SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2023
ORGANIZATION AND MANAGEMENT SERIES NO. 186

A STUDY ON THE DISTANCES BETWEEN COMPANIES IN POLAND AND IN SELECTED COUNTRIES OF THE EUROPEAN UNION WITH RESPECT TO THE USE OF ICT RESOURCES AND COMPETENCIES

Anna JANIGA-ĆMIEL

University of Economics in Katowice; anna.janiga-cmiel@ue.katowice.pl, ORCID: 0000-0002-7668-9225

Purpose: The aim of the paper is to employ the proposed taxonomic distance methods to investigate the level of the use of information and communication technology by enterprises in Poland and in selected European countries during the examined periods.
Design/methodology/approach: The study examines the use of the Internet and information and communication technologies by enterprises of the selected country, with special emphasis placed on the Covid-19 pandemic period. Data were drawn from Eurostat, taking into account the thematic scope of the study and data availability. The study covered the years 2013-2020, including the time of the Covid-19 pandemic. Selected taxonomic methods were used in the analysis. In the first step of the study, a synthetic variable was determined. The synthetic variable made it possible to compare the level of development of the phenomenon for selected countries. Then the distance matrix was determined. The distance of the level of development of the phenomenon that separates Poland from the studied countries has been determined.
Findings: The study analyzes internet and ICT usage by enterprises in the selected country in the years 2013-2020, with special focus on the COVID-19 pandemic period. To sum up, comparative analysis performed by means of taxonomic methods can be an effective tool to study the elements of a complex process, can provide a broad picture of this process.
Research limitations/implications: The main limitation is that it is not possible to collect a comparable data set over a long period of years. The final set of diagnostic data included only 11 variables.
Originality/value: The concept of comparative analysis of the phenomenon under consideration presented and implemented in this study can be applied to compare other countries, using relevant measures, or to perform comparative analysis of other aspects of the issue, and the findings of these studies will contribute to further research in this area. The results of the proposed research methodology applied to explore the selected research problem and the set of data the study was based on can be used in the analyses of economic and socio-economic policies.

Keywords: taxonomic methods, Internet and ICT usage, COVID-19.

Category of the paper: Research paper.

1. Introduction

Recent years have seen dynamic development and transformation of ICT resources and competencies. Socio-economic processes are becoming increasingly reliant on new technologies and so is the information society, which we have turned into, both in the public and private spheres. The coronavirus pandemic also brought about significant changes that contributed to the transformation of economies in numerous countries. Enterprises, public administration units, educational institutions, health care facilities, citizens, etc. faced both challenges and opportunities arising from the rapid introduction of remote work and remote communication, digitization of internal processes, acceleration of operations due to the use of the internet, etc. (Goban-Klas, Sienkiewicz, 1999).

These developments have not only catapulted digital transformation but also provided employees with new convenient solutions, e.g. electronic document signing, electronic document circulation, video verification, biometric technologies, remote work management and remote task monitoring tools and software, data analysis systems, etc. Of course, the scope and the nature of changes made by various enterprises and organizations was and is dependent on their type and size as well as their ability to adopt technological innovation and maintain optimum competitiveness at the same time (Śledziewska, Włoch, 2020).

Some of the most common technologies include e-commerce - a subset of e-business gaining increasing popularity over recent years, virtual reality, artificial intelligence, cloud computing, blockchain, mainframe technology, etc. The Internet of Things is becoming an integral part of our daily lives, with new technologies employed not only in households, but also in workplaces. Artificial intelligence is growing in importance, as it can replace humans in many situations and support decision-making. Chatbots and voicebots are being adopted by companies to provide customer service 24 hours a day (Gajewski et al., 2016).

The current digital revolution requires continuous education and training of young people so that they can learn to use various IT tools and develop digital skills, which i.a. prevents digital exclusion. Digital reality forces us to acquire, process and manage information and apply new technologies. However, when using modern technologies, we mustn't forget about potential threats they pose, which is why new cybersecurity measures are being introduced.

