Multivariate Statistical Analysis of the E-Communication Indicators in the European Union

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Abstract

The aim of the paper is to analyze the e-communication in the member states of the European Union. On the basis of data from the Eurobarometer 75.1 survey and from the Eurostat database the differences in e-communication level among the European Union states were analyzed. Principal component analysis was used for the general analysis of differences between the states of European Union. It was possible to explain 77% of the total variance by the first two components. The first component represents the level of e-communication while the second component characterizes quality of services and proportion of advanced Internet users. The overall e-communication level was evaluated using the component indicator. The Northern states together with the Netherlands and Luxembourg achieve the highest e communication level. On the other hand, the southern states (Greece, Italy, Portugal) together with the two new member states (Romania, Bulgaria) received the lowest rating, while Romania has been found an outlier on the basis of principal component analysis as well.

Keywords	***JEL code***
E-Communication, households with internet, internet and computer skills, principal component analysis, composite indicators	*C38*

INTRODUCTION

Computer and Internet education is a key prerequisite of the information access. Knowledge of information and communication technologies, also called „computer literacy“, constitutes basic requirement for further development of individuals in modern world. This claim is based on the assumption that about a half of productivity growth in modern economies is related to the use of information and communication technologies (see EDCL, 2012).

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Technological advancement has totally changed the field of communication. Information and communication technology (ICT) has become ever more ubiquitous throughout society. The Internet is now the center of economic, cultural and political life. It is used as a mechanism for delivery of public services, personal communication, and as a vast source of information and entertainment. A detailed analysis of this issue is essential for measuring and comparing computer literacy across the EU. The results can be used to set a policy of information education.

The main aim of this paper is to analyze the level of e-communication in different countries of the European Union. The analysis combines information obtained from the Eurobarometer survey and from the accessible resources of Eurostat. The major issue was to analyze the frequency of access to the Internet and its usage by individuals. In addition, the quality of Internet connection in households was examined. This is an important factor for evaluating the effectiveness of access to information. Another examined indicator was the usage of mobile connectivity as a modern e-communication tool.

Detailed analysis was based on the important indicators related to e-communication. These refer to indicators related to ICT equipment (proportion of individuals having computer, proportion of households with computer connected to the Internet, proportion of individuals having mobile Internet, or proportion of broadband penetration rate), quality of services (mobile phone satisfaction index and internet satisfaction index), and users´ knowledge and skills (computer and Internet skills, proportion of individuals using internet banking or e government, proportion of individuals making phone calls over the Internet, or ordering goods over the Internet).

1 INFORMATION AND COMMUNICATION TECHNOLOGIES

Technological advancement is a permanent feature of human society. However, this advancement is by its nature an inconsistent phenomenon, with periods of relative stability in technological capability punctured by periods of rapid innovation that can have profound consequences for society. Berry (2011) points out that in the field of information technology have been rapid developments in computing since the post-war period. Computers have made an immense progress in terms of processing power, speed and capacity in recent decades. In communication, the progression aimed at ever more sophisticated and flexible means of communication, from the telegraph to the mobile telephone. Over the last 30 years these two spheres have largely ceased to develop separately. But it is the synergy between information and communication technology that has been most revolutionary.

The most remarkable way of the biggest technological advancement is the World Wide Web. This technology began its life as a relatively simple means to enable communication between linked computers, and has evolved into ever more diverse forms, from websites, e-mail and social networking to telephony, video streaming and interactive virtual worlds. This technology is used in countless varieties of form. Among other uses, it is a mechanism for the delivery of public services, a means of personal communication, a vast source of information, knowledge, and entertainment, and a tool allowing for new industrial practices (Berry, 2011).

