Folia Oeconomica
Acta Universitatis Lodziensis
ISSN 0208-6018 e-ISSN 2353-7663

https://www.czasopisma.uni.lodz.pl/foe/
4(361) 2022
DOI: https://doi.org/10.18778/0208-6018.361.02

Aleksandra Kupis-Fijałkowska https://orcid.org/0000-0002-2528-5511

University of Lodz, Department of Statistical Methods, Lodz, Poland
aleksandra.kupis-fijalkowska@uni.lodz.pl

Małgorzata Misztal https://orcid.org/0000-0002-8719-2097

University of Lodz, Department of Statistical Methods, Lodz, Poland, malgorzata.misztal@uni.lodz.pl

ICT Usage in Enterprises in the Years 2010–2019 – Poland in Comparison with Other European Union Countries

Abstract: As Eurostat's glossary explains, the term Information and Communication Technologies (ICT): 'covers all technical means used to handle information and aid communication. This includes both computer and network hardware, as well as their software.' In both local and global perspective, the ICT impact on modern economies and societies is undeniable. Moreover, it is growing, as the usability and technical capabilities are expanding. The researchers recognised that the ICT expansion in enterprises is a stimulant for economic development, as it strengthens competitiveness and innovation. Its impact on labour markets is significant, and constantly increasing demand for digital competences and ICT specialists can be observed. In both global and local perspective, the ICT sector is growing dynamically along with its value share in GDP. Monitoring the development of ICT usage as well as analysing how it stimulates socio-economic transformations and growth are crucial for global leaders, governments and local authorities all over the world in order to formulate policy at all levels. Also, it plays a significant role in modern businesses expansion, as it strengthens innovativeness and competitiveness.

The main objective of the paper is to study the ICT usage development in Poland against other EU countries from the enterprises' perspective in the years 2010–2019 (before the COVID–19 pandemic and Brexit). The research presented was based on Eurostat data. The variables were selected on the basis of the literature review on ICT usage, as well as the criterion of data availability and comprehensiveness. The exploratory data analysis methods dealing with three-way data structures, i.e. the between and within-class principal component analysis, were used, and the presentation of the results was supported by factorial maps (scatterplots and biplots).

In the analysed period, enterprises in all the European Union Member States intensified their ICT usage. Despite the positive trend from 2010 to 2019, Poland remained far behind the leading countries, and more precisely, was in the group of the least developed ones.

Keywords: information and communication technologies, ICT, enterprises, multivariate exploratory data analysis, principal component analysis, PCA, EU

JEL: C38, O30, O33

1. Introduction

In the Eurostat glossary term 'Information and Communication Technologies' (henceforth ICT) 'covers all technical means used to handle information and aid communication. This includes both computer and network hardware, as well as their software' (Eurostat, 2016). Statistics Poland defines it as 'a family of technologies that are processing, collecting and sending information in an electronic format' (Statistics Poland, 2018).

ICT are omnipresent in individuals' daily life, their personal and professional communication (e.g.: Ferscha et al., 2012), manufacturing and services sectors (e.g.: Evangelista, Guerrieri, Meliciani, 2014), as well as in education, health services and public administration (e.g.: OECD, 2013; European Commission, Directorate-General for the Information Society and Media et al., 2017; Smyrnova-Trybulska, 2018). Moreover, their impact on society and business, especially in the sense of strengthening services and production competitiveness by innovation, is significant. It results in social development reinforcement and acceleration of economic growth (e.g.: Pradhan, Mallik, Bagchi, 2018; Lechman, Kutrzeba, Mustakoski, 2020; Cheng, Chien, Lee, 2021), and it also supports achieving goals of sustainable development (e.g.: Higon, Gholami, Shirazi, 2017).

The European Commission and all the European Union Member States' governments, as well as other nongovernment European organisations, pay a great deal of attention to collecting and analysing ICT related data. Information on ICT usage, their functionalities and the ICT sector itself as well as research on the relationship between ICT development and various social and economic phenomena are important to understand the transformations that economies and societies are going through. This knowledge helps to formulate development policies aimed at enforcing innovations and economic potential, improving digital competences and reducing digital exclusion (e.g.: Ministry of Development Funds and Regional Policy, 2014). It is also important in building strategies for sustainable development (e.g.: Hilty, Aebischer, 2015; Kostoska, Kocarev, 2019). Hence, monitoring, analysing and evaluating the development of ICT, their potential as well as their impact on other phenomena are valuable for governments, societies and institutions of all kind all over the world.

There are two main objectives of the paper:

1) to investigate the ICT usage development in Poland against other EU countries in the years 2010–2019 (before COVID–19) from the enterprises' perspective;
2) to distinguish subgroups of countries within the European Union similar in terms of: ICT access and usage in enterprises, frequency and main purposes for using websites and social media by enterprises and the interest of employers in recruiting ICT specialists.

The conducted analyses are based on the data provided by Eurostat. Since the datasets constituted data cubes: *objects* × *variables* × *time*, the exploratory data analysis methods dealing with three-way data structures (i.e. the between and within-class principal component analysis) were applied to meet the objectives of the paper. The between and within-class PCA (Dufour, 2008; Thioulouse et al., 2018) – the exploratory data methods dealing with three-way data structures – were chosen to meet the above-listed research objectives.

The variables were selected on the basis of the literature review on the usage of ICT by enterprises and Eurostat's database variables in the section of *Digital economy and society statistics: ICT usage in enterprises* along with the criterion of data comprehensiveness. The frequency and main purposes for using websites and social media, digital competences and employers' interest in hiring ICT specialists were taken into account.

The omnipresence of ICT arouses interest of scientists from many disciplines. The literature discussing ICT themselves and innovations in ICT, analysing their spread and usage by individuals and enterprises, demonstrating and measuring their impact on and linkage with various social and economic phenomena, researching their development in specific places (locally and globally, within the country and in comparison with other countries) and in relation to many other associated issues is extensive.

A great deal of attention is paid to ICT as the stimulants of economic growth (e.g.: Khalili, Lau, Cheong, 2014; Jorgenson, Vu, 2016; Niebel, 2018; Pradhan, Mallik, Bagchi, 2018; Lechman, Marszk, 2019) and to how positively they affect social development (e.g.: Ziemba, 2019; Lechman, Kutrzeba, Mustakoski, 2020). Also, the role of ICT in sustainable development is discussed by researchers, and has been identified as significant (e.g.: Hilty, Aebischer, 2015; Kostoska, Kocarev, 2019). However, the study of ICT is not limited only to their positive dimension (e.g.: Higon, Gholami, Shirazi, 2017).

The European Commission provides current data on ICT via Eurostat and releases regularly reports on The Digital Economy and Society Index, where the current situation concerning digital performance and evolution in digital competitiveness in all the Member States is described (European Commission, 2020). The World Economic Forum presents reports on The Networked Readiness Index (Dutta, Lanvin, 2019), and the ICT Development Index (The International Telecommunication Union, 2018) is published regularly by the International Telecommunication Union – a specialised agency of the United Nations. The first of the reports mentioned provides formal information for the European Union countries about their ICT growth. In the latest years' reports (European Commission, 2017; 2020), Poland did not perform well: in 2017 and 2018, it was listed in the 25th position and it moved to the 23rd position in 2019. It needs to be mentioned that the score of Poland was equal to 45 (respectively 41.6 and 38.8 in the previous years), while the European Union average was 52.6 (respectively in the previous years' reports: 52.5 and 49.8). Hence, although being below the average, Poland slightly improved at a pace faster than the EU average dynamics. In 2019, Poland was far away from the leading countries in the 'business digitalization' sub-category, holding the 26th position with a score equal to 40, while leaders had above 60.

In many papers on analyses and comparisons of the ICT development level, authors used the mentioned indexes and rankings based on them (Moroz, 2017; Preda et al., 2019). Research papers on ICT development and related issues contained various statistical methods – from simple (e.g.: Bajdor, 2015; Preda et al., 2019; Zečević, Radović-Stojanović, Čudan, 2019) to more advanced ones (e.g.: Wojnar, 2015; Billon, Marco, Lera-Lopez, 2017; Khan, Sana, Arif, 2020; Cheng, Chien, Lee, 2021). Also other approaches can be found, for example, econometrical methods were applied by Pradhan, Mallik, and Bagchi (2018), and Becker et al. (2018) used the analytic network process (ANP). Regarding ICT usage development in European enterprises, when taking into account the analyses conducted before the COVID–19 by Bajdor (2015), Savulescu (2015), Billon, Marco, and Lera-Lopez (2017), Zečević, Radović-Stojanović, and Čudan (2019) and the ranking of Poland in the above-mentioned indexes (The Digital Economy and Society Index – DESI, The Networked Readiness Index – NRI and ICT Development Index – IDI), the country is in the group of the UE–28 least developed Member States, and although a positive development trend can be observed, it lags far behind the EU average.

2. Research methodology

The analyses were based on Eurostat data on enterprises with 10 or more persons employed. The time series describing Internet access in enterprises and the frequency of possession and usage of the company website covered the years 2010–2019. Datasets on the social media use by type were available for the years 2014–2019 and by purpose for the years: 2013, 2015, 2017, and 2019. The time series characterising ICT competence in enterprises and the need for ICT skills covered the years 2014–2019. The trend-based single imputation was applied to fill in the few missing data.

The proposed datasets would facilitate verification of the following two hypotheses:
1) the level of ICT usage in Polish enterprises was increasing year by year in the considered period;
2) in the considered period, in terms of ICT usage in enterprises – although the positive trend was identified – Poland remained far behind the group of the leading countries.

To analyse the spatial-temporal data, several approaches can be considered. In the research, exploratory data analysis methods dealing with three-way data structures, based on the principal component analysis (PCA), were selected and applied.

Considering datasets for the years 2010–2019, it is possible to perform ten separate PCAs, one for each year, or one classical PCA after concatenating all datasets. The second approach mixes temporal and spatial typologies (Dufour, 2008: 7). Therefore, there is a need to separate these two effects.

Spatial-temporal structures can be thought of in terms of groups. In the research, the groups can correspond to the individual EU countries or to the consecutive years. Taking the existence of groups of samples in a data table into consideration, Thioulouse et al. (2018) suggest applying a particular type of analysis, called a between-class analysis, which models the differences between groups by computing the group means and analysing the resulting table. The aim of such an analysis is to investigate visually the existence of the specific groups and to describe the main characteristics of the differences between the groups. In the research, the between-class analysis based on principal component analysis was applied. As mentioned above, the basis for the between-class analysis is the table of the group means. For groups corresponding to individual countries, the values of each variable are averaged across the considered time and then the between-countries PCA can be performed. If the groups correspond to individual years, then the values of each variable are averaged across the considered EU countries and the between-years PCA can be carried out.

The between-class analysis may be complemented by the within-class analysis. The within-class analysis operates with the residuals between observed data and the group means. It aims at looking for structures remaining in the data after removing the effect of the differences between groups of samples. Dufour (2008: 11) pointed out that the within-class and between-class PCA can be regarded as an exploratory generalisation of the one-way ANOVA. For both spatial and temporal effects, the total inertia (variability) of $\mathbf{X}$ (the matrix containing p variables measured on n objects) can be decomposed into two parts: the inertia of $\mathbf{X}_W$ (the within model after removing the effect of groups) and the inertia of $\mathbf{X}_B$ (the between model, revealing the effect of groups).

A more formal description of these methods, based on Thioulouse et al. (2018: 119–135), is briefly summarised below.

Let $\mathbf{X}$ be a $n \text{x} p$ matrix with the measurements of p variables for n individuals (objects).

Let $(\mathbf{X},\mathbf{Q},\mathbf{D})$ be the associated statistical triplet, where $\mathbf{Q}$ is a $p \text{x} p$ diagonal matrix of column (variable) weights and $\mathbf{D}$ is a $n \text{x} n$ diagonal matrix of row (individual) weights: $\mathbf{D} = \text{diag}(w_1,\ldots,w_n)$. Let us also consider a categorical variable with g categories (groups): $G_1,\ldots,G_k,\ldots G_g$, measured on the n individuals that can be coded as a $n \text{x} g$ matrix $\mathbf{H} = [h_{ik}]$ of dummy variables:

$$h_{ik} = \begin{cases} 1\, if\ i \in G_k \\ 0\, if\ i \notin G_k \end{cases} \quad (1)$$

The table $\mathbf{X}$ can be decomposed in two additive parts:

$$\mathbf{X} = \mathbf{P_H}\mathbf{X} + (\mathbf{I}_n - \mathbf{P_H})\mathbf{X} = \mathbf{X}_B + \mathbf{X}_W, \quad (2)$$

where:

$$\mathbf{P_H} = \mathbf{H}(\mathbf{H}^{\mathrm{T}}\mathbf{DH})^{-1}\mathbf{H}^{\mathrm{T}}\mathbf{D}. \quad (3)$$

The $n \text{x} p$ matrix $\mathbf{X}_B$ contains the group means (computed using weights in $\mathbf{D}$), repeated within each group $\left(\mathbf{X}_B = \left[\overline{x}_j^k\right] \text{for}\ i \in G_k\right)$, where $\overline{x}_j^k = \sum_{i \in G_k} w_i x_{ij}$ is the mean of the j-th variable for the group k.

The $n \text{x} p$ matrix $\mathbf{X}_W$ contains differences between observed values and the group means: $\left(\mathbf{X}_w = \left[x_{ij} - \overline{x}_j^k\right]\right)$.