To sum up, the COVID-19 pandemic threatened the global economy, including the economy of the European Union. The measures taken by the EU countries in response to the pandemic such as restrictions on social contact, quarantine, travel restrictions or bans for certain countries, shutdown of commercial and cultural facilities, restrictions imposed on tourism, transport, etc., had a significant impact on the functioning of public administration, as well as large, small and medium-sized enterprises in the European Union.

The study analyzes internet and ICT usage by enterprises in the selected country in the years 2020-2013 with special focus on the COVID-19 pandemic period.

The aim of the paper is to employ the proposed taxonomic distance methods to investigate the level of the use of information and communication technology by enterprises in Poland and in selected European countries during the examined periods.

2. The set of diagnostic characteristics of the problems under study

The study examines the use of the internet and information and communication technologies by enterprises of the selected country, with special emphasis placed on the Covid-19 pandemic period. Data were drawn from Eurostat, taking into account the thematic scope of the study and data availability. The diagnostic variables selected for the study had to be measurable and best describe the level of development of the examined phenomenon. Based on the calculated values of the coefficients of variation and the results of verifying correlation analysis conducted by means of an inverted correlation matrix, the final set of diagnostic characteristics which describes the phenomenon for a given country was adopted (Młodak, 2006; Panek, 2009; Zeliaś, 2004; Narayan, 2004; Fisher, 1978; Hartigan, 1985; Jardine, Sibson, 1971). Due to the lack of statistical data, it was necessary to reduce the thematic scope of the dataset. The final set of diagnostic variables was the basis for the analysis (due to the construction of the synthetic variable, x_6 was added) (Bolch, Huang, 1974; Anderberg, 1973; Cole, 1969; Gordon, 1981; Greenacre, 1984; Harrison, 1968). The following set of variables was adopted in years: 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020.

x_1 - Number of enterprises having received orders online – [%] of enterprises (S).

x_2 - Share of enterprises' turnover on e-commerce – [%] (S).

x_3 - Percentage of the ICT sector on GDP [%] (S).

x_4 - Digital single market - promoting e-commerce for individuals [%] (S).

x_5 - High-tech exports [%] (S).

x_6 - Population on 1 January (S).

x_7 - Number of individuals using the internet for selling goods or services [%] (S).

x_8 - E-banking and e-commerce [%] (S).

x_9 - Individuals using the internet for interacting with public authorities [%] (S).

x_{10} - High-tech trade by high-tech group of products in million euro (S).

x_{11} - E-government activities of individuals via websites [%] (S).

In describing the variables, the determination S – stimulant was introduced (Mika, 1995). The table 1 includes descriptive characteristics of the variables.