The computer literacy is a part of information literacy. Recent studies (see Dombrovská, 2011, Dohnálková, Landová, 2009) in this context refer to the information literacy, which consists of document, literary, linguistic, numeric and computer literacy. American Library Association (1989) defines information literacy as a set of abilities requiring individuals to "recognize when information is needed and have the ability to locate, evaluate, and use effectively the needed information". Information literacy is also increasingly important in the contemporary environment of rapid technological change and proliferating information resources. It is related to information technology skills, which enable an individual to use computers, software applications, databases, and other technologies to achieve a wide variety of academic, work-related, and personal goals. Information literacy, while showing significant overlap with information technology skills, is a distinct and broader area of competence. Increasingly, information technology skills are interwoven with, and support information literacy.

Recent studies show that main determinants of the intensity of Internet use in Europe are education and household income (for details see Montagnier, Wirthmann 2011). Differences between the countries can be caused by the different approaches of governments to the support and expansion of ICT. Issue of accessing the Internet by older people and excluded social groups can be found for example in Berry, 2011.

2 DATA SET AND METHODS

E-commmunication of the EU states was characterized by a set of fourteen indicators (see Table A1 in the Annex). Each indicator represents the percentage of population with a specified characteristic (having computer, using Internet banking etc.). The data set used in the e communication analysis was obtained from the Eurobarometer 75.1 survey (for details see European Commission, 2011) and from the Eurostat data source: section Information society. The statistics in this section track the usage of information and communication technologies (ICT). The methodological manual for surveys on ICT usage can be found on Eurostat web pages (Eurostat, 2012). The aggregated variables taken from Eurostat database refer mainly to the year 2011, only the *Broadband penetration rate, E-government usage and Internet banking usage* were available just for the year 2010. The Eurobarometer 75.1 was realized also in 2011 (February – March). It is particularly focused on e-communication in the household: mobile phone, television and Internet. In all, Eurobarometer 75.1 interviewed 26 836 citizens in the 27 countries of the European Union. All respondents were residents in the respective country, nationals and non-nationals but EU-citizen aged 15 and over. A multi-stage, random (probability) sampling design was used for this Eurobarometer. For the purpose of the further analysis the *WEIGHT EU27 (W22)* was used. It adjusts each sample in proportion to its share in the total population of the European Union aged 15 and over. It includes all 25 member countries after the 2004 enlargement, and the new members as of 2007 Romania and Bulgaria (for details see European Commission, 2011).

The Eurobarometer data set contains computed satisfaction indexes. These indexes are presented as discrete variables at four point ordinal scale. The mobile Internet satisfaction index was computed from the following questions: *mobile phone never cuts-off, it is always able to connect, user doesn't limit calls due to charges, and user doesn't limit mobile Internet due to charges.* The Internet satisfaction index was based on questions: *connection never breaks down, speed matches contract conditions, and the provider's support is useful.*

The indicators are presented on a six point ordinal scale in the Eurobarometer survey. For the purpose of further analysis the responses of individual respondents were aggregated. The proportion of positive responses in each state was used in following computations. Also the proportions of positive responses of aggregated indicators from the Eurostat database were used.

2.1 Principal component analysis

By reducing a data set from a group of related variables into a smaller set of components, the principal component analysis (PCA) achieves parsimony by explaining the maximum amount of common variance using the smallest number of explanatory concepts.

The original variables x_i, $i = 1, ..., m$, can be reduced to a smaller number of principal components y_j. The principal components are uncorrelated linear combinations of the original variables. All linear combinations are related to other variables or to the data structure. The principal components explaining the maximum amount of variance of the original variables (for details see Hebák et al., 2007, Rencher, 2002, or SAS Documentation, 2008). The first principal component corresponds to the direction of maximum variance; the second principal component corresponds to the direction of maximizing the remaining variance, and so on. Each principal component corresponds to a certain amount of variance of the whole dataset.

For the purpose of constructing the composites indicators the unstandardized principal component scores were normalized according to the equation:

$$\gamma_r = \omega_r \sqrt{\lambda_{(r)}}, \tag{1}$$

where γ_r is the normalized vector of component loads, ω_r are eigenvectors and $\lambda_{(r)}$ represent the eigenvalues (Hebák et al., 2007).