The total inertia of the analysis of $(\mathbf{X},\mathbf{Q},\mathbf{D})$ can be decomposed as follows:

$$I_{(\mathbf{X},\mathbf{Q},\mathbf{D})} = \text{Trace}(\mathbf{X}^{\mathrm{T}}\mathbf{DXQ}) = \text{Trace}\left((\mathbf{X}_B + \mathbf{X}_W)^{\mathrm{T}}\mathbf{D}(\mathbf{X}_B + \mathbf{X}_W)\mathbf{Q}\right). \quad (4)$$

Therefore:

$$I_{(\mathbf{X},\mathbf{Q},\mathbf{D})} = I_{(\mathbf{X}_B,\mathbf{Q},\mathbf{D})} + I_{(\mathbf{X}_W,\mathbf{Q},\mathbf{D})}. \quad (5)$$

The first component ($I_{(\mathbf{X}_B,\mathbf{Q},\mathbf{D})}$) measures the inertia explained by the differences between groups. The between-class analysis focuses on these differences and it is the analysis of the triplet $(\mathbf{X}_B,\mathbf{Q},\mathbf{D})$. The second component ($I_{(\mathbf{X}_W,\mathbf{Q},\mathbf{D})}$) measures differences within groups, hence the within-class analysis is the analysis of the triplet $(\mathbf{X}_W,\mathbf{Q},\mathbf{D})$.

For the $g \times g$ diagonal matrix of group weights: $\mathbf{D}_g = \mathbf{H}^{\mathrm{T}}\mathbf{D}\mathbf{H}$, the $g \times p$ matrix of group means: $\bar{\mathbf{X}} = \mathbf{D}_g^{-1}\mathbf{H}^{\mathrm{T}}\mathbf{X}$ can be defined. Therefore, the between-class analysis corresponds also to the analysis of the triplet $(\bar{\mathbf{X}},\mathbf{Q},\mathbf{D}_g)$ and can be defined as the principal component analysis of the group means table, leading to the diagonalisation of $\bar{\mathbf{X}}^{\mathrm{T}}\mathbf{D}_g\bar{\mathbf{X}}\mathbf{Q}$. The rank of that matrix is equal to $r = \min(p, g-1)$. The total inertia of this analysis equals the between-class inertia.

The between-class analysis searches for a principal axis $\mathbf{a}$ maximising $\bar{\mathbf{X}}\mathbf{Q}\mathbf{a}^2_{\mathbf{D}_g}$. Hence, the aim of the analysis is to determine coefficients ($\mathbf{a}$) to compute a linear combination of variables ($\bar{\mathbf{X}}\mathbf{Q}\mathbf{a}$) which best separates the groups by maximising the between-class inertia. Objects (rows of the initial table) can be projected on the principal axes, their coordinates are given by $\mathbf{XQA}$.

The within-class analysis is the analysis of the matrix of the residuals obtained by eliminating the between-class effect. It leads to the diagonalisation of matrix $\mathbf{X}_W^{\mathrm{T}}\mathbf{D}\mathbf{X}_W\mathbf{Q}$. The total inertia of this analysis is equal to the within-class inertia.

The within-class analysis searches for a principal axis $\mathbf{a}$ maximising $\mathbf{X}_W\mathbf{Q}\mathbf{a}^2_{\mathbf{D}}$. Hence, the aim of the analysis is to determine coefficients ($\mathbf{a}$) to compute a linear combination of variables ($\mathbf{X}_W\mathbf{Q}\mathbf{a}$) which best separates the objects after removing the differences among groups by maximising the within-class inertia.

The PCA-based methods may be recommended as useful tools for an exploratory and less formal analysis of data. However, their advantages and disadvantages should be carefully recognised. The strongest advantages of these methods are: the possibility of graphical presentation of the results using factorial maps (scatterplots and biplots) and the potentiality of drawing conclusions directly from the investigation of factorial maps, where the use of formal mathematics is minimal. Factorial maps show the approximate relationships between different points (representing e.g.: countries or years), as well as the relationships between the points and vectors representing the analysed variables.

According to Gower, Le Roux, and Gardner-Lubbe (2015: 43), an analysis of factorial maps makes it possible to reveal clusters of points, trends, outliers, and patterns in data – all in ways that text and tables do not allow. Other advantages of the PCA-based methods are: the lack of requirements as to the number of observations compared to the number of variables, and the possibility of analysing numerous variables, including strongly correlated ones.

On the other hand, a serious weakness of the proposed approach can be the loss of relevant information, since the applied between-class PCA is based on the table of group means. Taking this aspect into account, the proposed methods can be considered as an initial examination of data that should be supported in the next step by more formal methods of spatial-temporal data analysis, including, for example, the PCA for functional data (e.g.: Górecki, Krzyśko, 2012: 71–87) or the nonlinear PCA (e.g.: Krzyśko et al., 2018: 169–181).

To meet the objectives of the study, the between-countries PCA was applied (groups corresponded to 28 EU countries, so the spatial effect was taken into account). Then, the within-countries PCA revealed the temporal effect. All the results were presented graphically with the use of factorial maps: scatterplots and biplots.

All the calculations were performed with the use of the R-environment, specifically packages: ade4 and adegraphics.

3. Results

Below, in the subsections, the authors provide the results of the conducted analyses of ICT usage development in a breakdown into five areas: Internet access and usage, website usage, social media use by type, social media use by purpose, and ICT specialists demand.

3.1. The assessment of Internet access and usage changes in enterprises in the years 2010–2019

The following three variables were taken into consideration for the analysis purposes:
1) enterprises with Internet access (percentage of enterprises; X_1);
2) enterprises with broadband access (fixed or mobile, percentage of enterprises; X_2);
3) use of computers and the Internet by employees (percentage of total employment; X_3).

The results of the between-class PCA for groups corresponding to the EU countries[1] are presented in Figures 1 and 2. The total variability (inertia) in the classical PCA, performed on the combined datasets, equals the number of variables (three in this research). In the presented analysis, the between-class inertia is equal to 2.2296, i.e. 74.32% of the total inertia is due to the spatial factor.

1 The EU countries abbreviations used in the figures: BE – Belgium, BG – Bulgaria, CZ – Czechia, DK – Denmark, DE – Germany, EE – Estonia, IE – Ireland, EL – Greece, ES – Spain, FR – France, HR – Croatia, IT – Italy, CY – Cyprus, LV – Latvia, LT – Lithuania, LU – Luxembourg, HU – Hungary, MT – Malta, NL – Netherlands, AT – Austria, PL – Poland, PT – Portugal, RO – Romania, SI – Slovenia, SK – Slovakia, FI – Finland, SE – Sweden, UK – United Kingdom.

The results of the analysis are summarised with the use of a biplot (Figure 1). The variables are presented as vectors and objects (EU countries) as points. The angles between all vectors, as well as between the vectors representing the set of variables and the principal components (axes), can be used to assess the linear correlation coefficients. The direction of the vector corresponds to the direction of the highest variability of a given variable, while its length is proportional to the meaning of this variable.

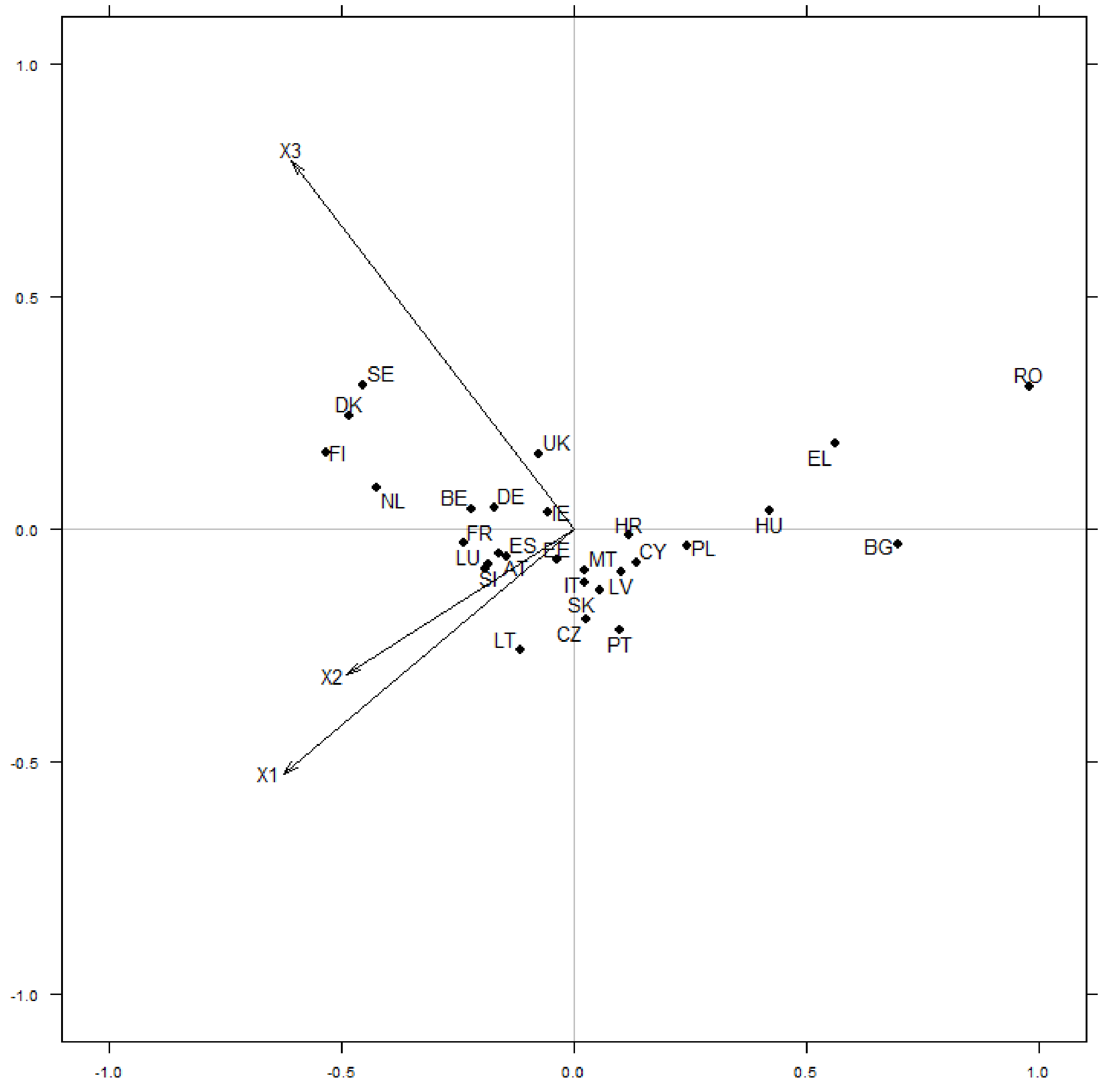


Figure 1. Internet access and usage in enterprises – the between-countries PCA biplot

Source: own elaboration based on Eurostat data

The first axis in Figure 1 is most strongly correlated with X_1 (percentage of enterprises with Internet access) while the second one with X_3 (the use of computers and the Internet by employees), with high levels of both variables towards the left.

The points representing the EU Member States can be projected perpendicularly onto the vectors, representing the variables to obtain the approximate ordering of the countries in order of the increasing level of Internet access and usage in enterprises.

Romania (RO), Bulgaria (BG), Greece (EL), Hungary (HU) and Poland (PL) are the countries characterised by the lowest percentage of enterprises with access to the Internet, as well as the lowest use of computers and the Internet by employees. The highest percentages of enterprises with Internet access and broadband Internet connection are identified in Finland (FI), the Netherlands (NL) and Lithuania (LT). Denmark (DK) and Sweden (SE) as well as Finland (FI) and the Netherlands (NL) are the countries with the highest level of computer and Internet usage by employees. The countries located close to the origin of the coordinate system on the biplot, such as Ireland (IE) and Estonia (EE), are characterised by the average level of all considered variables.

To investigate in more detail the similarities and differences across the EU Member States related to the assessment of the diversity of Internet access and usage for individual countries, star plots with ellipses are presented (Figure 2, top).