Table 1.
Basic descriptive characteristics of variables

Variable		Years							
		2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
X1	**Vx [%]**	45,30	44,09	40,12	41,22	35,19	36,38	36,43	31,73
	$\bar{x}$	13,15	13,58	14,41	15,14	15,98	16,12	17,55	18,28
	min	4,8	5,3	5,8	5,4	7,3	5,7	7,4	8,3
	max	25,7	26,5	24,6	26,6	24,3	28,8	29,6	29,6
X2	**Vx [%]**	43,14	49,50	44,07	45,08	42,43	44,08	45,46	36,32
	$\bar{x}$	12,28	13,19	14,94	15,	16,67	16,37	16,96	17,86
	min	2,7	3,1	5,2	3,9	5,4	5,2	4,5	6,1
	max	25,7	29,3	29,8	30,5	31,4	32,5	32,6	31,4
X3	**Vx [%]**	24,13	24,77	23,24	23,27	26,44	24,72	26,42	26,28
	$\bar{x}$	4,08	4,09	4,19	4,28	4,47	4,52	4,74	5,04
	min	2,41	2,56	2,97	2,99	3,03	3,13	3,35	3,4
	max	6,55	6,9	6,86	6,94	7,77	7,43	8	8,02
X4	**Vx [%]**	39,49	34,87	33,46	31,97	30,18	26,37	25,79	18,41
	$\bar{x}$	42,21	45,34	48,28	49,58	52,55	55,09	58,38	65,00
	min	14,05	16,68	16,46	17,68	22,09	26,91	26,83	38,81
	max	72,72	73,08	75,02	75,87	77,27	78,43	80,57	83,99
X5	**Vx [%]**	56,75	53,92	45,88	40,98	42,66	43,88	43,49	44,84
	$\bar{x}$	11,21	11,57	11,76	11,45	11,62	11,81	12,06	12,99
	min	4	3,9	4,4	5,1	5,4	5,8	6,3	6,8
	max	28,5	28,7	24,1	21,7	22,5	24,1	23,7	29,6
X6	**Vx [%]**	126,5	126,8	127,0	127,4	127,6	127,7	127,8	127,8
	$\bar{x}$	19460352,1	19566108,9	19609629,5	19668161,3	19689361,5	19707839,8	19689380,0	19698716,1
	min	422509	429424	439691	450415	460297	475701	493559	514564
	max	80523746	80767463	81197537	82175684	82521653	82792351	83019213	83166711
X7	**Vx [%]**	60,7	56,9	54,4	51,9	54,2	48,8	51,9	49,2
	$\bar{x}$	15,2	15,3	15,0	14,1	15,4	16,7	16,6	18,6
	min	9,24941835	8,738795773	8,133485699	7,318490305	8,329110164	8,169300665	8,602895224	9,177714857
	max	35,05	28,98	31,47	29,39	31,02	32,05	31,71	33,14
X8	**Vx [%]**	42,4	41,8	41,3	39,6	37,7	35,7	34,8	30,1
	$\bar{x}$	47,5	49,2	50,2	52,8	54,3	57,1	59,6	62,8
	min	8,07	7,6	8,8	6,73	8,56	10,86	12,34	19,44
	max	89,9	91,02	91,4	91,12	92,05	92,69	94,85	94,34
X9	**Vx [%]**	37,1	32,9	36,2	35,0	34,6	33,2	31,7	28,8
	$\bar{x}$	45,0	51,7	51,4	54,8	55,3	57,4	60,2	64,3
	min	8,66	18,82	16,47	15,66	13,78	13,44	17,92	21,68
	max	80,02	86,71	86,74	88,17	90,73	88,8	92,63	92,51
X10	**Vx [%]**	71,99	72,61	72,73	71,56	71,53	70,75	71,18	74,22
	$\bar{x}$	4894,26	5056,97	5802,45	6065,23	6640,76	7021,47	7501,41	7518,16
	min	449,87	310,17	304,92	265,43	254,86	461,69	541,91	555,67
	max	65918,79	71091,27	75514,21	76279,64	78517,53	80291,39	83973,62	83421,35
X11	**Vx [%]**	40,7	36,9	43,0	42,4	39,2	36,5	36,3	33,7
	$\bar{x}$	45,4	53,9	52,1	55,0	57,4	60,9	62,1	65,7
	min	5,06	10,74	10,98	8,68	8,22	8,44	11,11	14,76
	max	77,06	90,85	94,3	93,23	91,72	92,6	94,57	93,95

Source: based on own research (https://ec.europa.eu/eurostat).

In addition, for the selected data set, a graphical presentation of data from the Eurostat website has been added to compare the years 2013 and 2020 and to identify possible similarities or differences. The diagrams are shown below.