The further useful dimension reduction device is to evaluate the first two principal components for each observation vector and to construct a biplot. Biplot allows information on both samples and variables of a data matrix to be displayed graphically. Samples are displayed as points while variables are displayed either as vectors. A biplot is an enhanced scatterplot that uses both points and vectors to represent a structure. As used in principal component analysis, the axes of a biplot are a pair of principal components. A biplot uses points to represent the scores of the observations on the principal components, and it uses vectors to represent the coefficients of the variables on the principal components. For details of this application, see Meloun et al. (2006), or Rencher (2002).

For the purpose of this analysis the SAS 9.2 software was used to construct the principal components and related plots. The standardized principal components were computed in MS Excel according to the Equation 1.

The PRINCOMP Procedure was used to fit a principal component model. Also the PRINQUAL Procedure was used to fit a model with optimal linear transformation of the variables and for graphical results. The advantage of the PRINQUAL procedure is that results contain a biplot.

2.2 Composite indicators

The final part of the paper is focused on constructing composite indicators (CI). The composite indicators are widely used as a tool providing a simple but complex comparison of countries and regions. The most important advantages of composite indicators are the following: easier interpretation of the results compared to a set of indicators and also a dimension reduction without a loss of information (for detailed discussion see OECD, 2008).

To accomplish the different variables comparability the sub-indicators which are summarized by the use of CI have to be normalised first. There are several methods ensuring the data comparability. The selected method of normalisation should take into account the properties of the data – respect to the measurement units in which the indicators are expressed and the robustness against possible outliers in the data (see Ebert, Welsch, 2004).

The original values were expressed as a ratio to the median value. In case of such indicators where the lower value indicates better position of the state, the ratio was expressed inversely. The normalised values of all sub-indicators were then aggregated using the arithmetic mean.

The unweighted composite indicator for the i-th state is computed using the following formula:

$$CI_i = \frac{\sum_{j=1}^{p} y_{ij}}{p}, \tag{2}$$

where p is the number of indicators, y_{ij} is the ratio of the original value to the median value of the *j-th* indicator computed as $y_{ij} = x_{ij} / \tilde{x}_{.j}$, where x_{ij} is the original value for the *i-th* state and the *j-th* indicator, i=1, 2, …, 27 and j=1, 2, …, p and $\tilde{x}_{.j}$ is the median value of the *j-th* indicator.

The weighted composite indicator was computed using following formula:

$$wCI_i = \sum_{i=1}^{p} y_{ij} w_j, \tag{3}$$

where y_{ij} is the ratio of the original value to the median value of the *j-th* indicator and w_j is the weight of *j-th* indicator, $j=1,2, \ldots, p$ and $\sum_{j=1}^{p} w_j = 1$, p is the number of indicators. There are several weighting methods used for the construction of a composite indicator (see OECD, 2008, Saisana, 2002, Munda, Nardo, 2005). In case of correlation among the sub-indicators Saisana (2002) recommends to use the principal components with the objective of combining sub-indicators into composite indicators to reflect the maximum possible proportion of the total variation in the data set.

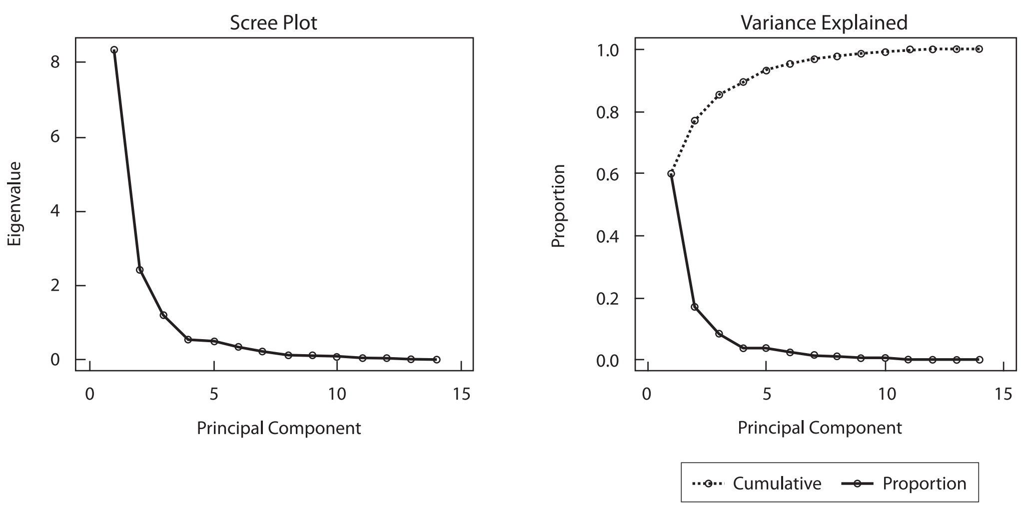
The composite indicators were computed in MS Excel as well as the construction of related figures.