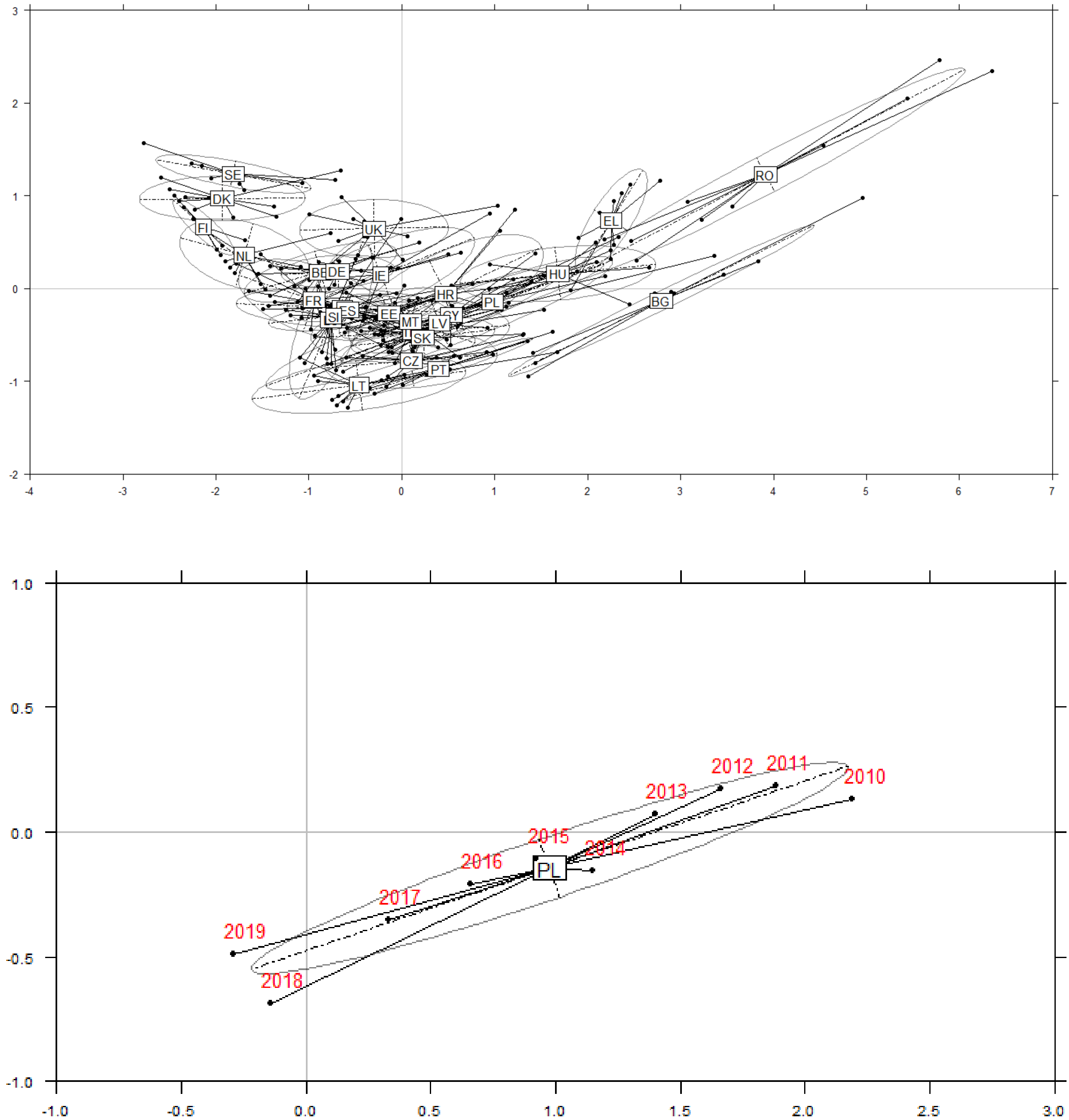


Figure 2. Diversity of Internet usage development in 2010–2019 for all the EU countries (top) and for Poland (bottom)
Source: own elaboration based on Eurostat data

The ten years for each country are grouped with the ten-pointed star and the ellipse. Each star is labelled with the country identification letters, which is located at the gravity of the star centre. In addition, the star plot for Poland is presented (Figure 2, bottom), where the respective years are labelled on the rays.

The ellipse shape facilitates the assessment of the diversity of Internet access and usage in enterprises within each European Union Member State. The smallest ellipse is observed for Finland (FI); hence this is the country characterised by the smallest variability in ICT usage development over the period from 2010 to 2019. The ellipses for Romania (RO), Bulgaria (BG) and Poland (PL) have elongated horizontal axes and are oriented in parallel to the vectors representing the variables X_1 (percentage of enterprises with Internet access) and X_2 (percentage of enterprises with broadband access). This means high variability with regard to the Internet and broadband Internet connection availability, while the percentage of employees using computers and the Internet is relatively stable.

When analysing the ellipse for Poland (PL) with the rays labelled in subsequent years, a noticeable increase of the percentage of enterprises with Internet access and broadband Internet connection year by year can be also observed.

The between-countries PCA was complemented by the within-countries PCA. The within-class PCA is based on the residuals between observed data and the group means. It aims at looking for structures remaining in the data after removing differences between groups of the samples.

The results of the within-countries PCA are presented in Figure 3. The spatial effect was removed. The within-countries inertia is equal to 0.7703, i.e. 25.68% of the total inertia is due to the temporal effect.

The annual variation for the four selected years is shown in the bottom panel of Figure 3 (the row score grouped by years). The analysis reveals a rather strong temporal structure related to broadband Internet connection development (X_2). The percentage of enterprises with the broadband Internet connection type increases year by year. The shrinking ellipses in subsequent years indicate a permanent reduction in inequalities between the EU countries due to ICT access and usage in enterprises.

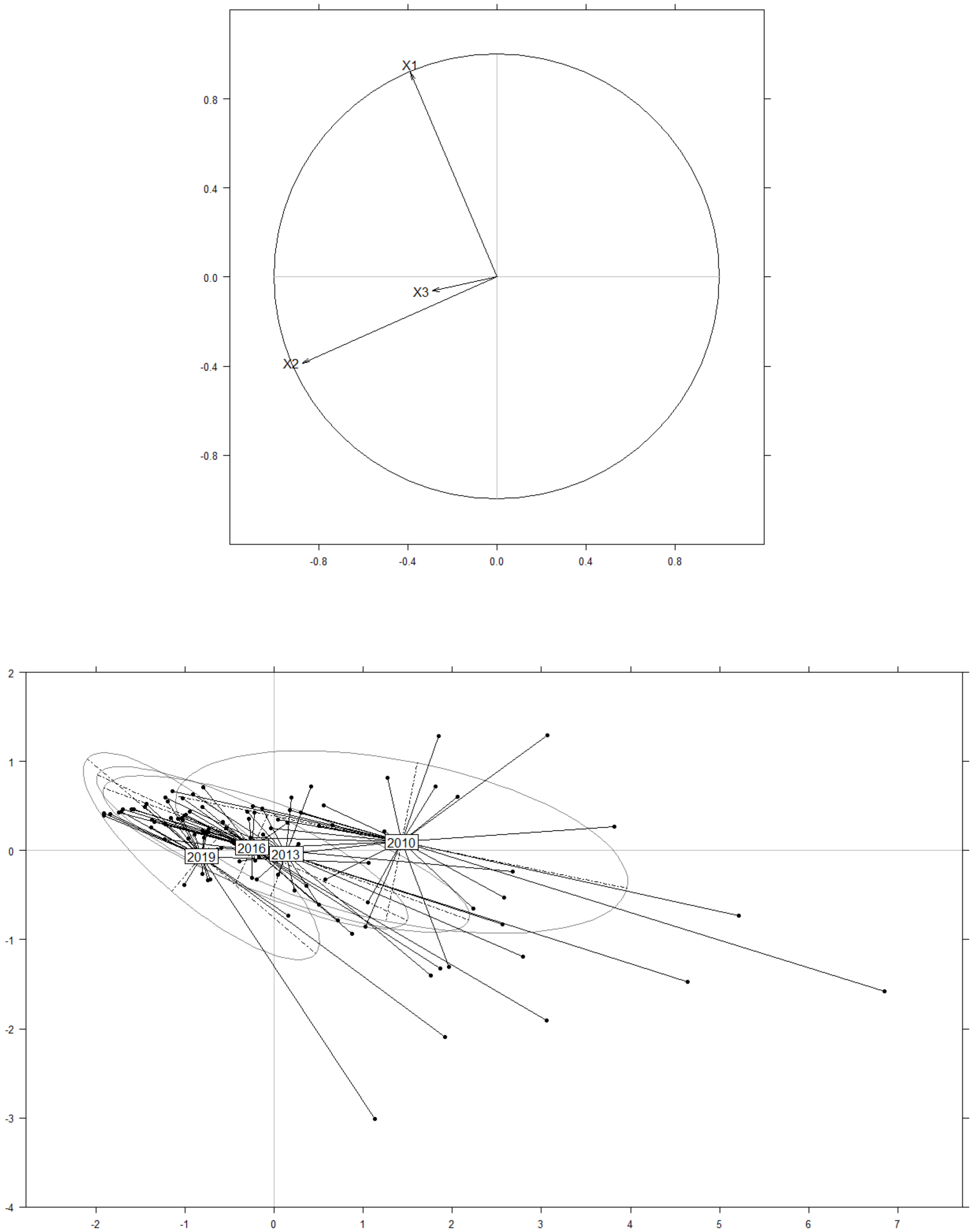


Figure 3. The within-countries PCA results: correlation circle (top); the annual variation in 2010, 2013, 2016, 2019 after removing the spatial effect (bottom)
Source: own elaboration based on Eurostat data

3.2. The assessment of website usage changes in the years 2010–2019

The following three variables were taken into consideration for the analysis of website usage in enterprises:

1) enterprises with a website (percentage of enterprises; X_1);
2) enterprises where the website provided a description of goods or services and price lists (percentage of enterprises; X_2);
3) enterprises where the website provided online ordering or reservation or booking, e.g.: shopping cart (percentage of enterprises; X_3).

The total inertia in the classical PCA equals three. The between-class inertia is equal to 2.2244, i.e. 74.15% of the total inertia is due to the spatial factor. The results of the analysis are summarised with the use of a biplot in Figure 4.

The most strongly correlated with the first PCA axis variable is X_1 (percentage of enterprises with the websites), while the second axis is correlated with variables describing website functionalities: negatively with X_2 and positively with X_3.

Bulgaria (BG), Romania (RO) and also Portugal (PT) are among the Member States where both having a company website and using its functionalities are clearly the most unpopular. In contrast, Denmark (DK) and the Netherlands (NL) as well as Sweden (SE) and Czechia (CZ) belong to the group of countries with the highest percentages of the enterprises with a website (X_1) and where a company website is used for online ordering, reservation or booking (X_3). Poland (PL) is characterised by a relatively low percentage of enterprises having a website and utilising its functionalities. More popular in Polish enterprises is the use of a website to provide a description of goods or services and price lists (X_2).

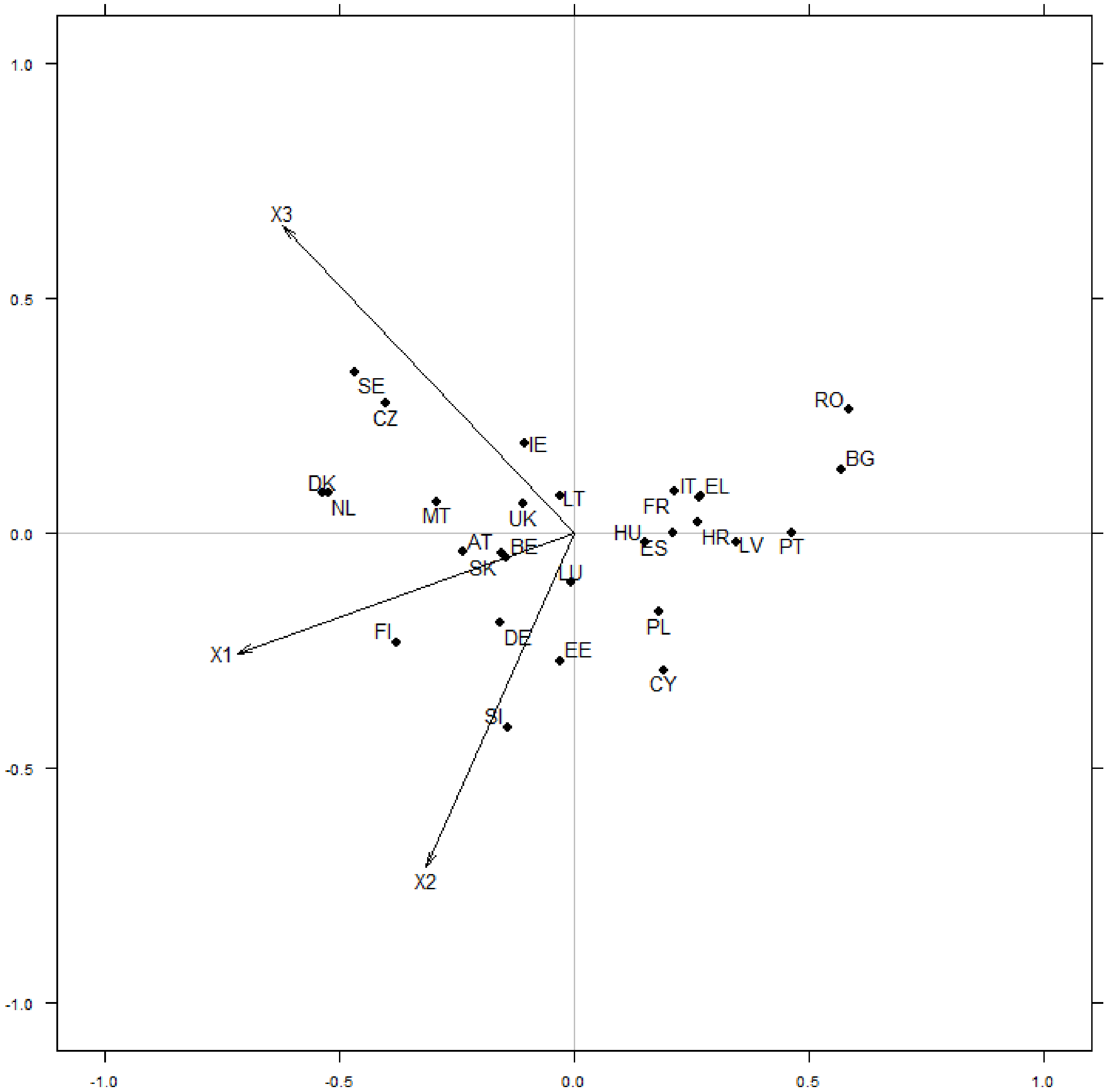


Figure 4. Websites and functionalities – the between-countries PCA biplot
Source: own elaboration based on Eurostat data

The star plots with ellipses for all the EU Member States are presented in Figure 5 (top). In addition, the star plot for Poland is also delivered (Figure 5, bottom), the respective years are labelled on the rays.

The highest variability in website possession and usage can be observed for Germany (DE) and Finland (FI). The ellipse shape for Poland (PL) is rather regular, a slight increase of the percentage of enterprises with a website (X_1) and enterprises where the website provided a description of goods or services and price lists (X_2) can be observed in the last few years.

