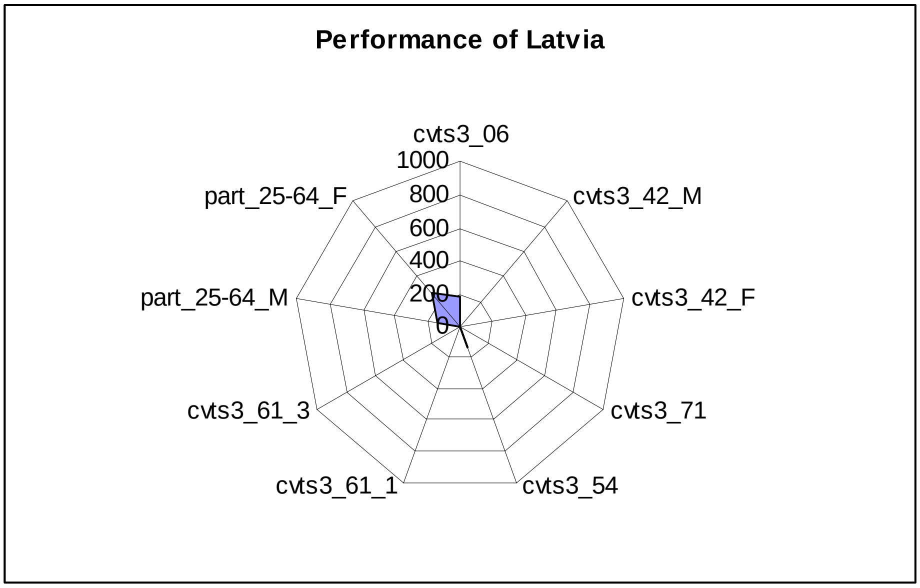


The performance of Cyprus is very robust as confirmed in the sensitivity analysis. Cyprus is ranked in the 14th position in 120 out of 126 simulations, which corresponds to the 95% of the total frequencies. The median and the mode of the distribution correspond to the 14th position which is the position achieved by the country in the LLL composite indicator.

Rank	12	13	14	15	16
Frequency N	0	5	120	1	0
Frequency %	0.00	3.97	95.24	0.79	0.00

Latvia

The performance of Latvia is not good and the country is ranked at the 21st position of the overall ranking, in line with the performances of the rest of the Eastern European Countries. Anyway, Latvia best performance is achieved for the dimensions of "*Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey);*" both for male and female, where the country respectively achieve a surprisingly 14th and 7th position. An encouraging performance is also recorded for the indicator of "*Percentage of enterprises providing CVT courses*" where the country is ranked at the 18th position.

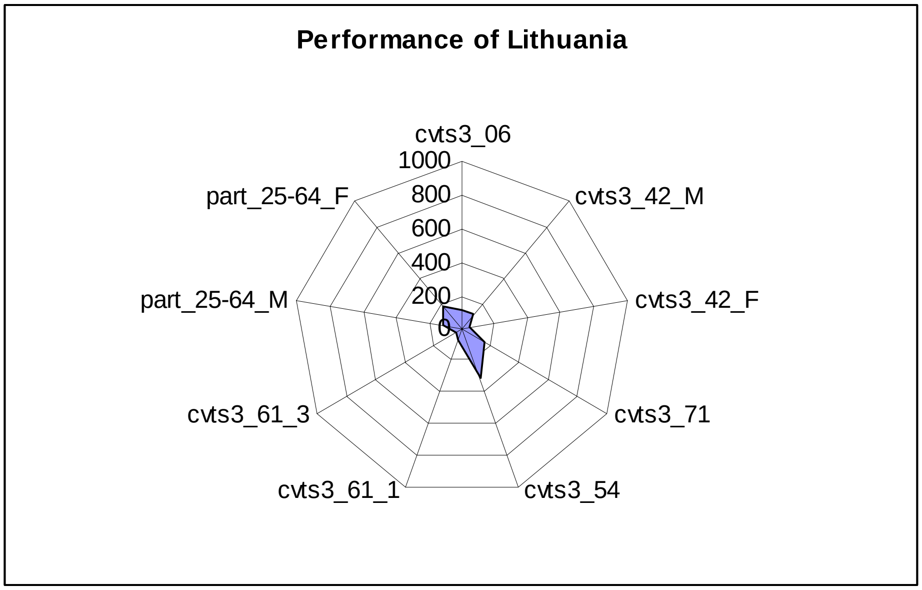


The performance of Latvia is quite stable and the 58% of the simulations falls in the 21st position of the ranking. The position of Latvia varies from the 20th to the 23rd. The median and the mode of the distribution of the simulations are recorded in the 21st position, which correspond the position achieved by Latvia in the LLL composite indicator.

Rank	19	20	21	22	23
Frequency N	0	11	73	37	5
Frequency %	0.00	8.73	57.94	29.37	3.97

Lithuania

Lithuania is ranked at the 19th position of the overall ranking of the Life Long Learning Composite Indicator. The best performance achieved by Lithuania is in the indicator of female "*Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey);*" where the country is ranked at the 10th position. A good performance in terms of score is also achieved for the indicator of "*Cost of CVT courses as % of total labour cost (all enterprises)*".

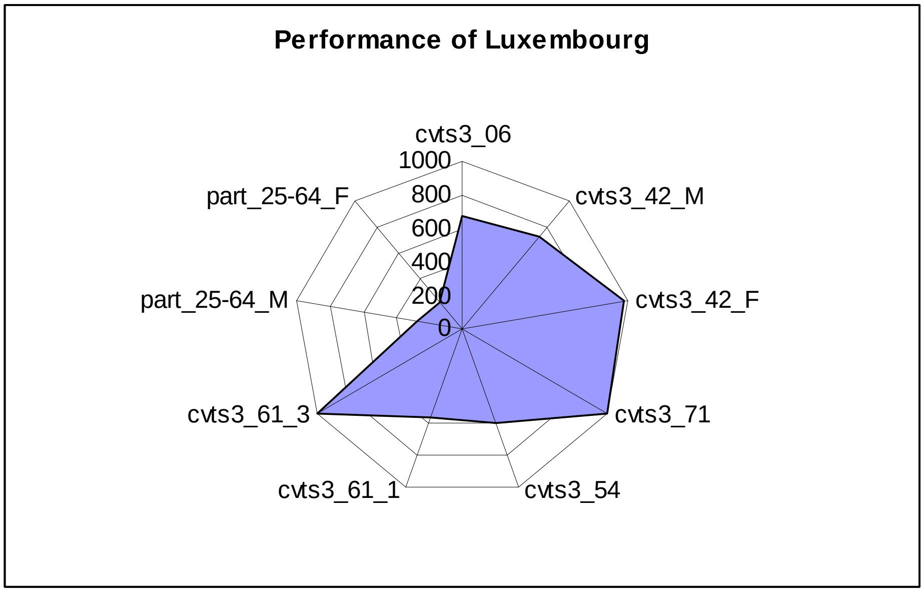


The performance of Lithuania is very robust. The country is ranked in the 19th position in 121 out of 126 simulations, which corresponds to the 96% of the total frequencies. The median and the mode of the distribution correspond to the 19th position which is the position achieved by the country in the LLL composite indicator.