3 DATA ANALYSIS AND RESULTS

The principal component analysis (PCA) was used for the general analysis of differences between the states of European Union. PCA identifies patterns in data and highlights their similarities and differences according to a varied level of e-communication.

In PCA, we seek to maximize the variance of a linear combination of the input variables. The first two principal components account for 77% of variance of the whole dataset and the first three account for 85%. Figure 1 shows a scree plot and a plot of cumulative proportional eigenvalues. The eigenvalues indicate that two or three components provide a good summary of the data.

Figure 1 Scree plot of eigenvalues and proportion of explained variance plot



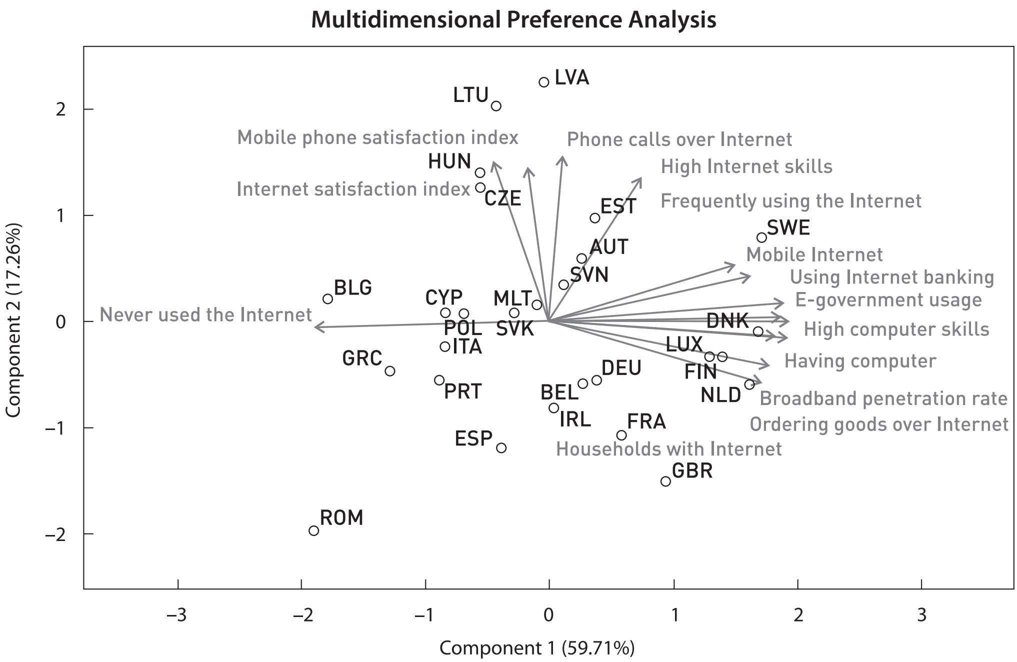
Source: Own construction

The first principal component is the linear combination with maximal variance. It explains about 60% of the total dataset. It largely represents 10 input variables, which are logically related. The corresponding eigenvector expresses an association of input variables with the first principal component (see Table 1). The second principal component accounts for 17% of variance and it has high positive loadings on four indicators.

The eigenvalue of the third component is 1.18 and it accounts for 8% of the total variance. The interpretation of the third component is not obvious, therefore it will not enter into following computations. Subsequent components contribute less than 5% of the total variance each. For the purpose of further analysis two dimensions are sufficient.