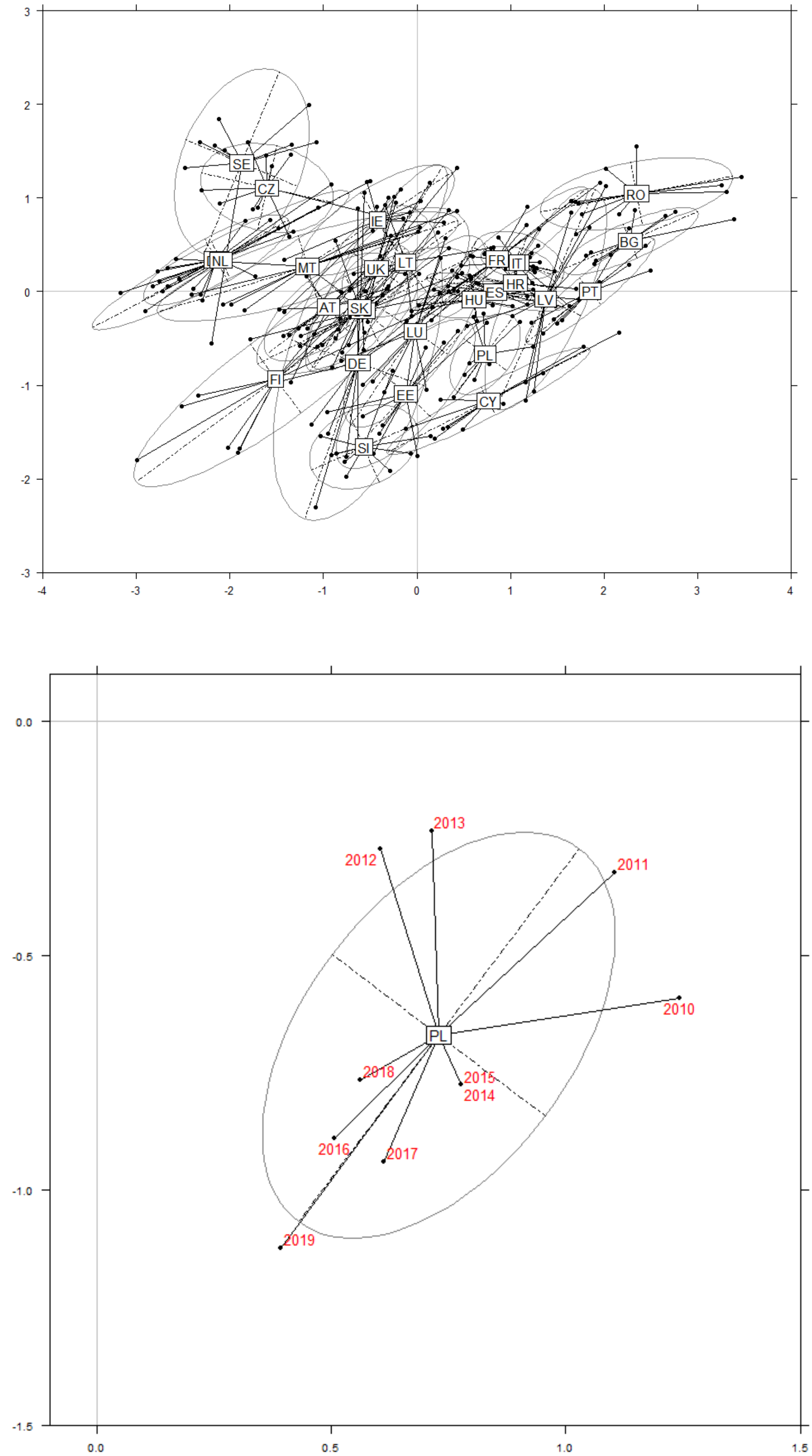


Figure 5. Diversity of website use and website functionalities in 2010–2019 for all the EU countries (top) and for Poland (bottom)

Source: own elaboration based on Eurostat data

The between-countries PCA was complemented by the within-countries PCA. The results of the within-countries PCA are presented in Figure 6.

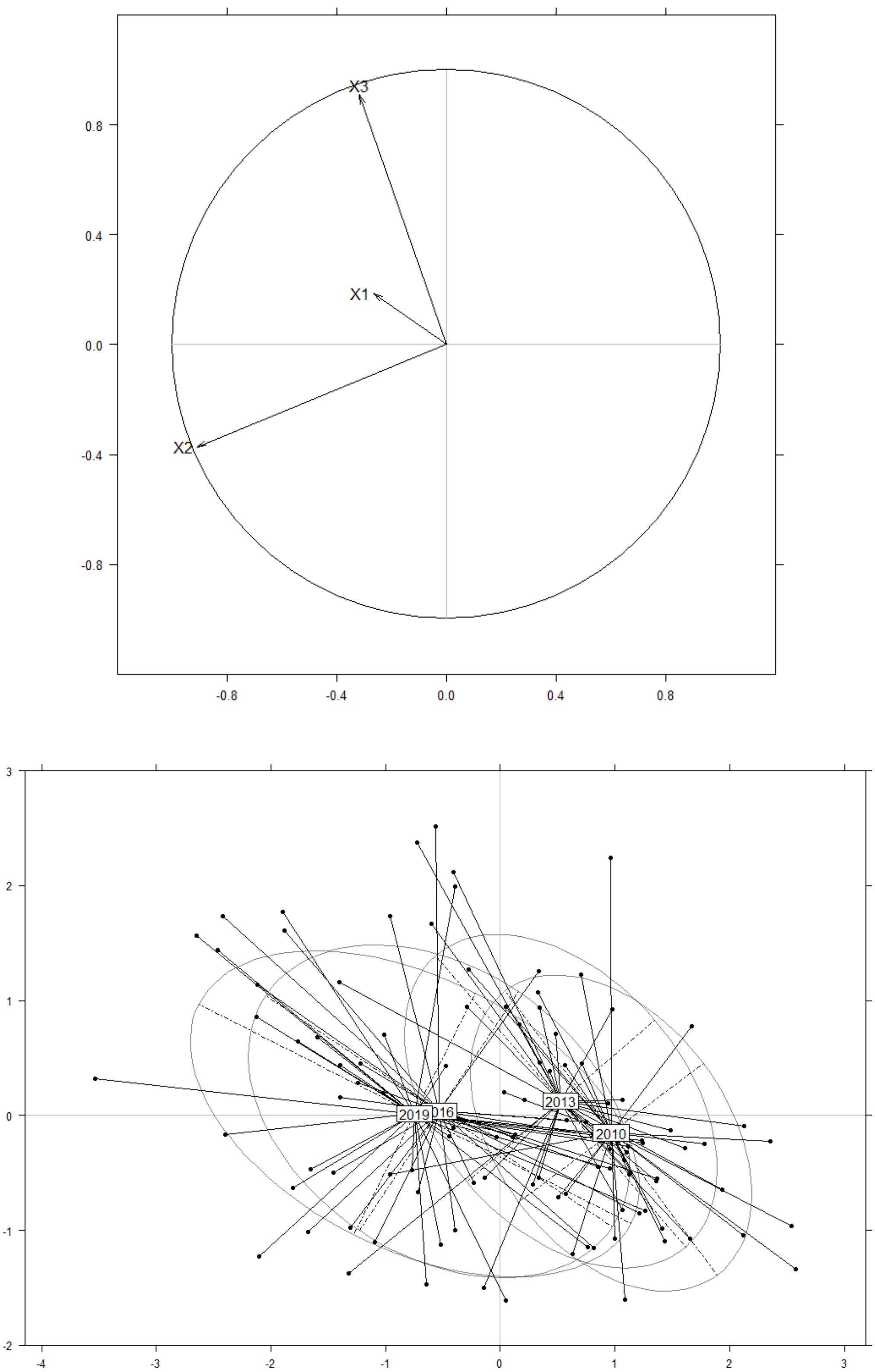


Figure 6. The within-countries PCA results: correlation circle (top); the annual variation in 2010, 2013, 2016, 2019 after removing the spatial effect (bottom)
Source: own elaboration based on Eurostat data

The within-countries inertia is equal to 0.7759, i.e. 25.86% of the total inertia is due to the temporal factor. It can be observed that the percentage of enterprises where the website provided a description of goods or services and price lists (X_2) increases year by year. The ellipses are oriented left-up, which means rather high variability due to the level of using the website for online ordering, reservation or booking (X_3).

3.3. Social media use by type – changes in the years 2014–2019

The complete data were available only for the years 2014–2019, therefore the analysis was conducted for this period. The following five variables were taken into account for the analysis of the type of social media usage in enterprises:

1) use of social networks (e.g.: Facebook, LinkedIn, Xing, Viadeo, Yammer, etc.; percentage of enterprises; X_1);
2) use of company blogs or microblogs (e.g.: Twitter, Present.ly, etc.; percentage of enterprises; X_2);
3) use of multimedia content sharing websites (e.g.: YouTube, Flickr, Picasa, SlideShare, etc.; percentage of enterprises; X_3);
4) use of wiki-based knowledge sharing tools (percentage of enterprises; X_4);
5) having a website and making use of any social media (percentage of enterprises; X_5).

The total inertia in the classical PCA equals five. In the presented analysis, the between-class inertia is equal to 4.0309, i.e. 80.62% of the total inertia is due to the spatial factor. The results of the between-class PCA for groups corresponding to the EU countries are presented in Figures 7 and 8.

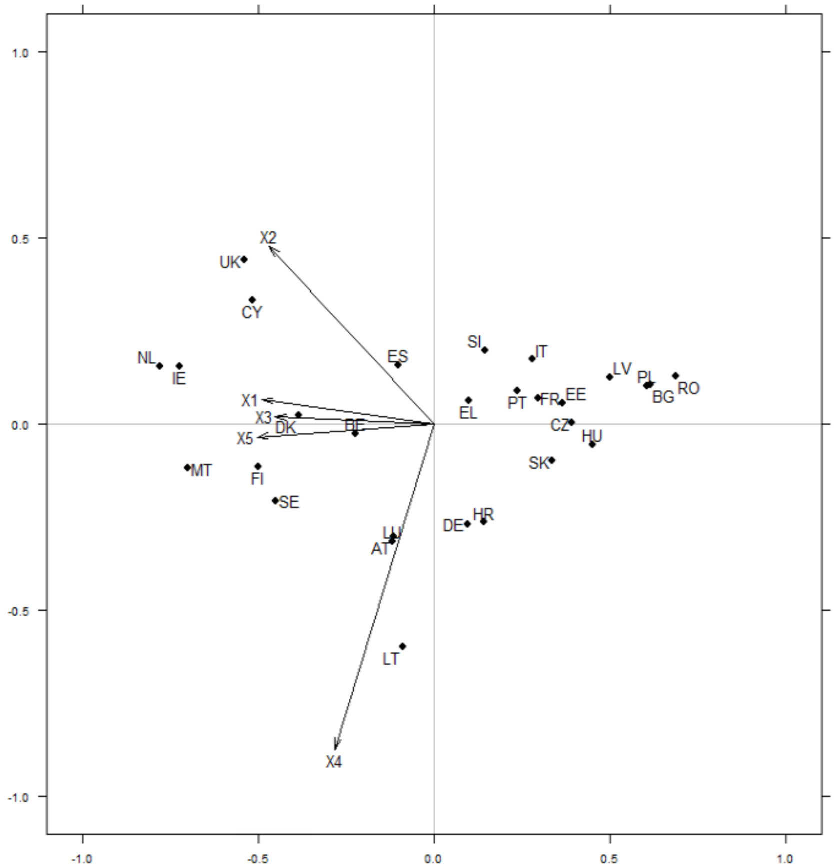


Figure 7. Social media use by type – the between-countries PCA biplot
Source: own elaboration based on Eurostat data

With the first PCA axis (biplot in Figure 7), the most correlated are the following variables: X_1 (social networks using), X_5 (having a website and using any social media) and X_3 (using multimedia content sharing websites), and respectively with the second one: X_4 (the use of wiki-based knowledge sharing tools), followed by X_2 (company blog or microblog usage).

As it can be seen on the biplot, clear clusters of the EU Member States related to different types of social media usage can be observed.

The Netherlands (NL), Ireland (IE), Malta (MT) and also the United Kingdom (UK) and Cyprus (CY) belong to the group of countries where having a website and using social media, specifically social networks, blogs and multimedia content sharing websites, are most widespread. In contrast, Lithuania (LT) is characterised by a rather average level of using social networks, blogs and tools such as YouTube or SlideShare, but is the leader when it comes to the use of wiki-based knowledge sharing tools.

On the right of the first PCA axis, the group of countries with enterprises characterised by the lowest percentage of enterprises using social media in their business activities can be found. This cluster includes Romania (RO), Bulgaria (BG), Poland (PL), Latvia (LV), and Hungary (HU).

To analyse in more detail the differences between the EU countries and to assess the diversity of social media usage for individual countries, the star plots with ellipses are needed (Figure 8, top).

Additionally, the star plot for Poland is also shown (Figure 8, bottom). The smallest variability in the development of social media usage by type over the analysed period can be observed mainly for those countries where the use of social media by enterprises is the rarest: Romania (RO) and Bulgaria (BG). The highest variability can be observed for Luxembourg (LU), Sweden (SE), Finland (FI), and Malta (MT). In Poland (PL), the use of social media in enterprises increases year by year. However, it needs to be emphasised that in this area, in comparison with most of the EU countries, Poland does perform poorly.