Rank	18	19	20	21
Frequency N	0	121	5	0
Frequency %	0.00	96.03	3.97	0.00

Luxembourg

Luxembourg is one of the top performers of the overall ranking of the Life Long Learning Composite Indicator with an achieved 3rd position. The performance of Luxembourg is mainly driven by top performances in the dimensions of "*Hours in CVT courses per employee (all enterprises)*" and "*Cost of CVT courses per employee (all enterprises) - Labour Cost of Participants*". An excellent performance is also recorded for the dimension of female "*Percentage of employees (all enterprises) participating in CVT courses*" *where the country is the 2nd position of that ranking.* On other hand, Luxembourg worst performance is achieved for the dimensions of "*Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey);*" both for male and female.

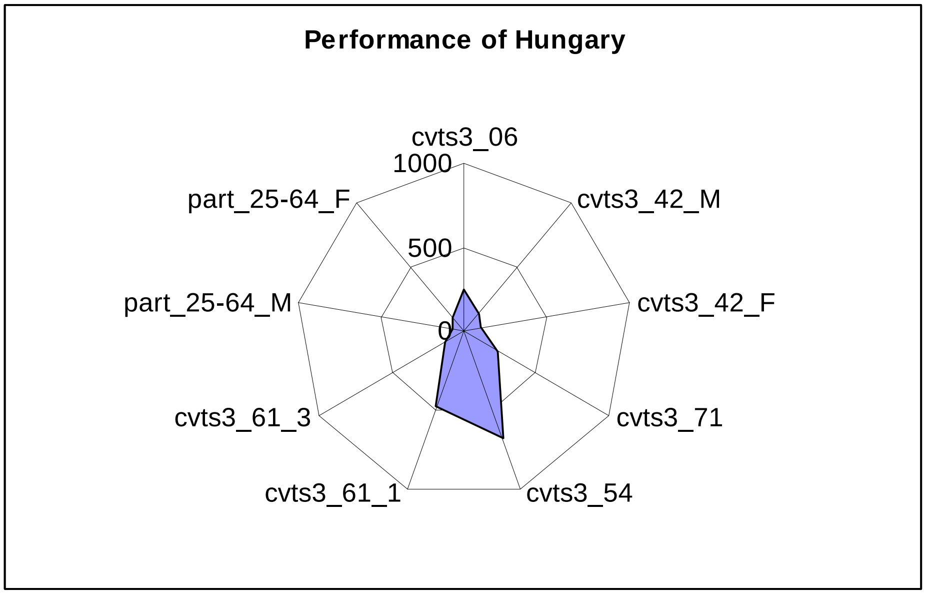


The position of Luxembourg is stable and the country position varies from the 2nd to the 5th position. By the way, most of the observations are recorded in the 3rd position (49%). The median and the mode of the distribution are recorded in the 3rd position which corresponds to the position recorded in the LLL composite indicator.

Rank	1	2	3	4	5	6
Frequency N	0	18	62	41	5	0
Frequency %	0.00	14.29	49.21	32.54	3.97	0.00

Hungary

The performance of Hungary is one of the best among the Easter European Countries and the country is ranked at the 15th position of the overall score. The performance of Hungary is driven by a good performance in the dimension of "*Cost of CVT courses as % of total labour cost (all enterprises)*" and "*Cost of CVT courses per employee (all enterprises) - Corrected Direct Cost*". On other hands, Hungary worst performance is recorded for the dimension of "*Percentage of employees (all enterprises) participating in CVT courses*", both for male and female.

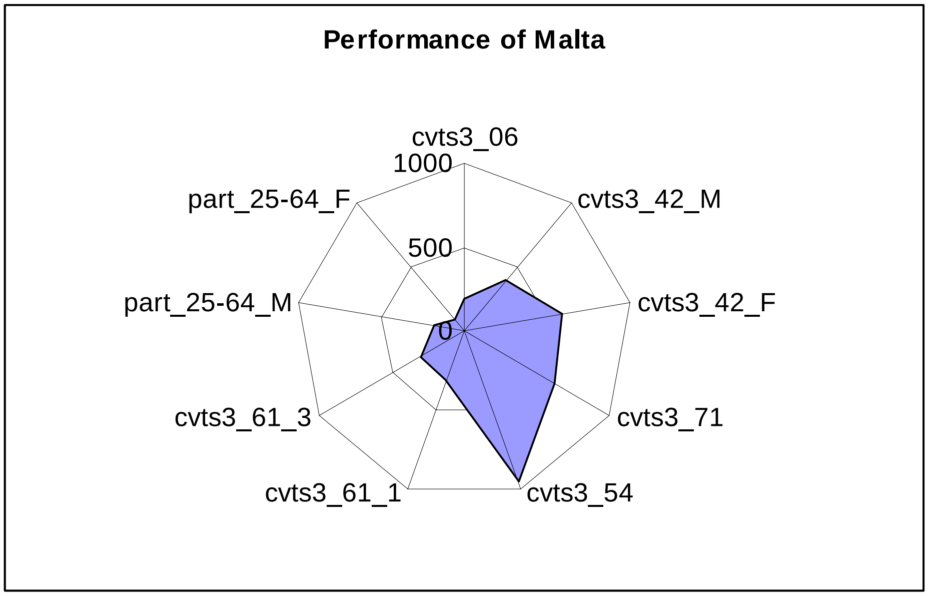


The position of Hungary is quite stable as confirmed by the uncertainty analysis. The position of Hungary varies from the 14th to the 18th position, even if the 97% of the observations are focused from the 15th to the 17th position. The median and the mode of the distribution fall in the 16th position which correspond to the position recorded in the LLL composite indicator.

Rank	13	14	15	16	17	18	19
Frequency N	0	1	18	65	40	2	0
Frequency %	0.00	0.79	14.29	51.59	31.75	1.59	0.00

Malta

The performance of Malta is good and the country is ranked at the 11th position of the overall ranking of the Life Long Learning Composite Indicator. This performance is mainly due by a top performance in the dimension of *"Cost of CVT courses as % of total labour cost (all enterprises)"*. Other good performances are also achieved for the dimension of *"Hours in CVT courses per employee (all enterprises)"* and female *"Percentage of employees (all enterprises) participating in CVT courses"*. Malta worst performances are recorded for the dimension of *"Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey);"* both for male and female.