The objective of the following analysis is to evaluate the first two principal components for each observation vector and to construct a biplot. Biplot uses points to represent the scores of the observations on the principal components, and it uses vectors to represent the coefficients of the variables on the principal components. A vector points in the direction, which is the most similar to the variable represented by the vector. This is the direction which has the highest squared multiple correlation with the principal components. The length of the vector is proportional to the squared multiple correlation between the fitted values for the variable and the variable itself. Vectors that point in the same direction correspond to variables that have similar response profiles, and can be interpreted as having similar meaning in the context set by the data. Figure 2 shows the constructed biplot of the first two principal components. Vectors represent questions, and the points represent states. A group of vectors pointing in the same direction correspond to a group of questions, which have a similar proportion of positive answers across all states.

Figure 2 Biplot of the first two principal components



Source: Own construction

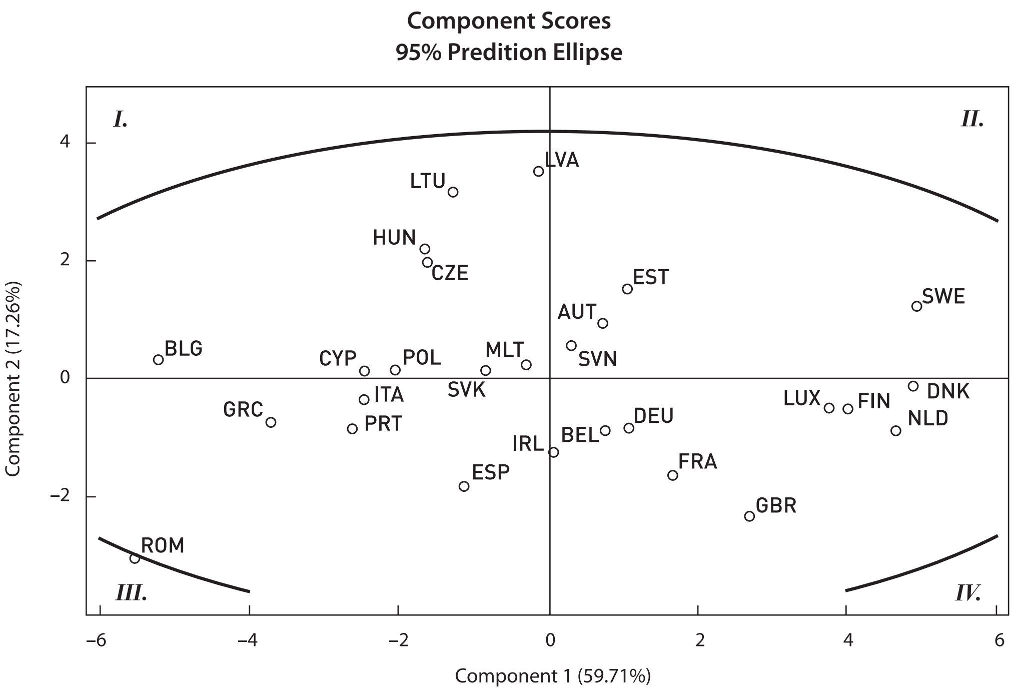
The first principal component has high negative loadings on variables *Never used the Internet* and high positive loadings on 9 input variables related to equipment and Internet use. Therefore it is obvious that the higher component score of this component means a higher level of e-communication in the country.

The second principal component represents four input variables. This component is correlated with indicators of the quality of services (mobile phone and Internet satisfaction index), and also with variables *Phone calls over Internet and High Internet skills*. It refers to the relationship between the level of the quality of services and the proportion of advanced Internet users.

Figure 3 displays the component score plot with a 95% prediction ellipse overlaid. It shows the spread of individual observations in the first two dimensions. The points that are close together correspond to observations that have similar scores. It is possible to identify regional trends on this plot or identify Romania as a possible outlier.