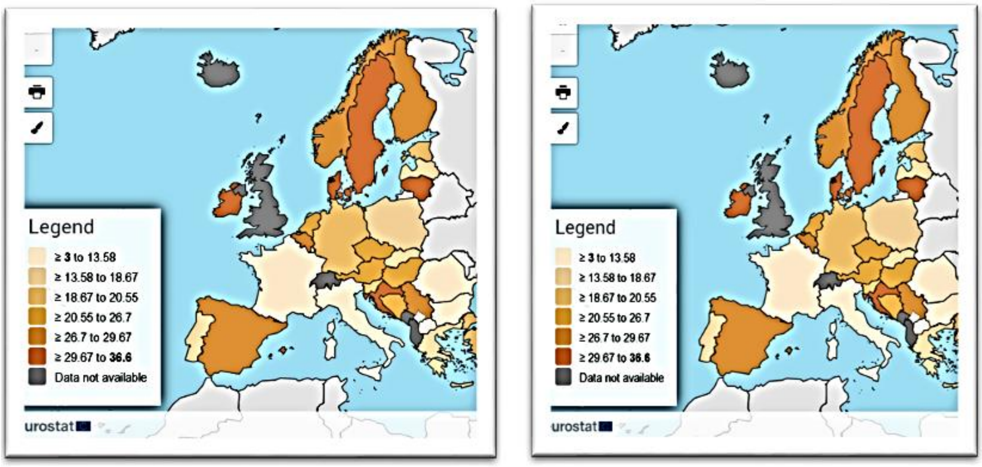

Figure 1. - Number of enterprises having received orders online – [%] of enterprises – 2013 and 2020.

Source: https://ec.europa.eu/eurostat.

The second variable was then taken into account - Share of enterprises' turnover on e-commerce – [%] – 2013 and 2020.

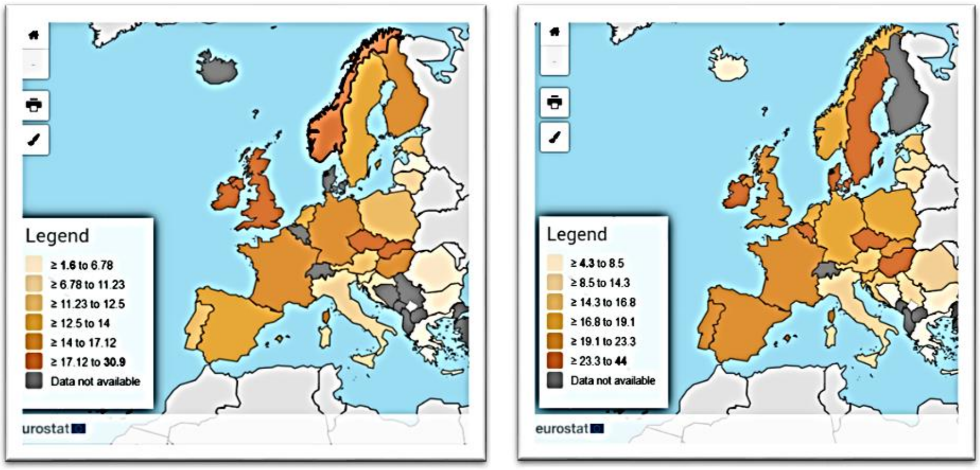

Figure 2. Share of enterprises' turnover on e-commerce – [%] – 2013 and 2020.

Source: https://ec.europa.eu/eurostat.

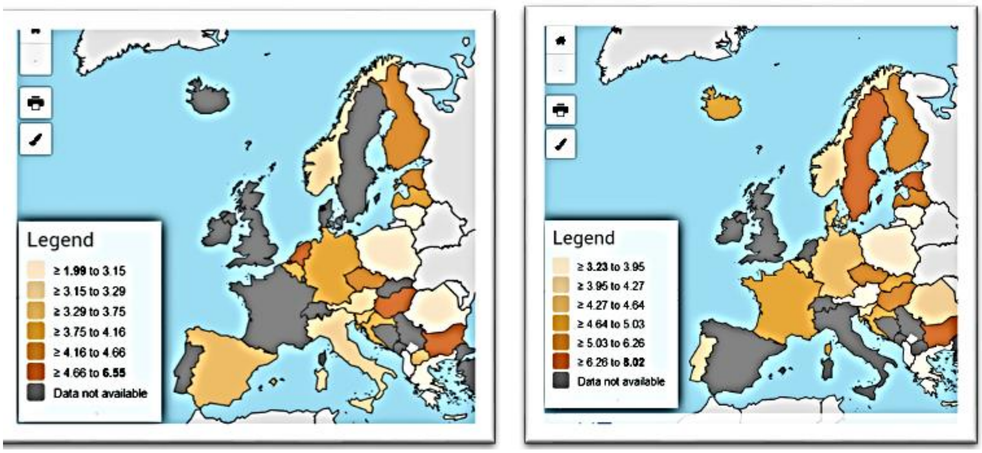

Figure 3. Percentage of the ICT sector on GDP [%] – 2013 and 2020.

Source: https://ec.europa.eu/eurostat.