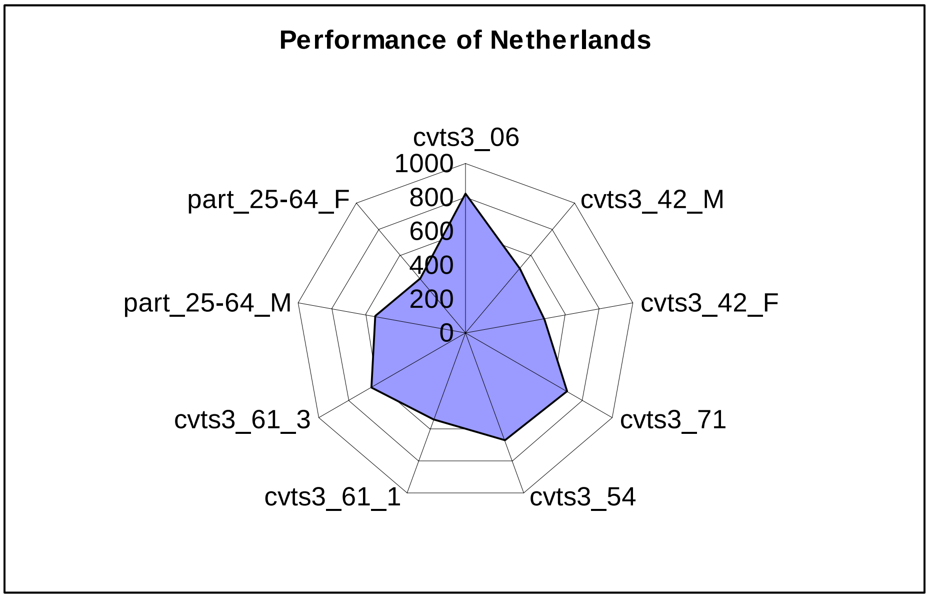


The performance of Malta in the uncertainty analysis shows a considerable variability in the ranking positions, which varies from the 8th to the 13th, even if the 90% of observations are recorded from the 10th to 13th position. For Malta the median of the distribution (11th) do not correspond with the ranking recorded in the LLL composite indicator (10th). On other hand, the mode falls in 10th position.

Rank	7	8	9	10	11	12	13	14
Frequency N	0	3	11	48	19	28	17	0
Frequency %	0.00	2.38	8.73	38.10	15.08	22.22	13.49	0.00

Netherlands

The Netherlands perform very well in the overall ranking where the country is ranked at the 5th position. The best performance of the Netherlands is achieved in the dimension of "*Percentage of enterprises providing CVT courses*" where the country is ranked at the 4th position. Good performances are also achieved for the dimension of "*Cost of CVT courses per employee (all enterprises) - Labour Cost of Participants* ". The worst performance of the Netherlands is recorded in the dimension of "*Percentage of employees (all enterprises) participating in CVT courses*" where the country is ranked at the 8th position for males and at the 11th position for females.

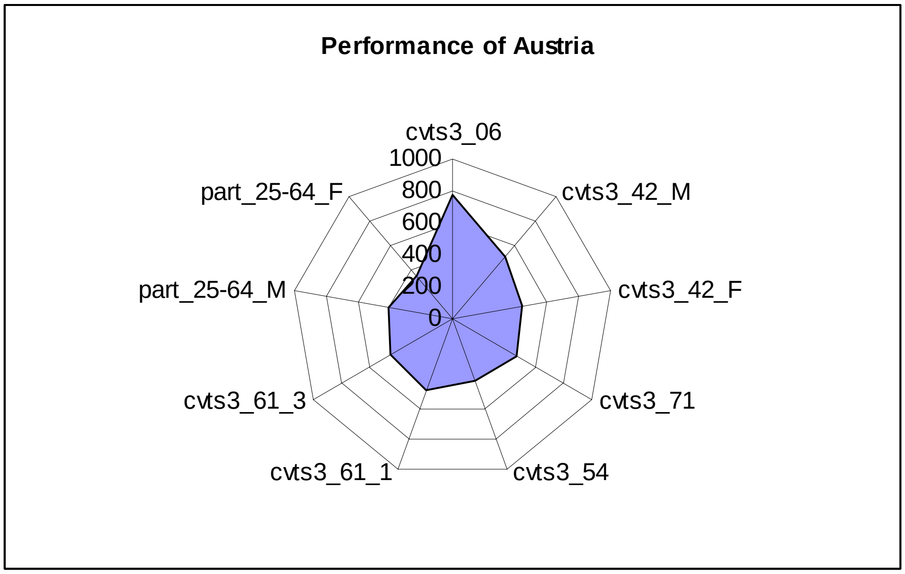


The performance of the Netherlands is very robust. Although the position of the country varies from the 3rd to the 6th, most of the observations (74%) are recorded in the 5th. The median and the mode of the distribution of the 126 simulations correspond with the position recorded in the LLL composite indicator (5th).

Rank	2	3	4	5	6	7
Frequency N	0	10	9	93	14	0
Frequency %	0.00	7.94	7.14	73.81	11.11	0.00

Austria

Austria show a good performance in the overall ranking of Life Long Learning Composite Indicator where the country is ranked at the 8th position. This good performance is due to an excellent performance in the "*Percentage of enterprises providing CVT courses*". For the other indicators Austria shows a robust and consistent performance achieving similar levels of score.

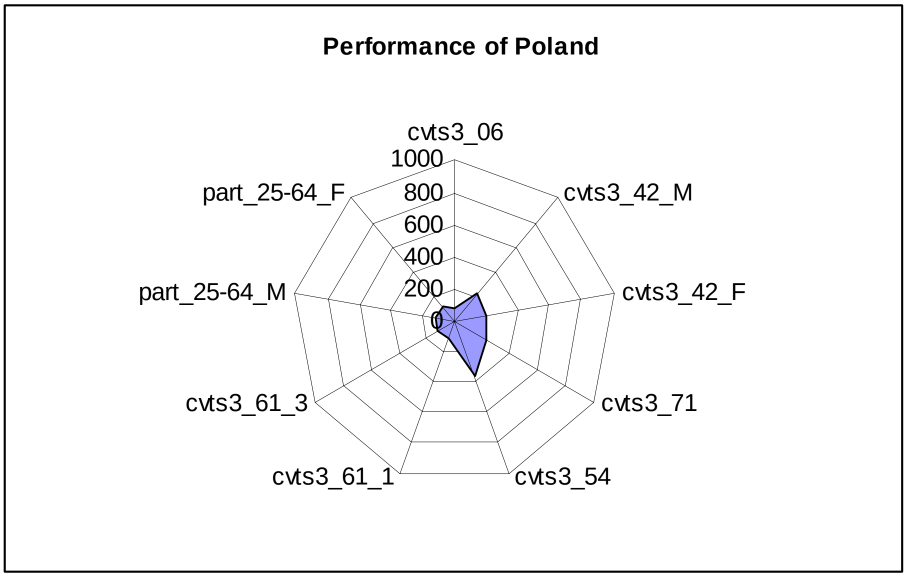


The position of Austria is quite stable as confirmed by the uncertainty analysis. The position of Hungary varies from the 6th to the 10th position, even if the more than the 90% of the observations are focused from the 7th to the 9th position. The median and the mode of the distribution fall in the 8th position which correspond to the position recorded in the LLL composite indicator.

Rank	5	6	7	8	9	10	11
Frequency N	0	8	29	56	32	1	0
Frequency %	0.00	6.35	23.02	44.44	25.40	0.79	0.00

Poland

The performance of Poland is not very good and the country is ranked at the 18th position, in line with the other performances of the Eastern European countries. The best performance achieved by Poland is recorded for the dimensions of "*Cost of CVT courses as % of total labour cost (all enterprises)*" and "*Hours in CVT courses per employee (all enterprises*)" where the country is ranked at the 14th and 16th position. The worst performance of Poland is recorded in the dimension of "*Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey);*" both for male and female.