The plot can be split into 4 different quadrants. First quadrant represents a low level of household's equipment and Internet use and a high level of the quality of services. It includes mostly the countries of Central and Eastern Europe, such as Czech Republic, Hungary, Lithuania, Latvia, Bulgaria, Cyprus, Poland, Slovakia, and Malta. Although the quality of services provided by individual operators and other companies in these countries are usually not achieving the level of western countries, the users are mostly satisfied with it.

Figure 3 Component score plot with a 95% prediction ellipse



Source: Own construction

The second quadrant, which represents the highest level of e-communication (the highest level of ICT usage, and the quality of services) includes four states only: Slovenia, Austria, Estonia and Sweden. The first three of these states are located closer to the center of the plot, while Sweden reached the highest value of the component score in the 1st components. Together with Denmark, the Netherlands, Finland and Luxembourg it has the highest level of e-communication usage and equipment.

The third quadrant represents a low level of e-communication. It contains coastal states: Greece, Italy, Portugal, Spain, and Romania with the lowest level at all. With the exception of Romania, there are western countries with developed agriculture and tourism – people working on farms or in accommodation services do not see the Internet and electronic communication as a significant contribution to their work.

The fourth quadrant includes states with high level of ICT usage, but also with high requirements to the quality of services. Residents of the states with those services are rather dissatisfied, which may not mean lower standards than in other EU countries, but rather the higher demands of users. This quadrant represents the most advanced EU member states, such as: Ireland, Belgium, France, Great Britain, Luxembourg, Finland, Denmark, and Netherlands.

3.1 Composite indicator

To evaluate the overall e-communication level among the EU states a composite indicator (CI) was constructed. The original values of all fourteen sub-indicators were expressed as a ratio to the median value. While there are wide differences among the EU states from the view of selected ICT indicators the median was used instead of the mean which is sensitive to extreme values. The ratio then reflects the position of each state while higher values indicate better position of the state (the values above one indicate the position above the median value). In case of such indicators (e.g. *percentage of people who never used Internet*) where the lower value indicates better position of the state, the ratio was expressed inversely.

The normalised values of all sub-indicators were then aggregated using the arithmetic mean. So the values close to one indicate that the state is in average close to the median value of the EU states on the basis of the selected indicators. The higher is the value of the composite indicator, the better is the position of the state.

The composite indicator of the e-communication level was constructed in both unweighted and weighted forms, while the weights were based on the results of the principal component analysis.

The weight was set down on the basis of the higher factor loading of each variable either with the first or second principal component. To reflect the proportion of the total variance explained by the first and second component, the factor loadings were multiplied by the proportion of variance explained (for more details see OECD, 2008). The weights for each sub-indicator are summarized in Table 1. The weights were corrected therefore the sum equals one.

Table 1 Standardized eigenvectors and weights

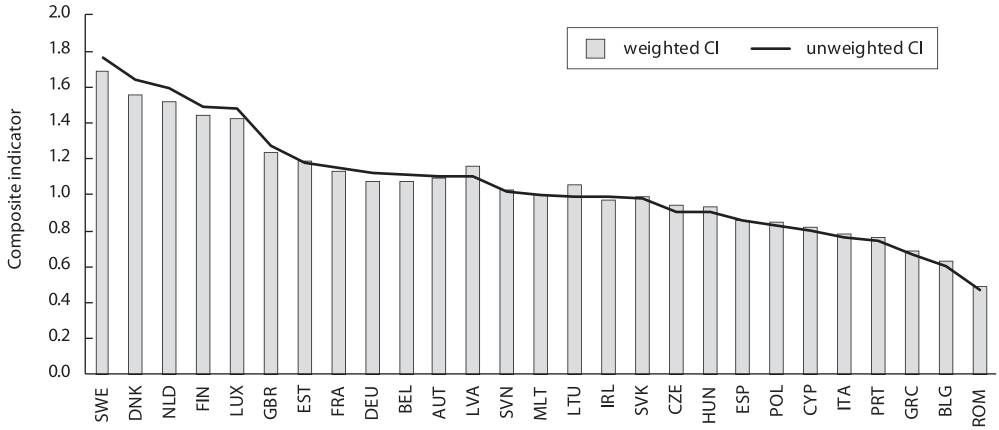
Variable	Prin1	Prin2	Weight
Having computer	0.93	–0.08	0.08
Mobile internet	0.75	0.26	0.05
Phone calls over Internet	0.06	0.78	0.06
Mobile phone satisfaction index	–0.09	0.73	0.05
Internet satisfaction index	–0.23	0.76	0.06
Broadband penetration rate	0.90	–0.20	0.08
E-government usage	0.95	0.02	0.09
Ordering goods over Internet	0.87	–0.28	0.07
Never used the Internet	–0.95	–0.03	0.09
Frequently using the Internet	0.98	0.00	0.09
Using internet banking	0.95	0.09	0.09
High computer skills	0.81	0.22	0.06
High Internet skills	0.38	0.67	0.04
Households with Internet	0.95	–0.08	0.09