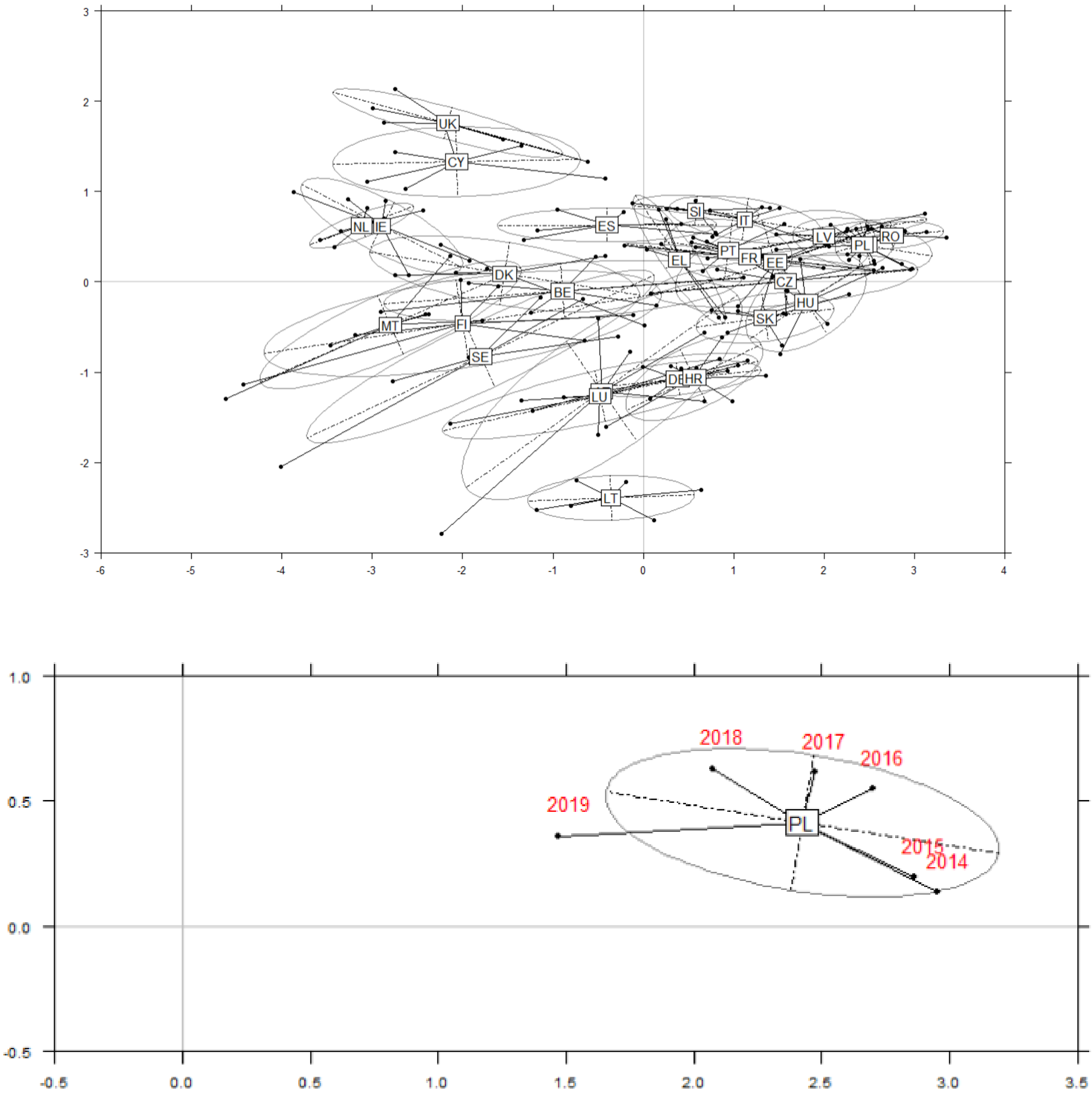


Figure 8. Diversity of social media use by type in 2014–2019 for all the EU countries (top) and for Poland (bottom)

Source: own elaboration based on Eurostat data

The between-countries PCA was complemented by the within-countries PCA. The within-countries inertia is equal to 0.9688, i.e. 19.38% of the total inertia is due to the temporal factor. The results of the within-countries PCA are presented in Figure 9.

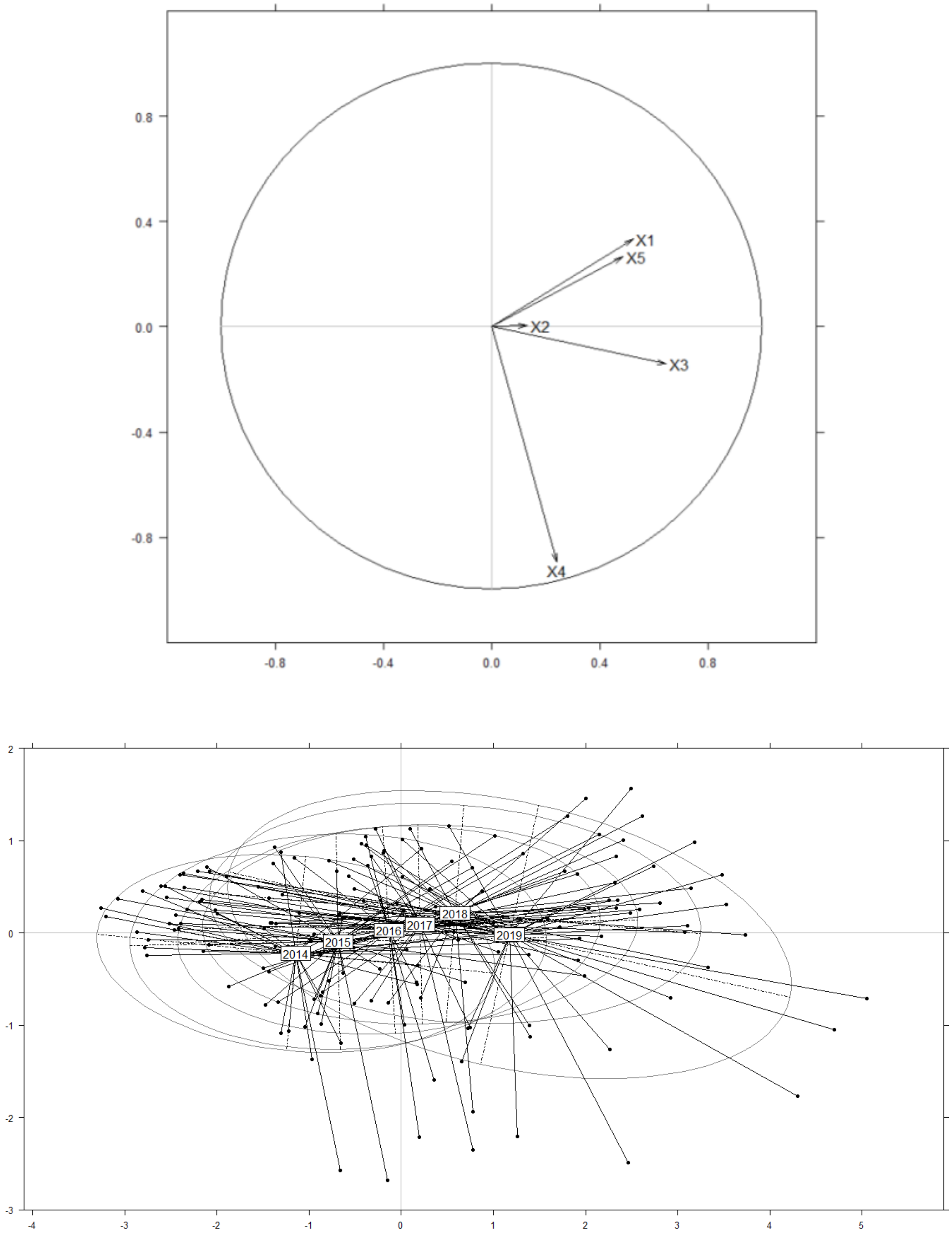


Figure 9. The within-countries PCA results: correlation circle (top); the annual variation in the years 2014–2019 after removing the spatial effect (bottom)
Source: own elaboration based on Eurostat data

It is clearly visible that having a website and using social media in business activities becomes more popular year by year.

3.4. Social media use by purpose – changes in the years: 2013, 2015, 2017 and 2019

The following six variables were taken into consideration for the analysis of the purpose of social media usage in enterprises:
1) developing the enterprise's image or market products (percentage of enterprises; X_1);
2) obtaining or responding to customer opinions, reviews and questions (percentage of enterprises; X_2);
3) involving customers in development or innovation of goods or services (percentage of enterprises; X_3);
4) collaborating with business partners (e.g.: suppliers, etc.) or other organisations (e.g.: public authorities, non-governmental organisations, etc.; percentage of enterprises; X_4);
5) recruiting employees (percentage of enterprises; X_5);
6) exchanging views, opinions or knowledge within the enterprise (percentage of enterprises; X_6).

Complete data were available only for the years 2013, 2015, 2017 and 2019, therefore the analysis was conducted for those four years.

The total inertia in the classical PCA equals four. In the presented analysis, the between-class inertia is equal to 3.8089, i.e. 63.48% of the total inertia is due to the spatial factor. The results of the between-class PCA for groups corresponding to the EU countries are presented in Figures 10 and 11.

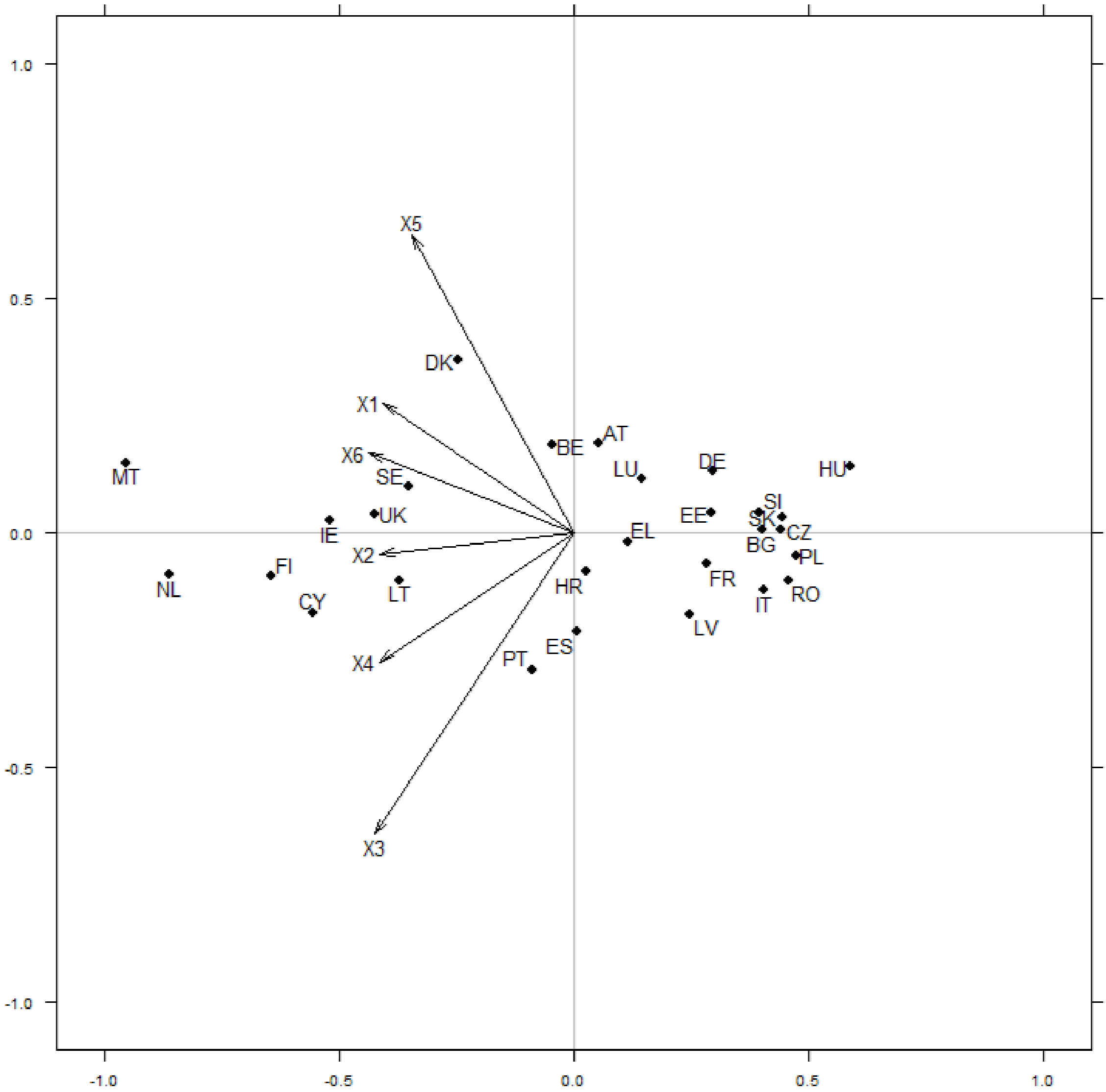


Figure 10. Social media use by purpose – the between-countries PCA biplot
Source: own elaboration based on Eurostat data

The first PCA biplot axis (Figure 10) is correlated with X_6 (exchange of views, opinions or knowledge within the enterprise), X_2 (obtaining or responding to customer opinions, reviews and questions) and X_4 (collaborating with business partners or other organisations) and the second one is correlated with X_3 (involving customers in development or innovation of goods or services) and X_5 (recruiting employees).