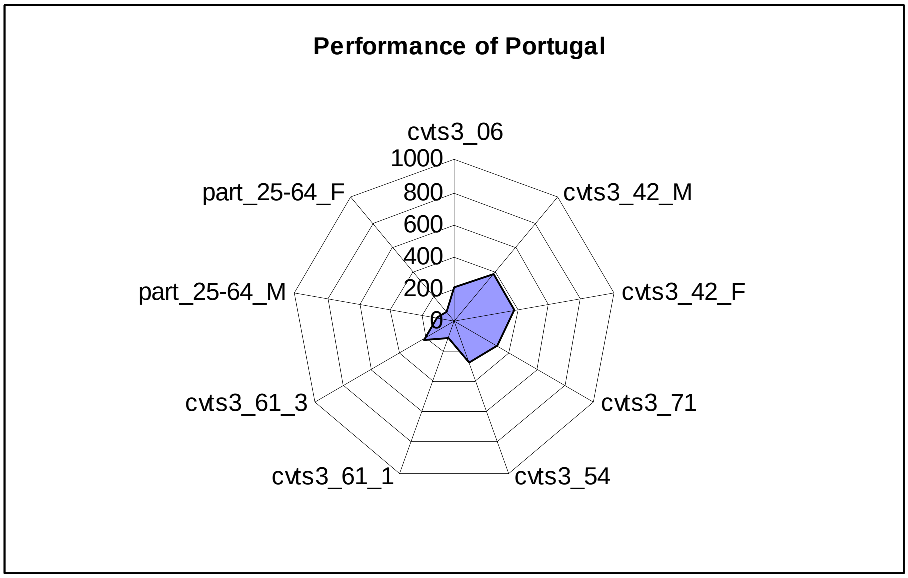


The performance of Poland is the most robust among all the countries. The country is ranked in the 18th position in 124 out of 126 simulations, which corresponds to the 98% of the total frequencies. The median and the mode of the distribution correspond to the 18th position which is the position achieved by the country in the LLL composite indicator.

Rank	16	17	18	19
Frequency N	0	2	124	0
Frequency %	0.00	1.59	98.41	0.00

Portugal

Portugal is ranked at the 17th position of the overall ranking of the Life Long Learning Composite Indicator. Portugal best performance is achieved for the dimensions of "*Percentage of employees (all enterprises) participating in CVT courses* "both for male and female, where the country is recorded respectively at the 15th and at the 14th position of the ranking. The Portugal worst performance is indeed recorded for the indicators of "*Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey*);" where the country is ranked at the 20th position for females, and at the 19th position for males.

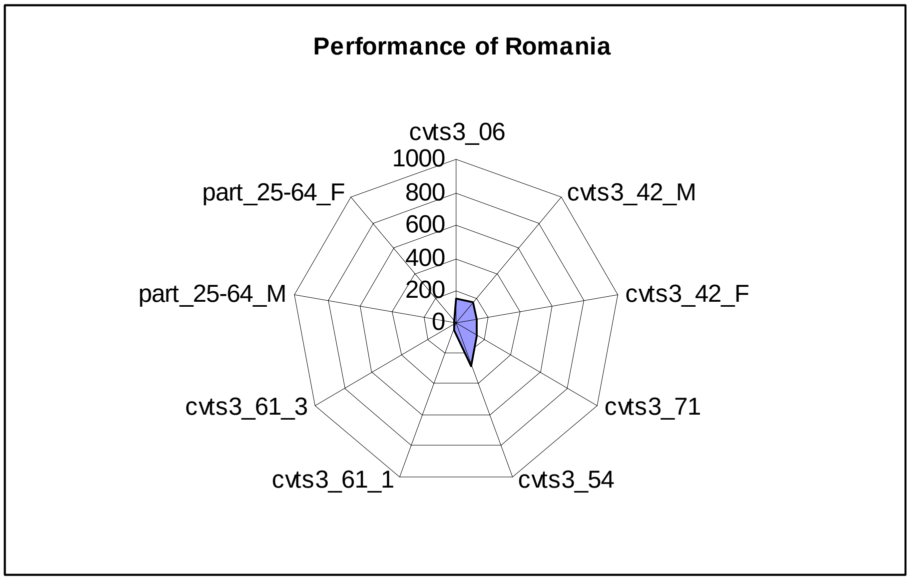


The performance of Portugal is robust in the uncertainty analysis and the position of the countries varies from positions 15th to 17th, even if the 98% of the frequencies are concentrated on positions 16th and 17th. The median and the mode of the distribution correspond to the position of the country achieved in the LLL composite indicator (17th).

Rank	14	15	16	17	18
Frequency N	0	2	40	84	0
Frequency %	0.00	1.59	31.75	66.67	0.00

Romania

Romania is ranked at the 20th position of the overall ranking, in line with the other performances of the Eastern European Country. The best performance of Romania is recorded for the indicator of "*Cost of CVT courses as % of total labour cost (all enterprises)*". On other hands, Romania worst performance is recorded for the indicators of "*Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey*);" where the country is ranked at the 22nd position, both for males and females.

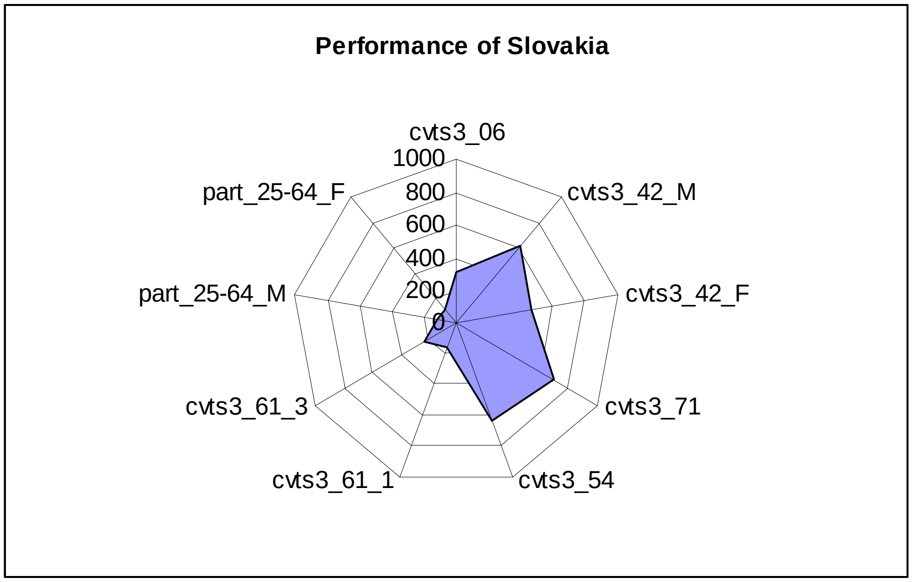


The performance of Romania is very robust as confirmed in the sensitivity analysis. Romania is ranked in the 20th position in 110 out of 126 simulations, which corresponds to the 87% of the total frequencies. The median and the mode of the distribution correspond to the 20th position which is the position achieved by the country in the LLL composite indicator.