Source: Own construction

The highest weights can mostly be seen for the indicators reflecting computer and Internet availability and usage. These variables are then more important for the reflection of differences among the EU states.

Figure 4 depicts the position of the EU states on the basis of the composite indicator, both the weighted and unweighted forms.

Figure 4 Level of e-communication on the basis of composite indicator, EU-27, 2010/2011

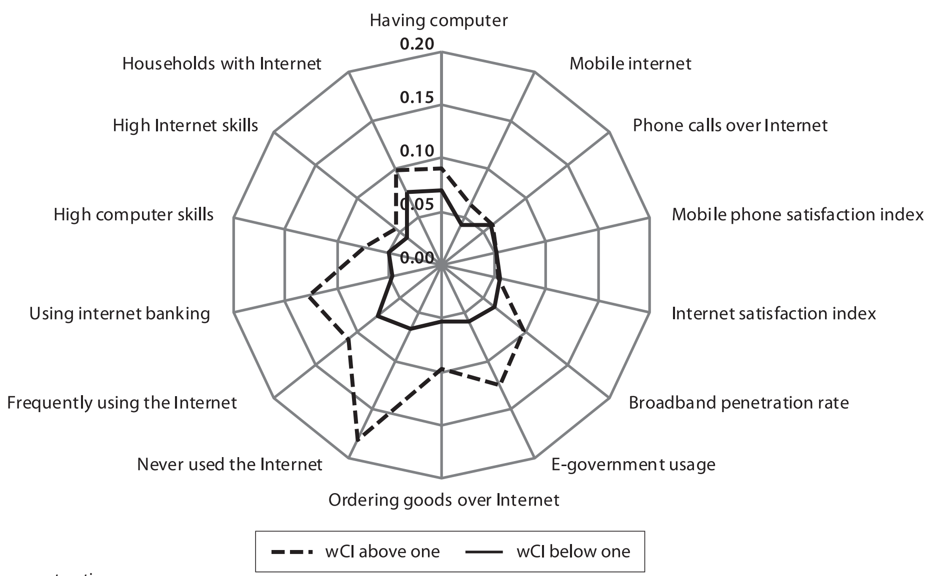


Source: Own construction

As it is seen from the results depicted in Figure 4 the weighted composite indicator reflects better the differences among the member states. This fact can be illustrated by comparing the variability using the coefficient of variation (V). The variation among the EU states is higher in case of weighted composite indicator (V = 30.27%), while in case of unweighted form V = 27.55%.

Figure 5 illustrates the contribution of each sub-indicator to the composite indicator and it enables to identify the sub-indicators which are of the highest differences among the EU. For this purpose the states were split up into two groups. The first group consists of states with the value of wCI above one. The second group of states represents states with the average proportion to median below one. Each point represents the average value for each normalised indicator, separately for the two groups of the states.

Figure 5 Contribution of each sub-indicator to the composite indicator



Source: Own construction

The biggest differences can be recognised from the view of sub-indicators percentage of people never used Internet, percentage of people ordering goods over Internet, egovernment usage and broadband penetration rate.