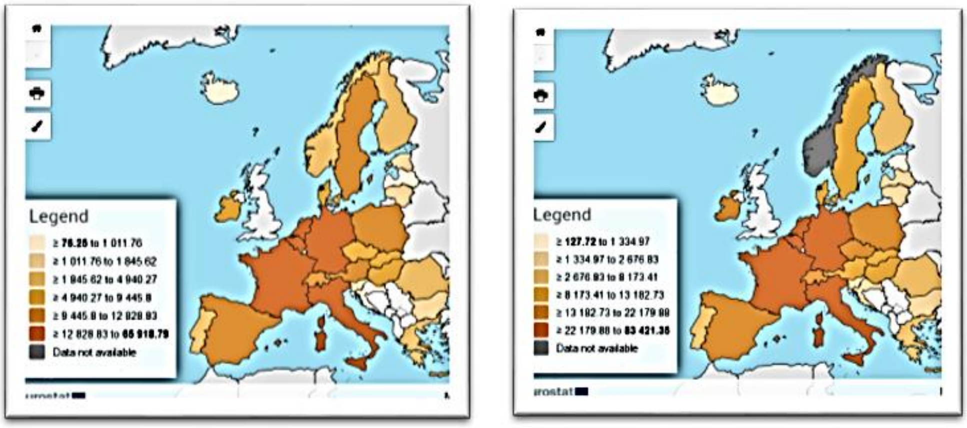

Figure 4. High-tech trade by high-tech group of products in million euro – 2013 and 2020.
Source: https://ec.europa.eu/eurostat.

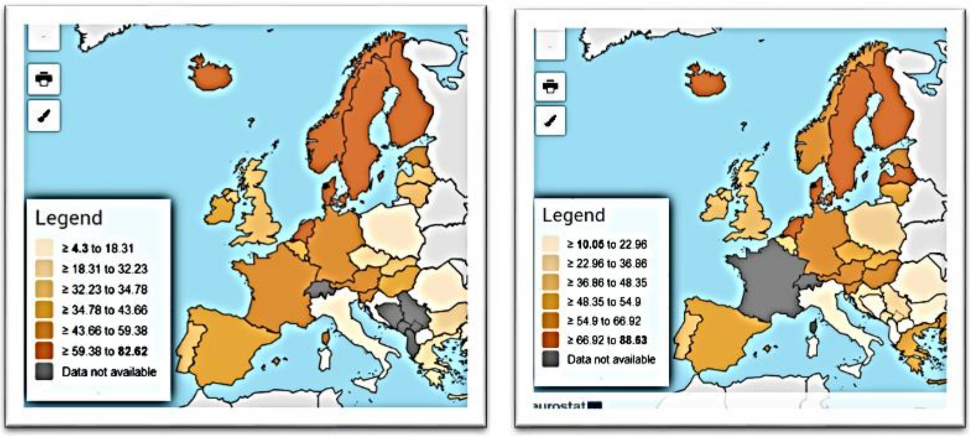

Figure 5. E-government activities of individuals via websites [%] – 2013 and 2020.
Source: https://ec.europa.eu/eurostat.

3. The synthetic variable

The first information about the synthetic variable can be found in the works of Z. Hellwig, who developed a method for presenting a complex phenomenon by means of one synthetic variable (Edwards, Cavalli-Sforza, 1963; Hellwig, 1972). Variables which describe a particular phenomenon are usually diverse in character, as there are both stimulants and destimulants among them (Mika, 1995; Wishart, 1969). The aim of the synthetic variable is to aggregate all the structure features of the variables that are used for its construction (Chomątowski, Sokołowski, 1978; Zeliaś, 2004; Strahl, 1990; Malina, 2008; Hartigan, 1975; Sneath, Sokal, 1973; Szczotka, 1972; Ward, 1963; Everitt, 1974; Johnson, 1967).