Rank	18	19	20	21	22
Frequency N	0	5	110	11	0
Frequency %	0.00	3.97	87.30	8.73	0.00

Slovakia

Slovakia is ranked at the 12th position of the overall ranking and its performance can be considered quite good, especially compared with the other Eastern European Countries. Slovakia shows a considerable good performances for the dimensions of "*Hours in CVT courses per employee (all enterprises)*" and "*Cost of CVT courses as % of total labour cost (all enterprises*)" where the country is ranked at the 7th and 8th position respectively. Slovakia worst performance is instead achieved for the dimensions of "*Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey);*".

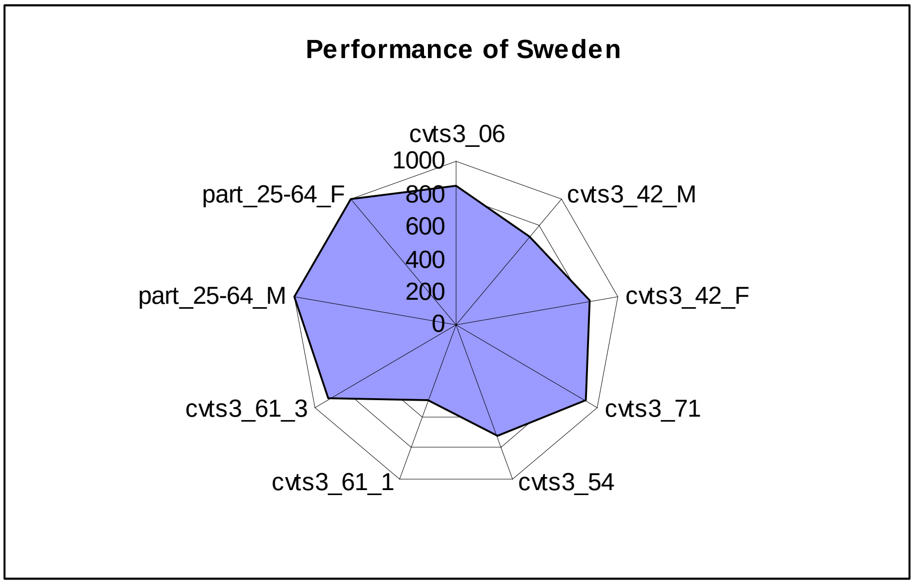


Although the uncertainty analysis shows that the ranking position of Slovakia varies from the 9th to the 14th, the performance of Slovakia can be considered stable because the 94% of the frequencies fall from position 11th to 13th. The median and the mode of the distribution fall in the 12th position which is the position recorded by the country in the LLL composite indicator.

Rank	8	9	10	11	12	13	14	15
Frequency N	0	1	2	35	42	41	5	0
Frequency %	0.00	0.79	1.59	27.78	33.33	32.54	3.97	0.00

Sweden

Sweden is the leader of the overall ranking of the Life Long Learning Composite Indicator. The Sweden top performance is achieved with an excellent performance in all the indicators. In particular Sweden achieve the top performance in the *"Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey);"* both for males and females. The less impressive performance of Sweden is recorded for the dimensions of *"Cost of CVT courses per employee (all enterprises) - Corrected Direct Cost"* where the country achieve the 5th position.

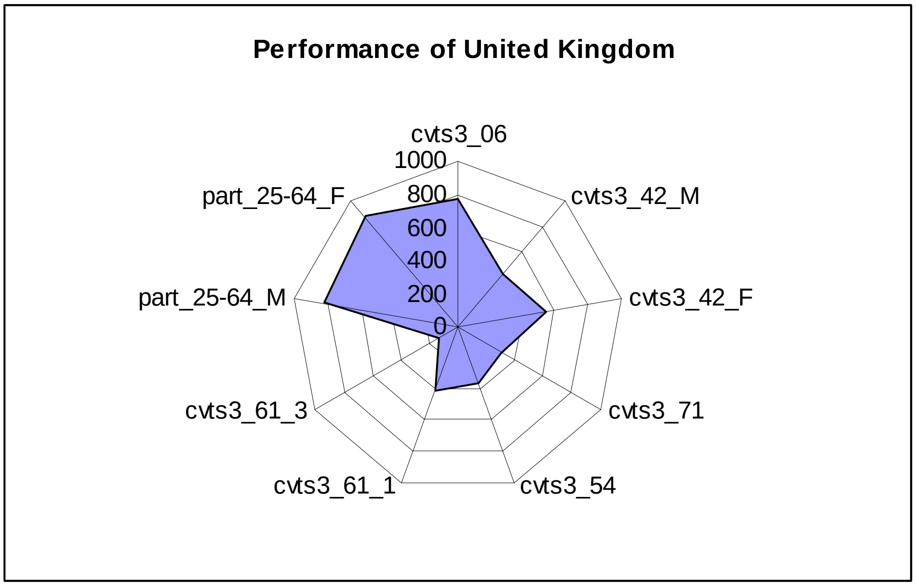


The performance of Sweden is very robust as confirmed in the sensitivity analysis. Sweden reaches the top of the ranking in 102 out of 126 simulations, which corresponds to the 81% of the total frequencies. The median and the mode of the distribution correspond to the 1st position which is the position achieved by the country in the LLL composite indicator.

Rank	1	2	3
Frequency N	102	24	0
Frequency %	80.95	19.05	0.00

United Kingdom

United Kingdom performs quite well and achieves the 9th position of the overall ranking. The performance of the United Kingdom is mainly driven by a good performance in the dimensions of "*Participation of the adult population aged 25-64 participating in education and training (over the four weeks prior to the survey);*", where the country achieve the 2nd position of the males and the 3rd for females, and for the dimension of "*Percentage of enterprises providing CVT courses*" where the country is recorded in the 5th position. On other hands, United Kingdom worst position is recorded for the indicator of "*Cost of CVT courses per employee (all enterprises) - Labour Cost of Participants,*" where the country is ranked at the 15th position.



United Kingdom is the country showing the largest variability observed with the sensitivity analysis. The rank of United Kingdom varies from the 4th to the 12th position, even if most of the observations are concentrated between the 6th and the 10th position. By the way, the median and the mode of the distribution correspond to the 9th position which is the position achieved by the country in the LLL composite indicator.

Rank	3	4	5	6	7	8	9	10	11	12	13
Frequency N	0	1	0	10	13	24	57	17	3	1	0
Frequency %	0.00	0.79	0.00	7.94	10.32	19.05	45.24	13.49	2.38	0.79	0.00

ANNEX 2

UNCERTAINTY AND SENSITIVITY ANALYSIS

Composite indicators may send misleading, non-robust policy messages if they are poorly constructed or misinterpreted. In fact, the construction of composite indicators involves stages where judgement has to be made: the selection of sub-indicators, the choice of a conceptual model, the weighting of indicators, the treatment of missing values etc. All these sources of subjective judgement will affect the message brought by the CIs in a way that deserve analysis and corroboration. A combination of uncertainty and sensitivity analysis can help to gauge the robustness of the composite indicator, to increase its transparency and to help framing a debate around it.