It can be observed that some clusters of the EU Member States related to different purposes of social media usage in enterprises are very clearly visible. On the left of the first PCA axis, there are countries characterised by the highest percentages of enterprises using social media to exchange opinions and knowledge within the enterprise, to obtain and respond to customer opinions and questions, to collaborate with business partners, and also to develop the company's image or market products. Malta (MT), the Netherlands (NL), Finland (FI), Cyprus (CY) and Ireland (IE) are included in this group, as well as Lithuania (LT), the United Kingdom (UK) and Sweden (SE). The point representing Denmark (DK) is also located close to the mentioned cluster, but the high percentage of enterprises using social media for recruiting employees makes Denmark divergent from this group.

On the opposite side of the first PCA axis, there are countries where the use of social media for any purpose is marginal. Poland (PL) belongs to that group, as well as Hungary (HU), Romania (RO), Czechia (CZ), and Slovenia (SI).

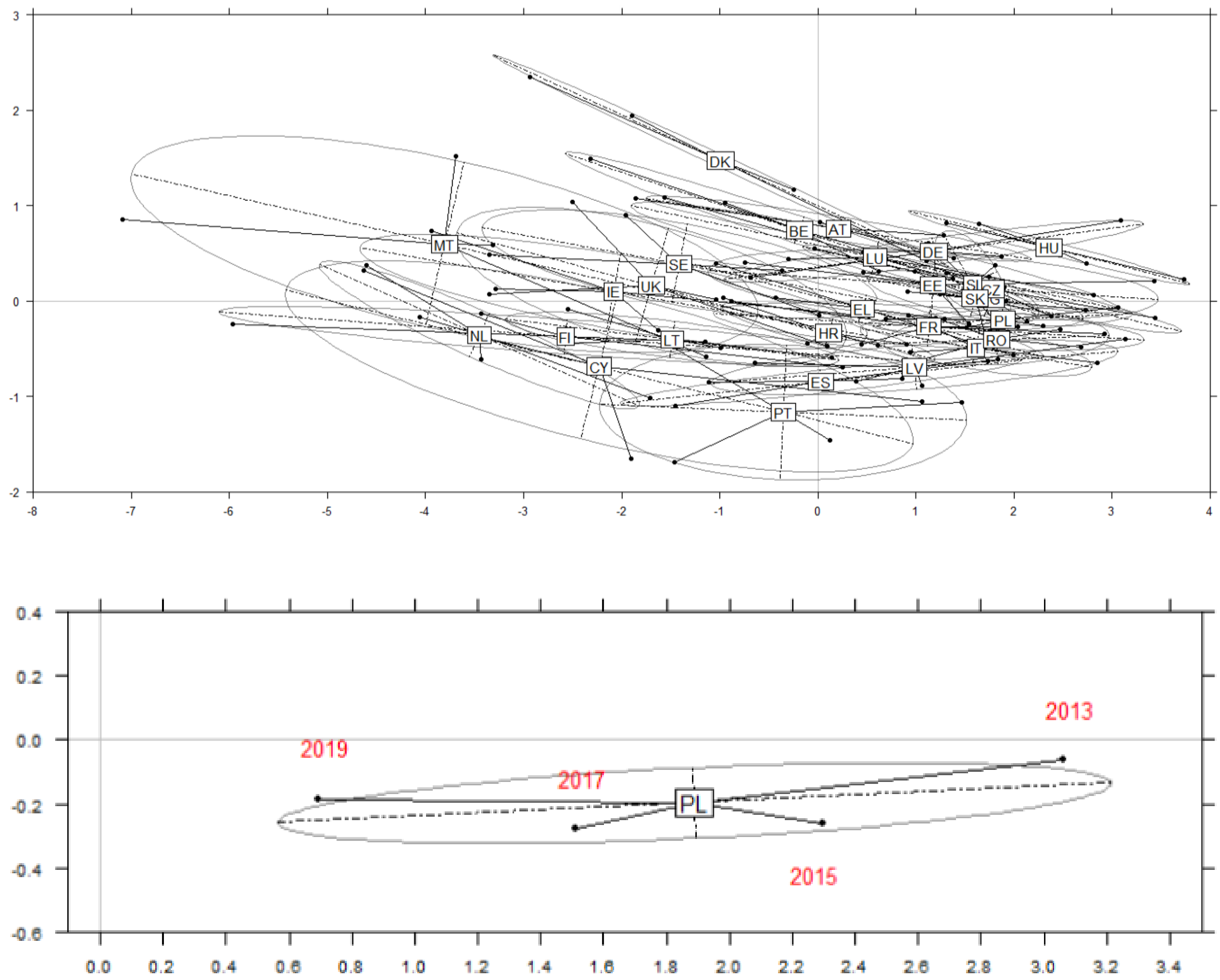
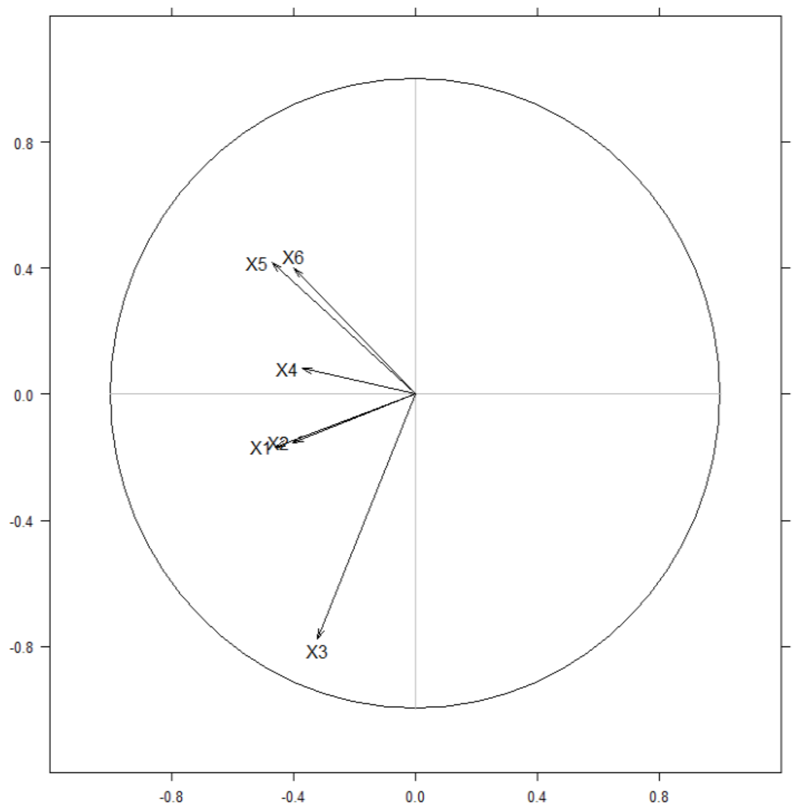


Figure 11. Diversity of social media use by type in 2013, 2015, 2017, 2019 for all the EU countries (top) and for Poland (bottom)
Source: own elaboration based on Eurostat data

When analysing the star plots with ellipses for all the EU Member States (Figure 11, top), it can be observed that the ellipses are oriented left-up for most countries. This means rather high variability in the analysed years due to the use of social media for recruitment purposes (X_5), development of the company image (X_1), as well as intra-company exchange of knowledge and opinions (X_6). The ellipse for Poland (Figure 11, bottom) is oriented in parallel to the first PCA axis, which indicates high variability – mainly with regard to X_2 (obtaining or responding to customer opinions, reviews and questions).

The between-countries PCA was complemented by the within-countries PCA. The within-countries inertia is equal to 2.1911, i.e. 36.52% of the total inertia is due to the temporal factor. The results of the within-countries PCA are presented in Figure 12.



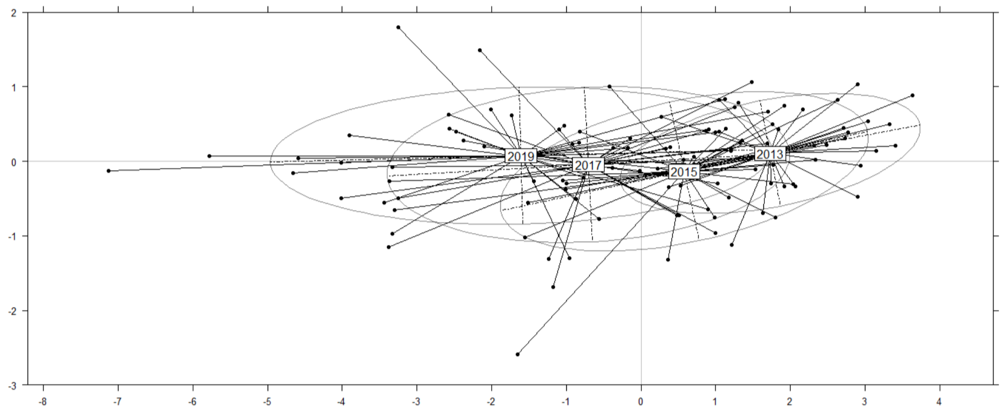


Figure 12. The within-countries PCA results: correlation circle (top); the annual variation in the years 2013, 2015, 2017, 2019 after removing the spatial effect (bottom)

Source: own elaboration based on Eurostat data

It can be seen that the changes take place along the first within-PCA axis: the percentages of enterprises using social media to collaborate with business partners (X_4), develop the enterprise's image (X_1) and obtain and respond to customer opinions (X_2) constantly increase year by year in the analysed period.

3.5. Need for ICT specialists in enterprises – changes in the years 2014–2019

The following three variables were taken into account for the analysis of ICT competence and demand for ICT skills in enterprises:

1) enterprises that employ ICT specialists (percentage of enterprises; X_1);
2) enterprises that recruited or tried to recruit ICT specialists (percentage of enterprises; X_2);
3) enterprises that provided training to develop/upgrade ICT skills of their personnel (percentage of enterprises; X_3).

Complete data were available for the years 2014–2019, therefore the analysis was conducted for this period.

The total inertia in the classical PCA equals three. In the presented analysis, the between-class inertia is equal to 2.6095, i.e. 86.98% of the total inertia is due to the spatial factor. The results of the between-class PCA for groups corresponding to the EU Member States are presented in Figures 13 and 14.

The first axis in the between-countries PCA biplot (Figure 13) corresponds to ICT specialists employment (X_1) and recruitment (X_2). The second axis is strongly correlated with ICT training (X_3).

As it can be seen in Figure 13, there are clear clusters related to the level of ICT competence and the need for ICT skills in enterprises. Ireland (IE) and Belgium (BE), Malta (MT), Denmark (DK), the Netherlands (NL), Luxembourg (LU), as well as Hungary (HU) and Finland (FI) are included in the group of countries characterised by the highest percentage of enterprises that employ and recruited or tried to recruit ICT specialists. Interestingly, these countries do not report a high percentage of enterprises providing ICT training to employees.

Spain (ES) and Austria (AT) are the countries described by the highest percentage of enterprises that provided training to develop and upgrade ICT skills of their employees.

Romania (RO), Poland (PL) and Italy (IT) perform the worst when compared to other EU countries in terms of employing ICT specialists in enterprises, as well as providing training to develop ICT skills for their own employees.

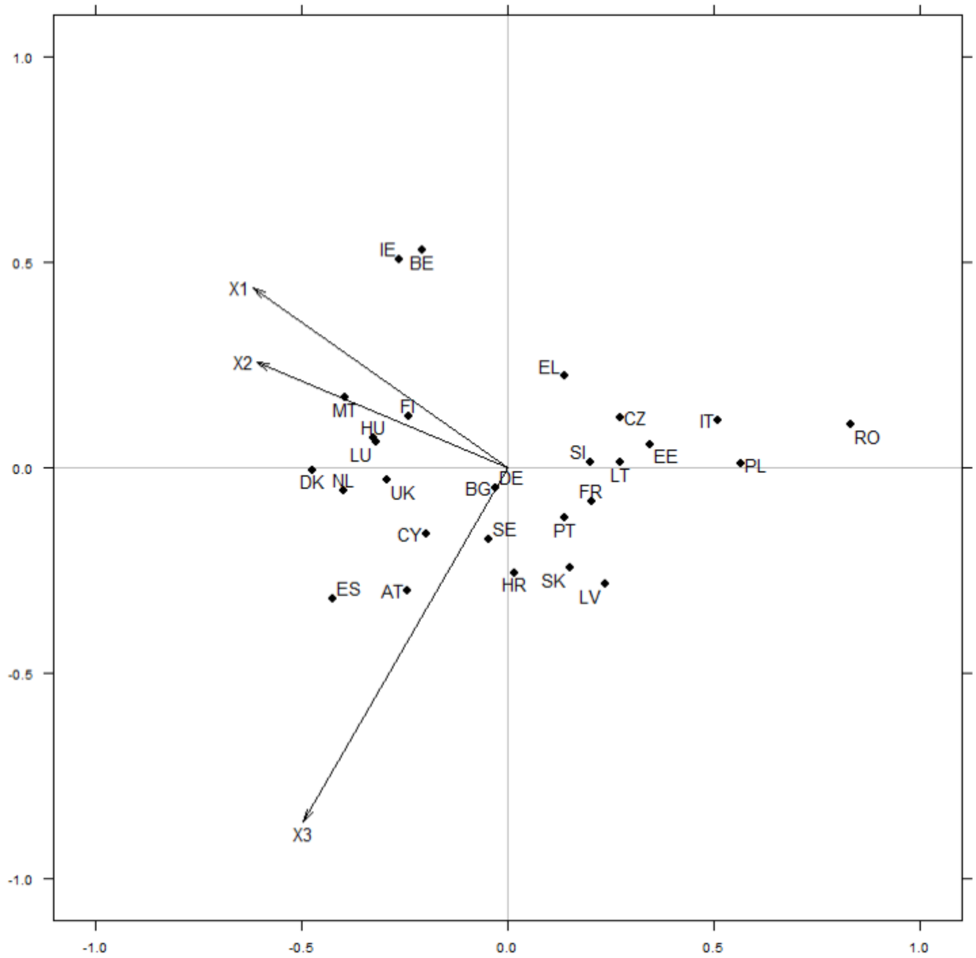


Figure 13. ICT specialists employment – the between-countries PCA biplot
Source: own elaboration based on Eurostat data

The star plots with ellipses (Figure 14) provide the possibility of assessing the diversity in demand for ICT specialists within each country.