The analyzed set of diagnostic variables includes stimulants and destimulants, which have to be converted into stimulants according to formula (Zeliaś, 2004; Strahl, 1990; Tryon, Bailey, 1970):

$$x_{ijt}^{S} = 2\overline{\boldsymbol{x}} - x_{ijt}^{D},\ i = 1, \ldots, m;\ j = 1, \ldots, k;\ t = 1, \ldots, n, \quad (1)$$

where:

x_{ijt}^{D} - the value of the destimulant for the object *i* in time unit *t*,

x_{ijt}^{S} - the value of the stimulant for the object *i* in time unit *t*,

$\overline{\boldsymbol{x}}$ **-** weighted average of selected variable for countries,

k - the number of variables that make up the final set of variables,

m - the number of objects,

n - the number of time units.

A negative value of the stimulant for a given object indicates its unfavorable state. The next step involves normalizing variables by means of formula (Chomątowski, Sokołowski, 1978; Pociecha et al., 1988; Młodak, 2006; Panek, 2009; Zeliaś, 2004; Strahl, 1998; Malina, 2008):

$$S_{ijt} = \frac{x_{ijt}}{\sum_{i=1}^{m} x_{ijt}}, \quad (2)$$

S_{ijt} - the value of the normalized *j*-th variable for object *i* in unit time *t*,

I = 1, …, *m; j* = 1, …, *k; t* = 1, …, *n.*

The transformation preserves the volatility of the variable and the measurement scale. Once the variables are normalized, we synthesize each of the selected groups of measures and calculate a synthetic variable (the arithmetic mean of the normalized variables).

4. Determination of a synthetic variable - an empirical example

Once the variables are normalized, we synthesize each of the selected groups of measures and calculate a synthetic variable. The values of the synthetic variable for the i-th country in time t are: $\boldsymbol{z_{it}}$ (*t* = 1, …, *n*, *I* = 1, …, *m*). The analysis covered 17 countries (*m* = 17, Belgium, Bulgaria, Czechia, Germany, Estonia, France, Italy, Latvia, Lithuania, Hungary, Malta, Austria, Poland, Romania, Slovenia, Slovakia, Finland), the time frame was 8 years (*n* = 8, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020) and the number of variables was 11 (*k* = 15, variables listed in the previous chapter). Table 2 shows the calculated values of the synthetic variable for selected countries in the years analysed.

Table 2.
Determined values of the synthetic variable

Country	Years							
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Belgium	0,0679	0,0697	0,0685	0,0692	0,0677	0,0696	0,0720	0,0700
Bulgaria	0,0286	0,0260	0,0268	0,0254	0,0261	0,0276	0,0279	0,0301
Czechia	0,0647	0,0677	0,0619	0,0623	0,0645	0,0674	0,0696	0,0665
Germany	0,1159	0,1136	0,1165	0,1153	0,1134	0,1088	0,1061	0,1051
Estonia	0,0539	0,0605	0,0639	0,0640	0,0600	0,0598	0,0573	0,0556
France	0,1047	0,1010	0,1012	0,0984	0,0965	0,0932	0,0928	0,0874
Italy	0,0515	0,0514	0,0533	0,0523	0,0536	0,0547	0,0539	0,0554
Latvia	0,0386	0,0411	0,0426	0,0460	0,0465	0,0452	0,0443	0,0470
Lithuania	0,0410	0,0405	0,0420	0,0438	0,0460	0,0456	0,0472	0,0483
Hungary	0,0563	0,0579	0,0563	0,0551	0,0546	0,0566	0,0565	0,0614
Malta	0,0590	0,0583	0,0585	0,0571	0,0592	0,0606	0,0605	0,0623
Austria	0,0598	0,0569	0,0578	0,0582	0,0583	0,0556	0,0564	0,0570
Poland	0,0511	0,0528	0,0532	0,0567	0,0554	0,0560	0,0574	0,0553
Romania	0,0255	0,0264	0,0273	0,0273	0,0274	0,0285	0,0292	0,0350
Slovenia	0,0564	0,0517	0,0465	0,0463	0,0477	0,0480	0,0458	0,0468
Slovakia	0,0558	0,0546	0,0537	0,0534	0,0542	0,0561	0,0548	0,0543
Finland	0,0691	0,0700	0,0701	0,0691	0,0690	0,0666	0,0682	0,0624

Source: based on own research (https://ec.europa.eu/eurostat)

For the determined values of the synthetic variables, a graph is presented below.