General procedures to assess uncertainty in the Life Long Learning composite indicators building are in this section applied and analyzed. In particular, we tried to tackle all possible sources of uncertainty, which arise from:

5) Data Normalization
6) Weighting Scheme
7) Composite Indicator Formula (Aggregation Rule)
8) Inclusion/Exclusion of Basic Indicators

Two combined tools are suggested to assess the uncertainty in the Life Long Learning Composite Indicator: Uncertainty Analysis (UA) and Sensitivity Analysis (SA). UA focuses on how uncertainty in the input factors propagates through the structure of the composite indicator and affects the composite indicator values. SA studies how much each individual source of uncertainty contributes to the output variance.

In the field of building composite indicators, UA is more often adopted than SA (Jamison and Sandbu, 2001; Freudenberg, 2003) and the two types of analysis are almost always treated separately. A synergistic use of UA and SA is proposed and presented here, considerably extending earlier attempts in this direction (Tarantola et al., 2000).

With reference to the uncertainty sources (1 to 4 above), the approach taken to propagate uncertainties could include in theory all of the steps below:

1) Inclusion-Exclusion of basic indicators
2) Using alternative data normalisation schemes, such as rescaling, standardisation, use of raw data.
3) Using several weighting schemes, i.e. Equal Weights, predetermined set of weights, Principal Components weights, Data envelopment analysis weights.
4) using several aggregation systems, i.e. linear, another based on geometric mean

of un-scaled variable.

General Framework of the Analysis

As described above, we shall frame the analysis as a single Monte Carlo experiment, e.g. by plugging all uncertainty sources simultaneously, as to capture all possible synergistic effects among uncertain input factors. This will involve the use of triggers, e.g. the use of uncertain input factors used to decide e.g. which aggregation system and weighting scheme to adopt. To stay with the example, a discrete uncertain factor which can take integer values between 1 and 3 will be used to decide upon the aggregation system and another also varying in the same range for the weighting scheme. Other trigger factors will be generated to select which indicators to omit, the aggregation rule, the normalisation scheme and so on. Below, the sources of uncertainty affecting the LLL composite indicator are analyzed.

- **Inclusion – exclusion of individual sub- indicators**

No more than one indicator at a time is excluded for simplicity. A single random variable is used to decide if any indicator will be omitted and which one. Note that an indicator can also be practically neglected as a result of the weight assignment procedure. Although this is not the case of the LLL composite indicator, for instance imagine a very low weight is assigned by an expert to a sub-indicator q . Every time we select that expert in a run of the Monte Carlo simulation, the relative sub-indicator q will be almost neglected for that run.

- **Normalisation**

As described in (Nardo et al. 2005) several methods are available to normalise sub-indicators. The methods that are most frequently met in the literature are based on the re-scaled values or on the standardised values or on the raw indicator values. In the robustness assessment of the LLL composite indicator the Z-score standardization, the Min-Max standardization and the Ranking-based standardization are applied. These three methods are shortly described below.

The Min-Max Standardization

The basic standardisation technique that has been applied is the Min-Max approach. Each indicator, q, was standardised based on the following rule:

$$I_{qc} = \frac{x_{qc} - \min_c(x_{qc})}{\max_c(x_{qc}) - \min_c(x_{qc})} \quad .$$

Using this method, all the indicators have been rescaled and the standardised values lie between 0 (laggard $x_{qc}=\min_c(x_q)$) and 1 (leader, $x_{qc}=\min_c(x_q)$).

Standardisation (or Z-scores)

For each sub-indicator x_{qc}, the average across countries $\bar{x}_{qc}$ and the standard deviation across countries $\sigma_{x_{mn}}$ are calculated. The normalization formula is:

$$I_{qc} = \frac{x_{qc} - \bar{x}_{qc}}{\sigma_{x_{qc}}} \,,$$

So that all the y_{mn} have similar dispersion across countries. This approach converts all indicators to a common scale with an average of zero and standard deviation of one, yet the actual minima and maxima of the standardized values across countries vary among the sub-indicators.

Ranking of indicators across countries

The simplest normalisation method consists in ranking each indicator across countries. The main advantages of this approach are its simplicity and the independence to outliers. Disadvantages are the loss of information on absolute levels and the impossibility to draw any conclusion about difference in performance.

$$I_{qc} = Rank(x_{qc})$$

- **Weighting Scheme**

Central to the construction of a composite index is the need to combine in a meaningful way different dimensions measured on different scales. This implies a decision on which weighting model will be used and which procedure will be applied to aggregate the information.
Addressing the reader to (Nardo et al. 2005) for an exhaustive list of weighting schemes, in the robustness analysis of LLL composite indicator, three different weighting schemes are adopted and described below.

Equal Weights
In many composite indicators all variables are given the same weight when there are no statistical or empirical grounds for choosing a different scheme. Equal weighting (EW) could imply the recognition of an equal status for all sub-indicators (e.g. when policy assessments are involved).
Alternatively, it could be the result of insufficient knowledge of causal relationships, or ignorance about the correct model to apply (like in the case of Environmental Sustainability Index – World economic forum, 2002), or even stem from the lack of consensus on alternative solutions (as happened with the Summary Innovation Index - European Commission, 2001a). In any case, EW does not mean any weighting, because EW anyway implies an implicit judgment on the weights being equal. The effect of EW also depends on how component indicators are divided into categories or groups: weighting equally categories regrouping a different number of sub-indicator could disguise different weights applied to each single sub-indicator.

Factor Analysis Weights
Principal component analysis (PCA) and more specifically factor analysis (FA) group together sub-indicators that are collinear to form a composite indicator capable of capturing as much of common information of those sub-indicators as possible. The information must be comparable for this approach to be used: sub-indicators must have the same unit of measurement. Each factor (usually estimated using principal components analysis) reveals the set of indicators having the highest association with it. The idea under PCA/FA is to account for the highest possible variation in the indicators set using the smallest possible number of factors. Therefore, the composite no longer depends upon the dimensionality of the dataset but it is rather based on the “statistical” dimensions of the data. According to PCA/FA, weighting only intervenes to correct for the overlapping information of two or more correlated indicators, and it is not a measure of importance of the associated indicator. If no correlation between indicators is found, then weights can not be obtained estimated with this method. For methodological details we address the reader to (Nardo et al. 2005).

Data Envelopment Analysis, (DEA), Weights
Data envelopment analysis (DEA) employs linear programming tools (popular in Operative Research) to retrieve an efficiency frontier and uses this as benchmark to measure the performance of a given set of countries.17 The set of weighs stems from this comparison. Two main issues are involved in this methodology: the construction of a benchmark (the frontier) and the measurement of the distance between countries in a multi-dimensional framework.

The construction of the benchmark is done by some simple assumptions as: positive weights (the higher the value of one sub-indicator, the better for the corresponding country); non discrimination of countries that are best in any single dimension (i.e. sub indicator) thus ranking them equally; a linear combination of the best performers is feasible (convexity of the frontier). The distance of each country with respect to the benchmark is determined by the location of the country and its position relative to the frontier. The countries supporting the frontier are classified as the best performing, other countries are then ordered according to the distance with respect to the benchmark. For methodological details we address the reader to (Nardo et al. 2005).