For Poland (PL), only in 2018 and 2019, an increase of the demand for ICT specialists can be observed.

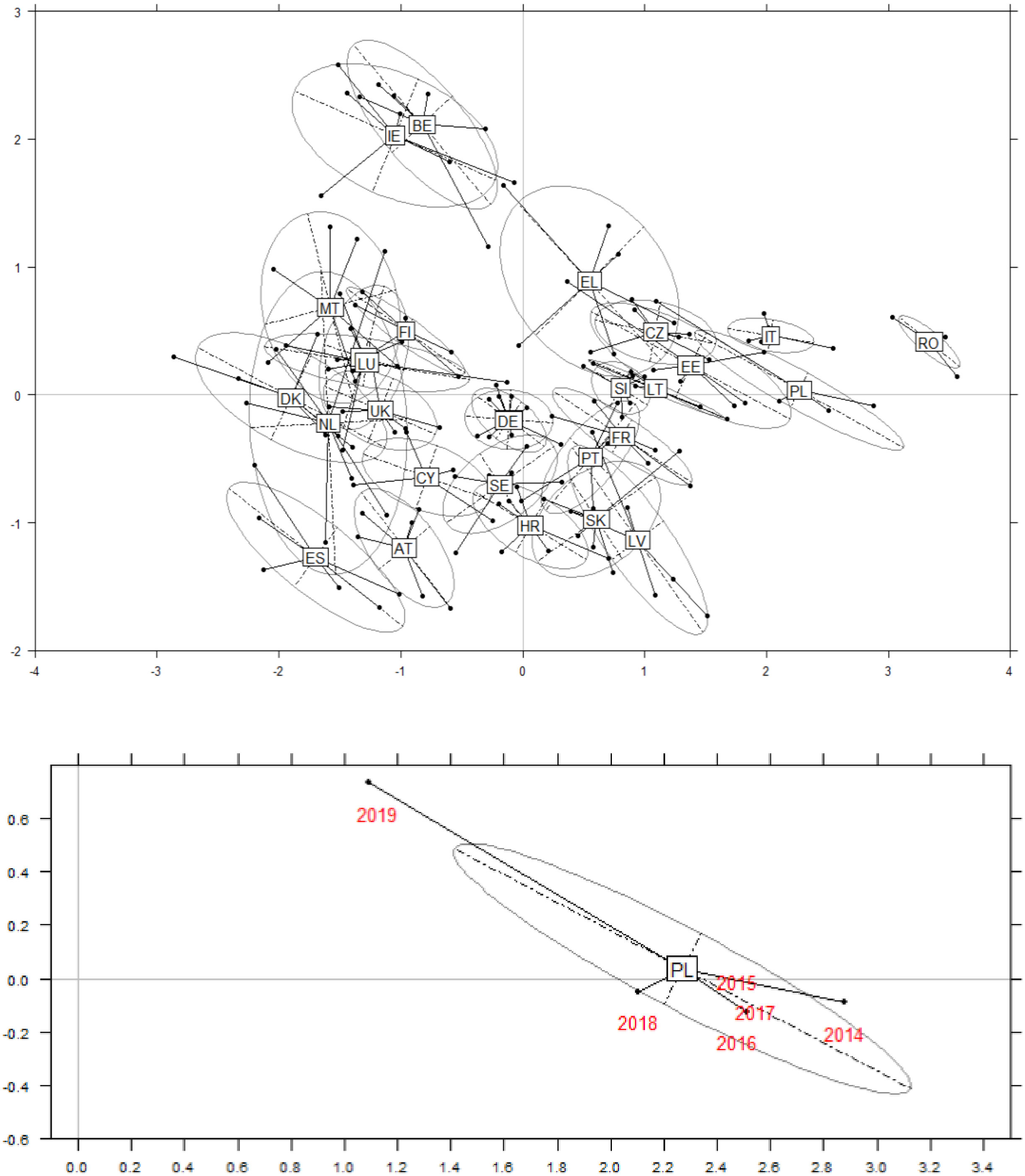


Figure 14. Diversity of ICT specialists employment in 2014–2019 for all the EU countries (top) and for Poland (bottom)
Source: own elaboration based on Eurostat data

The between-countries PCA was complemented by the within-countries PCA. The within-countries inertia is equal to 0.3905, i.e. 13.16% of the total inertia is due to the temporal effect. The results of the within-countries PCA are presented in Figure 15.

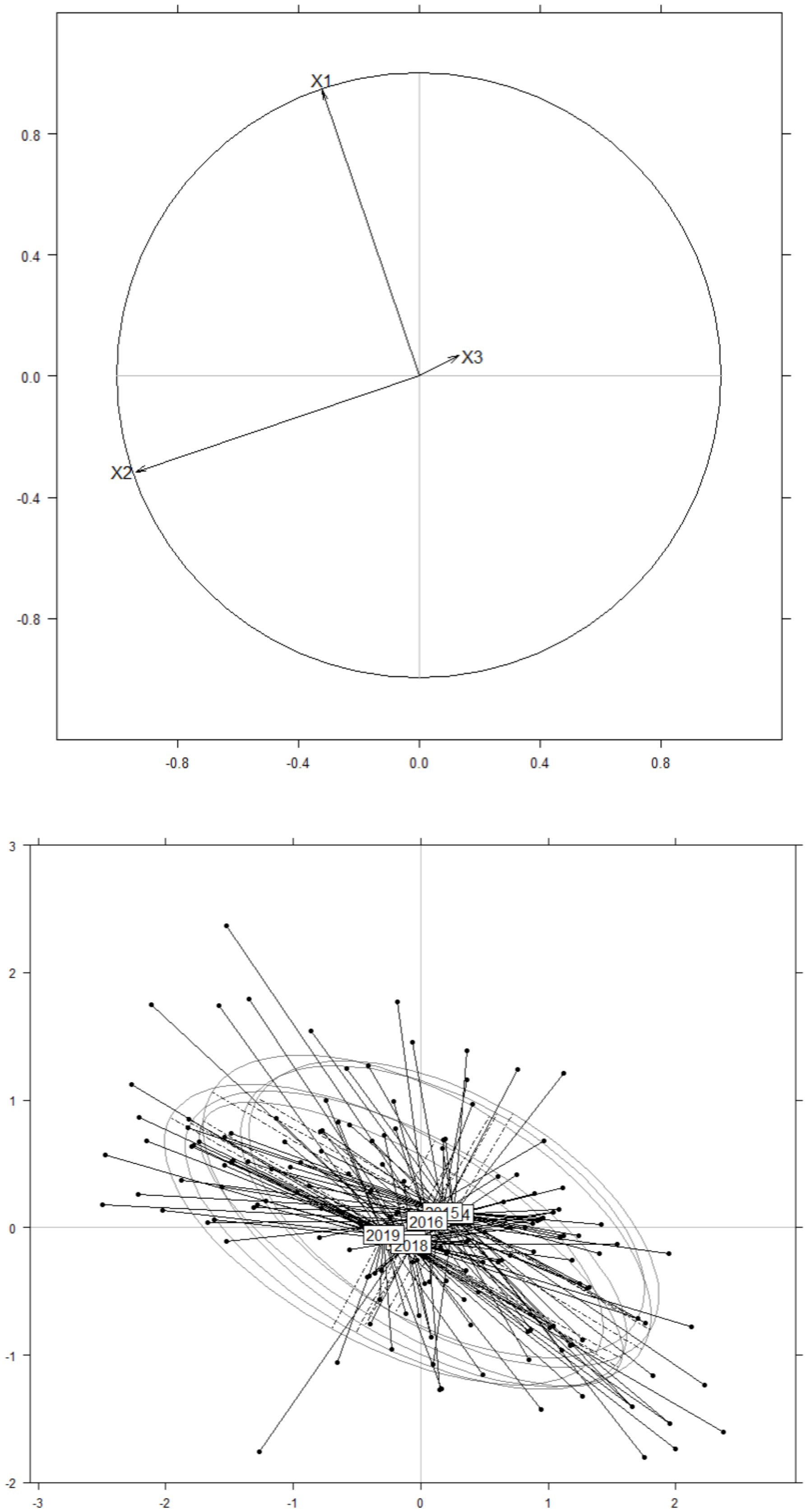


Figure 15. The within-countries PCA results: correlation circle (top); the annual variation in the years 2014–2019 after removing the spatial effect (bottom)
Source: own elaboration based on Eurostat data

After removing the differences related to the spatial effect, the temporal effect is not strong. Only in the last two years of the analysis an increase in the need for ICT specialists can be seen. Ellipses are oriented left-up. In the studied years, the gap across the EU Member States due to the level of employment of ICT specialists in enterprises does not decrease.

4. Discussion

The selected multivariate statistical analysis methods helped to meet the goals presented in the Introduction. The research hypotheses, formulated in the Research methodology section of the paper, were positively verified by the obtained results: ICT growth was identified and its level for all the European Union countries was assessed. Regarding ICT usage by enterprises, in all years of the considered period, the distance of Poland to the UE–28 leading Member States was considerable. The obtained results are coherent with the findings of the literature on the ICT development in the European Union's enterprises, presented in the Literature review section: Bajdor (2015), Savulescu (2015), Zečević, Radović-Stojanović, and Čudan (2019), and Billon, Marco, and Lera-Lopez (2017).

It is not possible to make a direct comparison of the results obtained by the authors with the outcomes of the analyses made in the cited literature, as most of them were based on a descriptive approach with simple statistical tools, including basic types of charts. The considered time series were rather short. All of the cited authors found that Poland was lagging behind the EU in terms of ICT growth, and most analyses pointed to its poor performance in comparison with the majority of the EU Member States.

Billon, Marco, and Lera-Lopez (2017) reached for more advanced statistical methods, though data for households and enterprises were mixed. Their research was focused on investigating relationships between ICT usage by firms and innovation, the analyses included the European regions at the first level of disaggregation (NUTS1) data. Regarding the findings on Poland: it was characterised by a similar level of ICT development as Bulgaria, Romania, Czechia, Hungary, Greece, Portugal, Spain, and Italy.

Savulescu (2015) showed that in 2013 and 2014 Poland was in the group of the European Union countries where the lowest ICT sector share in the national economy occurred. The author emphasised that in the 2013 ranking based on the Networked Readiness Index, Poland held the 23rd position among all the Member States.

Bajdor (2015) points out that Poland has a lower average percentage of enterprises using mobile devices than the EU, as well as insufficient usage of e-commerce tools.

Finally, Zečević, Radović-Stojanović, and Čudan (2019) listed Poland in the group of the European Union countries with the lowest percentage of enterprises using a fixed broadband Internet connection, relatively low usage of social media in business activities, the lowest share of enterprises using cloud computing services, a low percentage of enterprises using e-commerce tools, and a slightly lower percentage of businesses using ERP software. In the above-mentioned research, in most of analyses, the same clusters of countries were identified, while different variables were taken into account.

The authors have noted that this grouping can be explained by certain patterns based on geographical, historical and political conditions. The outcomes of analyses, which are described in the Results section, have led to the same conclusions: the Central and Eastern European countries perform poorly, while countries of the Benelux and Scandinavia are the leading ones in most of the analyses.

5. Conclusions

ICT usage in enterprises across the EU countries was investigated and significant differences were found between the Member States. Also, the groups of countries with similar ICT usage performance were identified. In the years of study, the trend was positive throughout the European Union. The analysis results obtained show that a systematic reduction in inequalities across the EU countries was observed, although those belonging to the least developed group of countries remained far behind the leaders. Poland performs poorly: although it has progressed in general, the country has not caught up to the EU average.

The results based on exploratory data analysis methods are consistent with the literature findings and the European Commission's rankings made for the EU Member States with the use of the Digital Economy and Society Index (since the DESI was developed, the highest rank achieved by Poland has been the 22nd; it was the 23rd in the DESI 2020 Report).

ICT usage development is an indispensable determinant of economic and social growth, hence the European Commission and all the EU governments should extensively support the acceleration of ICT growth. On the basis of the conducted analysis, some recommendations can be made: attention should be paid to reducing inequalities between the Members States, in parallel with building bridges between the leading and poor performing ones. ICT usage, spread and implementation are also fundamental in reaching the sustainable development goals for the EU, hence supporting enterprises in ICT usage growth is important.

The exploratory statistical methods dealing with three-way data structures, i.e. the between and within-class PCA, have great potential in investigating trends and patterns when multivariate data are considered. The extraordinary advantage they are characterised by is the fact that without very complicated mathematical models, friendly for interpretation factorial maps can be drawn. Despite their advantages, researchers in the fields of economics, finance and related areas have not recognised them as an efficient tool so far. The research results concerning ICT usage obtained with the use of these methods are consistent with other works and reports, therefore it can be concluded that they performed well. However, for a comprehensive overview of the researched phenomenon, supplementing them with others, for example, the PCA for functional data (Górecki, Krzyśko, 2012) and the nonlinear PCA (Krzyśko et al., 2018), should be considered.

The time series considered in this research cover 2010 to 2019 data, as the year 2020 was a turning point for ICT usage growth all over the world since the COVID–19 pandemic accelerated information and communication technologies development by forcing societies, governments and businesses to expand the existing applications and discover new ones.