CONCLUSION

The field of e-communication has been growing rapidly in the last few years, but the level of computer literacy in various countries of the European Union is still unbalanced. It means that the usage of information technology communication is on different levels, too. Western countries show an obvious advantage compared to Eastern ones. This is primarily due to the fact that in these countries, computer training began considerably earlier than in Eastern Europe (see EDCL, 2012). Berry (2011) points out those differences between the countries can be also caused by the different approaches of governments to the support and extended access of the older population and excluded social groups to the ICT.

The use of the information and communication technologies was evaluated by the principal component analysis and by the composite indicators. From the component score plot it is obvious that Romania, Bulgaria, and Greece are at the extreme left, with the lowest level of ICT usage. On the other hand, the Northern states tend to be at the right side of the plot with a high overall ICT usage. The Central European countries tend to be in the upper part of the plot, with a higher-than-average ratio of the quality of services and average ratio of ICT usage. On the other side the coastal states tend to be at the bottom of the plot with a low ratio of the quality of services.

In terms of composite indicators the highest level of e-communication was achieved in the Nordic countries. Sweden occupied the first place, followed by Denmark and the Netherlands. The Czech Republic was 18th from the EU-27 countries. Slovakia reached the best place of the Central European countries on the 17th place, followed by Czech Republic and Hungary on the 19th place.

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ANNEX

Table A1 Input variables expressed as percentage of population with given characteristic

State	Having computer	Mobile internet	Phone calls over Internet	Mobile phone satisfaction index	Internet satisfaction index	Broadband penetration rate	E-government usage	Ordering goods over Internet	Never used the Internet	Frequently using the Internet	Using internet banking	High computer skills	High Internet skills	Households with Internet
Austria	62	43	32	83	83	24	39	56	18	59	38	42	9	75
Belgium	71	23	28	72	81	30	32	53	14	65	51	28	10	77
Bulgaria	47	12	51	76	78	14	15	13	46	37	2	11	9	45
Cyprus	62	25	42	81	76	23	22	36	41	45	17	23	8	57
Czech Republic	56	47	49	84	85	20	17	41	24	41	23	25	12	67
Denmark	88	50	35	75	77	38	72	77	7	78	71	39	15	90
Estonia	69	43	45	76	80	26	48	27	20	59	65	32	21	71
Finland	79	48	33	73	66	29	58	69	9	76	76	43	19	84
France	75	39	35	70	65	32	36	67	18	62	50	29	13	76
Germany	69	32	21	81	81	31	37	77	16	63	43	25	5	83
Greece	55	24	24	73	81	19	13	33	45	37	6	24	8	50
Hungary	54	26	41	87	85	20	28	32	28	56	19	32	15	65
Ireland	69	42	32	73	72	23	27	56	21	55	34	26	7	78
Italy	61	21	24	79	75	21	17	27	39	49	18	25	12	62
Latvia	69	47	65	79	81	19	31	27	27	53	47	29	31	64
Lithuania	60	36	65	77	84	20	22	25	33	48	37	32	27	62
Luxembourg	78	43	43	73	71	33	55	71	8	76	56	43	13	91
Malta	69	21	35	82	80	29	28	65	30	55	38	24	13	75
Netherlands	95	38	30	74	70	38	59	74	7	79	77	32	19	94
Poland	64	37	34	75	83	15	21	46	33	45	25	18	10	67
Portugal	56	28	12	75	79	20	23	31	41	42	19	28	10	58
Romania	53	15	11	67	65	14	7	13	54	24	3	10	7	47
Slovakia	55	37	45	71	78	16	35	48	20	56	33	23	12	71
Slovenia	75	51	22	77	83	24	40	45	29	54	29	31	16	73
Spain	59	29	13	70	71	23	32	39	29	48	27	32	11	64
Sweden	91	59	32	79	83	32	62	75	5	80	75	42	20	91
United Kingdom	73	52	30	66	63	31	40	82	11	70	45	32	11	83

Source: Own construction, Eurobarometer 75.1, Eurostat