The benchmark could also be determined by a hypothetical decision maker (Korhonen et al. 2001, for an indicator of performance of academic research) who is asked to locate the target in the efficiency frontier having the most preferred combination of sub-indicators. In this case the DEA approach could merge with the budget allocation method (see below) since experts are asked to assign weights (i.e. priorities) to sub-indicators.

- Aggregation Rules

The literature of composite indicators offers several examples of aggregation techniques. The most used are additive techniques that range from summing up country ranking in each sub indicator to aggregating weighted transformations of the original sub-indicators. However, additive aggregations imply requirements and properties, both of component sub-indicators and of the associated weights, which are often not desirable, at times difficult to meet or burdensome to verify. To overcome these difficulties the literature proposes other and less widespread, aggregation methods like multiplicative (or geometric) aggregations or non linear aggregations like the multi-criteria or the cluster analysis. For the LLL composite indicator we focus our attention on additive methods and geometric aggregation.

Additive methods
The simplest additive aggregation method entails the calculation of the ranking of each country according to each sub-indicator and the summation of resulting ranking (e.g. Information and Communication Technologies Index - Fagerberg J. 2001). By far the most widespread linear aggregation is the summation of weighted and normalized subindicators:

$$CI_n = \sum_{m=1}^{M} w_m y_{mn}$$

Geometric aggregation
An undesirable feature of additive aggregations is the full compensability they imply: poor performance in some indicators can be compensated by sufficiently high values of other indicators. For example if a hypothetical composite were formed by inequality, environmental degradation, GDP per capita and unemployment, two countries, one with values 21, 1, 1, 1; and the other with 6,6,6,6 would have equal composite if the aggregation is additive. Obviously the two countries would represent very different social conditions that would not be reflected in the composite. If multicriteria analysis entails full non-compensability, the use of a geometric aggregation (also called deprivational index) is an in-between solution.

$$CI_n = \prod y_{q,c}^{w_q}$$

Uncertainty Analysis

All points showed above chain of composite indicator building can introduce uncertainty in the output variables Rank(CI_c). Thus we shall translate all these uncertainties into a set of scalar input factors, to be sampled from their distributions. As a result, all outputs Rank(CI_c) are non-linear functions of the uncertain input factors, and the estimation of the probability distribution functions (pdf) of Rank(CI_c) is the purpose of the uncertainty analysis. The UA procedure is essentially based on simulations that are carried on the various equations that constitute our model. As the model is in fact a computer programme that implements different scenarios, the uncertainty analysis acts on a computational model. Various methods are available for evaluating output uncertainty.

In the following, the Monte Carlo approach is applied, which is based on performing multiple evaluations of the model with k randomly selected model input factors. The procedure involves different steps and we address the reader to (Nardo et al, 2005, Saltelli et al. 2000a, Saltelli et al. 2000b, Saltelli, A. 2002, Saltelli et al. 2008).

The selected random factors for which the uncertainty is assessed to the LLL composite indicator are four and are listed below in table 9:

Table 9 - uncertainty factors for the LLL composite indicator

X_1	Standardization
1	Z-Score
2	Min-Max
3	Ranking across countries

X_2	Weighting Scheme
1	Equal Weight
2	Predetermined set of Weights
3	PCA weights
4	DEA weights

X_3	Aggregation Rule
1	Linear
2	Geometric
3	No further Aggregation (for DEA)

X_4	Excluded Sub-Indicator
1	Indicator 1 omitted
2	Indicator 2 omitted
3	Indicator 3 omitted
4	Indicator 4 omitted
5	Indicator 5 omitted
6	Indicator 6 omitted
7	Indicator 7 omitted
8	Indicator 8 omitted
9	Indicator 9 omitted
10	No indicator omitted

Where, trigger X_1 is used to select the standardization methods (Z-score, Min-Max, Ranking of Indicators across countries), trigger X_2 is used to select the weighting scheme (Equal weights, Predetermined set of weights, PCA weights, DEA weights).Then trigger X_3 is used to select the aggregation rule (linear/additive, geometric, no further aggregation (just in case of DEA). Finally, trigger X_4 is generated to select which sub-indicator –if any, should be omitted. Each input factor can be characterized by a probability density function; here we assume uniform distribution for the entire four input factors in order to do not penalize/reward any possible trigger modality.

After having generated the input factors distributions in step 1, we can now generate randomly N combinations of independent input factors X^l , l= l ,2 ,…,N where X^l is a set of outcomes of input factors, called a sample). For each trial sample X^l the computational model can be evaluated, generating values for the scalar output variable Y_l , where Y_l is the Rank(CI_c) , the value of the rank assigned by the composite indicator to each country.

In the case of the uncertainty analysis of the LLL composite indicator the total number of simulations performed is set equal to 126, which correspond to the total exploration of all the possible combinations of the input factors.

The results of the uncertainty analysis are presented below. For every country the results of the distribution of the scores of the 126 simulations are presented. The results of the simulations are organized in a frequency matrix and the overall LLL is calculated across the 126 scenarios. Besides the frequency matrix, the median rank per country was selected in order to compare with the rank recorded in the LLL composite indicator.

On figure 5 the frequency distribution of a country rank is presented. These frequencies are estimated over the 126 different scenarios. A colour code summarize s the frequencies as follows in table 10:

Table 10 - Colour Codes

(white)	Frequency lower than 15%
(light grey)	Frequency between 15% and 30%
(grey)	Frequency between 30% and 50%
(dark grey)	Frequency higher than 50%
bold	Position in the LLL composite indicator
Italic	median
orange	mode of the distribution

Moreover, **Bold**, *Italic* and Orange represent the country rank in the LLL composite indicator, the median and the 126 simulations respectively. For example Austria has a distribution encoded as follows, Table 11:

Table 11 - Austria performance in the 126 scenarios

	Rank 5	Rank 6	Rank 7	Rank 8	Rank 9	Rank 10	Rank 11	Rank 12	Rank 13
AUT	0	8	29	56	32	1	0	0	0

This means that the country is ranked in position 6th and 10th for 8 and 1 time respectively, with a frequency lower than 15%. Moreover the country is ranked in position 7th and 9th for 29 and 32 times respectively with a frequency between 15% and 30%. Finally Austria is ranked in position 8th for 56 times, which correspond to a frequency between 30% and 50% and position 8th is the mode, the median and position of the country in the LLL composite indicator. On figure 5 the results of the uncertainty analysis are shown.