The pandemic forced changes in ICT usage in all perspectives. All the world economies, societies and governments received an unexpected external stimulus to expand their ICT products and solutions usage. They were also forced to broaden the scope of ICT usage (for example, remote work and e-recruitment, e-commence, e-education at all levels, e-health services, e-administration, or e-courts). The existing stimulants and destimulants of ICT development have been redefined and a new chapter of ICT growth began in all countries: from developed, through in transition to developing ones. The authors' separate study aims to investigate to what extent the pandemic has intensified ICT usage and its scope in Polish versus European enterprises and to research how the course of the development path and the pace of changes in ICT growth have been affected by the COVID–19 pandemic so far.

Eurostat organised a special module in the survey on 'ICT usage and e-commerce in enterprise,' which was dedicated to the impact of COVID–19 on the use of ICT in enterprises and covered 2020. The collected data are available in the Eurostat database (Eurostat, 2022). The module results based on the EU enterprises (without Czechia, Estonia, Ireland, Greece, Spain, France, and Croatia) show that:

1) 50% of enterprises increased the number of remote meetings (Finland, the Netherlands, Sweden and Malta by over 70% and Poland by 29%);
2) 33% of enterprises increased the share of employees having remote access to the ICT systems of the enterprise other than e-mail (Malta: 58%, the Netherlands and Belgium by over 40% and Poland by 21%).

Also, on the basis of Eurostat data, the dynamics of ICT specialists employment in the EU–27 sped up, as the average annual rate of change in the years 2012–2019 was 4.1%, while in 2020 there was 7.3% more specialists employed.in comparison with 2019. It is worth mentioning that employment (all sectors) from 2012 to 2019 grew by 0.92% yearly, while in 2020 it decreased by 1.58%, which leads to the conclusion that the participation of ICT specialists increased in total employment.

The authors conducted separate detailed analyses taking into account the pandemic period which will be presented in a separate paper.

References

Bajdor P. (2015), *The Use of Information and Communication Technologies in Polish Companies in Comparison to Companies from European Union*, "Procedia Economics and Finance", vol. 27, pp. 702–712, https://doi.org/10.1016/S2212-5671(15)01051-5

Becker J., Becker A., Sulikowski P., Zdziebko T. (2018), *ANP-based analysis of ICT usage in Central European enterprises*, "Procedia Computer Science", vol. 126, pp. 2173–2183, https://doi.org/10.1016/j.procs.2018.07.231

Billon M., Marco R., Lera-Lopez F. (2017), *Innovation and ICT use by firms and households in the EU: A multivariate analysis of regional disparities*, "Information Technology People", vol. 30(2), pp. 424–448, https://doi.org/10.1108/ITP-05-2015-0098

Cheng C., Chien M., Lee C. (2021), *ICT diffusion financial development and economic growth: An international cross-country analysis*, "Economic Modelling", vol. 94, pp. 662–671, https://doi.org/10.1016/j.econmod.2020.02.008

Dufour A.B. (2008), *Within PCA and Between PCA*, http://pbil.univ-lyon1.fr/R/pdf/course4.pdf [accessed: 25.03.2019].

Dutta S., Lanvin B. (eds.) (2019*), The Network Readiness Index 2019: Towards a future-ready society*, Portulans Institute, Washington.

European Commission (2017), *Toolbox 2017 edition – Quality of Public administration*, https://ec.europa.eu/social/main.jsp?catId=738&langId=en&pubId=8055&type=2&furtherPubs=no [accessed: 1.03.2022].

European Commission (2020), *The Digital Economy and Society Index (DESI) 2020*, https://ec.europa.eu/digital-single-market/en/news/digital-economy-and-society-index-desi-2020 [accessed: 1.03.2022].

European Commission, Directorate-General for the Information Society and Media, Gualtieri V., Curtarelli M., Donlevy V., Shater Jannati M. (2017), *ICT for work: digital skills in the workplace: final report*, Publications Office, https://data.europa.eu/doi/10.2759/498467 [accessed: 1.03.2022].

Eurostat (2016), *Glossary: Information and communication technology (ICT)*, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Information_and_communication_technology_(ICT)&oldid=305431 [accessed: 1.03.2022].

Eurostat (2022), *Impact of COVID–19 on the use of ICT in enterprises*, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Impact_of_COVID-19_on_the_use_of_ICT_in_enterprises#Impact_of_COVID-19_pandemic_on_remote_access_to_enterprise_resources_and_remote_meetings [accessed: 30.03.2022].

Evangelista R., Guerrieri P., Meliciani V . (2014), *The economic impact of digital technologies in Europe*, "Economics of Innovation and New Technology", vol. 23, pp. 802–824, http://doi.org/10.1080/10438599.2014.918438

Ferscha A., Farrahi K., Hoven J. van den, Hales D., Nowak A., Lukowicz P., Helbing D. (2012), *Socio-inspired ICT*, "The European Physical Journal Special Topics", vol. 214, pp. 401–434, https://doi.org/10.1140/epjst/e2012-01700-6

Gower J.C., Le Roux N.C., Gardner-Lubbe S. (2015), *Biplots: quantitative data*, "WIREs Comput Stat", vol. 7, pp. 42–62, https://doi.org/10.1002/wics.1338

Górecki T., Krzyśko M. (2012), *Functional principal components analysis*, [in:] J. Pociecha, R. Decker (eds.), *Data Analysis Methods and its Applications*, C.H. Beck, Warszawa, pp. 71–87.

Higon D.A., Gholami R., Shirazi F. (2017), *ICT and environmental sustainability: A global perspective*, "Telematics Inform", vol. 34(4), pp. 85–95, https://doi.org/10.1016/j.tele.2017.01.001

Hilty L.M., Aebischer B. (2015), *ICT for sustainability: An emerging research field*, [in:] L.M. Hilty, B. Aebischer (eds.), *ICT Innovations for Sustainability. Advances in Intelligent Systems and Computing*, vol. 310, Springer, Cham, pp. 3–36, https://doi.org/10.1007/978-3-319-09228-7_1

Jorgenson D.W., Vu K.M. (2016), *The ICT revolution world economic growth and policy issues*, "Telecommunications Policy", vol. 40(5), pp. 383–397, https://doi.org/10.1016/j.telpol.2016.01.002

Khalili F., Lau W., Cheong K. (2014), *ICT as a source of economic growth in the information age: empirical evidence from ICT leading countries*, "Research Journal of Economics Business and ICT", vol. 9(1), pp. 1–18.

Khan F.N., Sana A., Arif U. (2020), *Information and communication technology (ICT) and environmental sustainability: a panel data analysis*, "Environmental Science and Pollution Research", vol. 27, pp. 36718–36731, https://doi.org/10.1007/s11356-020-09704-1

Kostoska O., Kocarev L. (2019), *A Novel ICT Framework for Sustainable Development Goals*, "Sustainability", vol. 11(7), pp. 1–31, https://doi.org/10.3390/su11071961

Krzyśko M., Łukaszonek W., Ratajczak W., Wołyński W. (2018), *Nonlinear Principal Component Analysis for Geographically Weighted Temporal-spatial Data*, "Acta Universitatis Lodziensis. Folia Oeconomica", vol. 4(337), pp. 169–181, https://doi.org/10.18778/0208-6018.337.11

Lechman E., Marszk A. (2019), *ICT-Driven Economic and Financial Development. Analyses of European Countries*, Academic Press, Cambridge, https://doi.org/10.1016/c2017-0-00344-0

Lechman E., Kutrzeba F., Mustakoski K. (2020), *ICT and social development. Conceptual considerations*, [in:] E. Lechman, M. Popowska (eds.), *Society and Technology. Opportunities and Challenges*, Routledge, London, pp. 1–12, https://doi.org/10.4324/9780429278945

Ministry of Development Funds and Regional Policy (2014), *Operational Programme Digital Poland for 2014–2020*, https://www.funduszeeuropejskie.gov.pl/media/10410/POPC_eng_1632015.pdf [accessed: 1.03.2022].

Moroz M. (2017), *The Level of Development of the Digital Economy in Poland and Selected European Countries: A Comparative Analysis*, "Foundations of Management", vol. 9, pp. 175–190, https://doi.org/10.1515/fman-2017-0014

Niebel T. (2018), *ICT and economic growth – Comparing developing emerging and developed countries*, "World Development", vol. 104, pp. 197–211, https://doi.org/10.1016/j.worlddev.2017.11.024

OECD (2013), *ICTs and the Health Sector. Towards Smarter Health and Wellness Models*, OECD Publishing, Paris, https://doi.org/10.1787/9789264202863-en

Pradhan R.P., Mallik G., Bagchi T.P. (2018), *Information communication technology (ICT) infrastructure and economic growth: A causality evinced by cross-country panel data*, "IIMB Management Review", vol. 30(1), pp. 91–103, https://doi.org/10.1016/j.iimb.2018.01.001

Preda A., Crisan D.A., Stanica J.L., Samuel N.A. (2019), *Innovation and ICT development: an analysis for the EU–28 Member States*, "Journal of Information Systems Operations Management", vol. 13(2), pp. 154–163.

Savulescu C. (2015), *Dynamics of ICT Development in the EU*, "Procedia Economics and Finance", vol. 23, pp. 513–520, https://doi.org/10.1016/S2212-5671(15)00552-3

Smyrnova-Trybulska E. (2018), *Technologie informacyjno-komunikacyjne i e-learning we współczesnej edukacji*, Wydawnictwo Uniwersytetu Śląskiego, Katowice.

Statistics Poland (2018), *Information society in Poland. Results of statistical surveys in the years 2014–2018*, Warszawa–Szczecin.

The International Telecommunication Union (2018), *Measuring the Information Society Report 2018*, Geneva.

Thioulouse J., Dray S., Dufour A.B., Siberchicot A., Jombart T., Pavoine S. (2018), *Multivariate Analysis of Ecological Data with ade4*, Springer, New York, https://doi.org/10.1007/978-1-4939-8850-1

Wojnar J. (2015), *Tempo rozwoju ICT w Polsce oraz syntetyczna ocena dystansu Polski od krajów Unii Europejskiej w zakresie wykorzystania technologii informacyjnych*, "Nierówności Społeczne a Wzrost Gospodarczy", vol. 44(4), pp. 372–381, https://doi.org/10.15584/nsawg.2015.4.2.32

Zečević A., Radović-Stojanović J., Čudan A. (2019), *Primena informaciono-komunikacionih tehnologija u preduzećima u zemljama Evropske unije*, "Ekonomski horizonti", vol. 21(3), pp. 273–294, https://doi.org/10.5937/ekonhor1903281Z

Ziemba E. (2019), *The contribution of ICT adoption to the sustainable information society*, "Journal of Computer Information Systems", vol. 59(2), pp. 116–126, https://doi.org/10.1080/08874417.2017.1312635

Wykorzystanie ICT w przedsiębiorstwach w Polsce i Unii Europejskiej w latach 2010–2019

Streszczenie: Według Eurostatu termin *technologie informacyjne i komunikacyjne* (ICT), „obejmuje wszystkie środki techniczne stosowane do obsługi informacji i pomocy w komunikacji. Dotyczy to […] sprzętu komputerowego i sieciowego, a także ich oprogramowania". Zarówno w ujęciu globalnym, jak i lokalnym wpływ ICT na gospodarkę i społeczeństwo jest ogromny. Zintensyfikowanie wykorzystania ICT w przedsiębiorstwach jest czynnikiem stymulującym wzrost gospodarczy, wzmacnia konkurencyjność oraz innowacyjność biznesu, ma coraz większy wpływ na rynek pracy, podnosi zapotrzebowanie na kompetencje cyfrowe i specjalistów ICT. Sektor ICT jest obecnie najszybciej rozwijającym się, a jego wartość ma coraz znaczniejszy udział w PKB. Monitorowanie rozwoju wykorzystania ICT i analizowanie ich wpływu na rozwój gospodarczy i społeczny są kluczowe dla wszystkich rządów i władz lokalnych, by rozumieć transformacje, jakie wywołują te technologie oraz by formułować skuteczną politykę. Technologie informacyjne i komunikacyjne kształtują kierunek rozwoju współczesnego biznesu, przede wszystkim poprzez zwiększanie innowacyjności przedsiębiorstw, a dalej ich konkurencyjności.

Głównym celem artykułu było zbadanie wykorzystania ICT w przedsiębiorstwach w Polsce na tle innych krajów Unii Europejskiej w latach 2010–2019 (przed pandemią COVID–19 oraz brexitem). Analizy oparto na danych dotyczących wykorzystania ICT w przedsiębiorstwach, publikowanych w bazach Eurostatu. Zmienne wybrano na podstawie przeglądu literatury oraz kryterium dostępności i kompletności danych. Zastosowano metody eksploracyjnej analizy wielowymiarowej: międzygrupową i wewnątrzgrupową analizę głównych składowych, jako że zbiór danych występuje w ujęciu trójwymiarowym (obiekty × zmienne × czas) w postaci tzw. kostki danych. Do prezentacji wyników wykorzystano mapy czynnikowe.

We wszystkich krajach UE w latach 2010–2019 zaobserwowano systematyczne zintensyfikowanie wykorzystania ICT przez podmioty gospodarcze. Niestety, pomimo pozytywnego trendu Polska pozostała daleko za liderami UE i znalazła się w grupie tych krajów członkowskich, w których przedsiębiorstwa w najmniejszym stopniu wykorzystywały technologie informacyjno-komunikacyjne.

Słowa kluczowe: technologie informacyjno-komunikacyjne, ICT, przedsiębiorstwa, wielowymiarowa eksploracyjna analiza danych, analiza głównych składowych, PCA, EU

JEL: C38, O30, O33

Received: 2021-11-07; revised: 2022-10-09. Accepted: 2023-01-27