	SWE	DNK	LUX	FRA	NLD	CZE	BEL	AUT	GBR	MLT	DEU	SVK	ESP	CYP	EST	HUN	PRT	POL	LTU	ROM	LVA	BGR	GRC
Rank 1	102	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rank 2	24	83	18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rank 3	0	15	62	40	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rank 4	0	4	41	69	9	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rank 5	0	0	5	15	93	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rank 6	0	0	0	1	14	35	59	8	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rank 7	0	0	0	0	0	37	47	29	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rank 8	0	0	0	0	0	27	15	56	24	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Rank 9	0	0	0	0	0	13	5	32	57	11	5	1	2	0	0	0	0	0	0	0	0	0	0
Rank 10	0	0	0	0	0	0	0	1	17	48	45	2	14	0	0	0	0	0	0	0	0	0	0
Rank 11	0	0	0	0	0	0	0	0	3	19	42	35	27	0	0	0	0	0	0	0	0	0	0
Rank 12	0	0	0	0	0	0	0	0	1	28	28	42	26	0	0	0	0	0	0	0	0	0	0
Rank 13	0	0	0	0	0	0	0	0	0	17	6	41	57	5	0	0	0	0	0	0	0	0	0
Rank 14	0	0	0	0	0	0	0	0	0	0	0	5	0	120	0	1	0	0	0	0	0	0	0
Rank 15	0	0	0	0	0	0	0	0	0	0	0	0	0	1	105	18	2	0	0	0	0	0	0
Rank 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	65	40	0	0	0	0	0	0
Rank 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	84	2	0	0	0	0	0
Rank 18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	124	0	0	0	0	0
Rank 19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	121	5	0	0	0
Rank 20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	110	11	0	0
Rank 21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	73	33	9
Rank 22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	53	36
Rank 23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	40	81
Total	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126

Figure 5 - Results of the Uncertainty Analysis, ranking distribution per country

A first consideration is that the overall ranking is quite stable; in fact considering the whole 126 simulations all countries clustered unambiguously. No doubt that the top performing countries are Sweden, Denmark, Luxembourg, France and the Netherlands. Then, Czech Republic, Belgium, Austria, United Kingdom, Malta, Germany, Slovakia and Spain follow the leaders and they show the highest variability. All the rest of the countries can be considered with a bad performance with respect to the Life Long Learning. However, these countries show a very stable ranking in all the 126 scenarios.

The overall variation in the position is shown is synthesized in Figure 6. The width of the 5%-95% percentile bounds across the 126 simulation represent the different rankings achieved by each country. Black marks correspond to the median LLL composite indicator rank and whiskers show best and worst rank occupied by a country considering the 126 simulations. The confidence bound proved the stability and robustness of the ranking. In fact over the 126 simulations 20 are the countries which shift less than 3 positions (approx. the 10% of the total number of countries) and just three countries show higher variability. These countries are Czech Republic, United Kingdom and Germany. This fact confirms that the ranking is very stable. The strong stability of the ranking can be due to the high correlation between indicators as assessed in section 2.

In the relevant literature, the median rank is proposed as a summary measure of a rank distribution. The median rank of all combinations of assumptions indicates that for 20 out of 23 countries the LLL rank corresponds with the most likely (median) rank. Thus, for the remaining countries the difference between the LLL rank and the most likely (median) rank is less than 2 positions. So that, for all the countries studied, the very modest sensitivity of the LLL ranking to the four input factors (standardization, weighting scheme, aggregation rule and inclusion/exclusion of a single indicator) implies a considerably high degree of robustness of the index for all the countries. The comparison of the median of the distribution of the 126 simulations with the overall ranking of the LLL shows that Czech republic, Malta and Spain show a different median values. The comparison is shown in table 12.

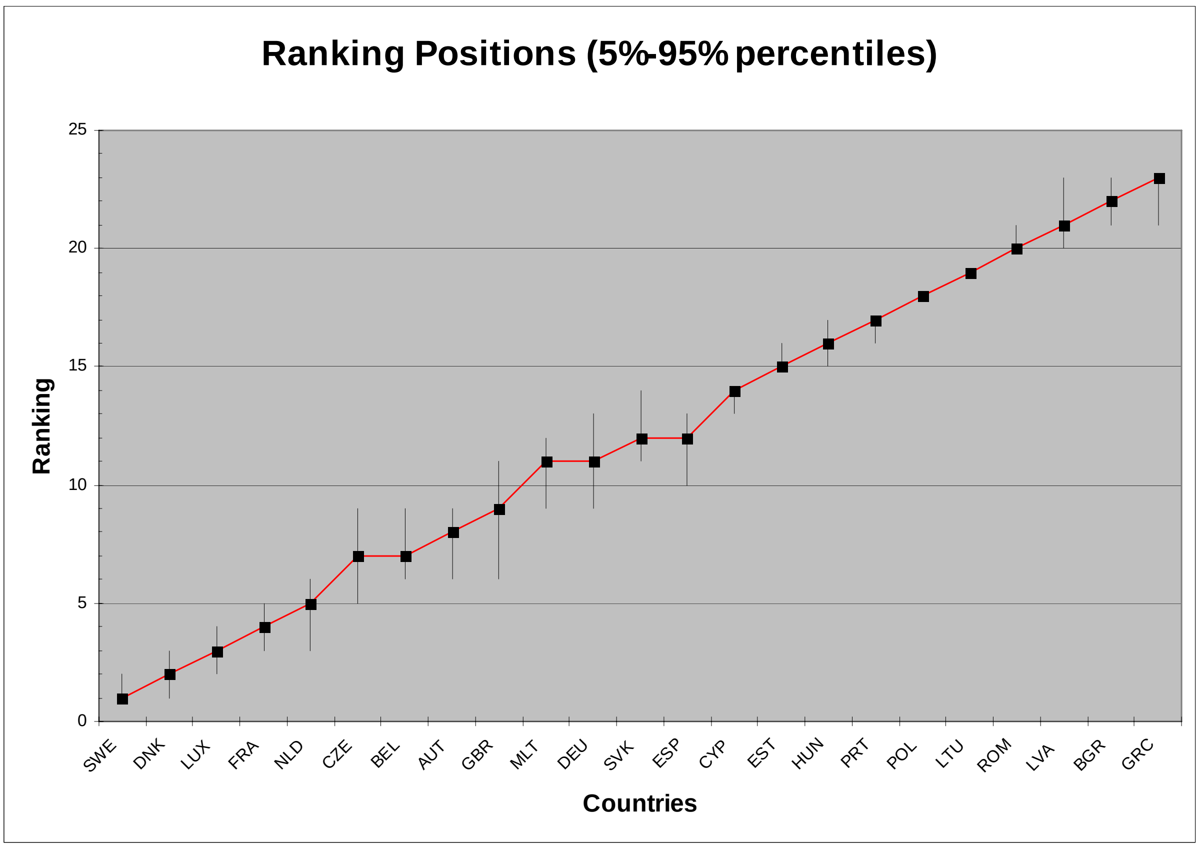


Figure 6 - Results of the Uncertainty Analysis - Ranking Positions (5%-95%) percentiles

Table 12 - Comparison of median values and LLL composite indicator ranking

	SWE	DNK	LUX	FRA	NLD	CZE	BEL	AUT	GBR	MLT	DEU	SVK	ESP	CYP	EST	HUN	PRT	POL	LTU	ROM	LVA	BGR	GRC
median	1	2	3	4	5	7	7	8	9	11	11	12	12	14	15	16	17	18	19	20	21	22	23
rank	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

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Abstract

A composite indicator on Lifelong Learning is developed. This represents the first step of a project that aims to cover the four main dimensions of flexicurity: i) modern labour laws; ii) effective active labour market policies; iii) modern social security systems; and iv) comprehensive lifelong learning policies. A composite indicator is calculated for EU Member States followed by sensitivity analysis to check their robustness. Results suggest a high degree of heterogeneity across Europe

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