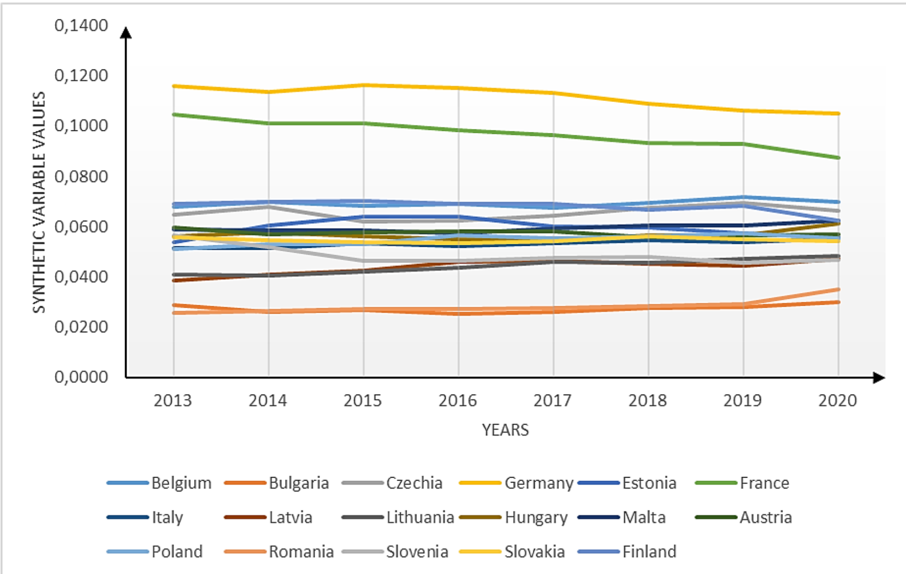

Figure 6. Synthetic variable values in 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020 for selected countries.

Source: based on own research.

The determined values of the synthetic variable describing the level of the analyzed phenomenon allow the countries to be ranked from the best to the worst. Table 3 shows the rank values assigned to the surveyed countries for the subsequent years analyzed.

Table 3.
Positions of selected countries by the level of the use of information and communication technology by enterprises in Poland and in selected European countries during the examined periods

Country	Years							
	2013	2014	2015	2016	2017	2018	2019	2020
Austria	6	9	8	7	8	11	10	8
Belgium	4	4	4	3	4	3	3	3
Bulgaria	16	17	17	17	17	17	17	17
Czechia	5	5	6	6	5	4	4	4
Estonia	11	6	5	5	6	7	8	9
Finland	3	3	3	4	3	5	5	5
France	2	2	2	2	2	2	2	2
Germany	1	1	1	1	1	1	1	1
Hungary	9	8	9	10	10	8	9	7
Italy	12	13	11	12	12	12	12	10
Latvia	15	14	14	14	14	15	15	14
Lithuania	14	15	15	15	15	14	13	13
Malta	7	7	7	8	7	6	6	6
Poland	13	11	12	9	9	10	7	11
Romania	17	16	16	16	16	16	16	16
Slovakia	10	10	10	11	11	9	11	12
Slovenia	8	12	13	13	13	13	14	15

Source: based on own research (https://ec.europa.eu/eurostat)

Analyzing the results, we can conclude that:

- the countries with the highest level of the phenomenon at the time studied are: Germany, France, Finland, Belgium,
- Poland maintained the highest level in 2019 (7), and the lowest in 2013 (13),
- countries with the lowest level are: Bulgaria, Romania, Latvia, Lithuania.

5. A distance matrix of the countries under study with respect to the problems examined in the paper

A multivariate comparative analysis is closely related to the quantitative disciplines. Taxonomic methods, which involve ordering a set of objects, are often employed to investigate research problems and research areas for which other tools cannot be applied.

Determining the distance between pairs of analyzed objects is a key element of the taxonomic analysis of multidimensional objects. A distance matrix provides a basis for comparing objects (countries). It is of the following form (Zeliaś, 2004; Malina, 2008; Malina, Zeliaś, 1998):

$$D = \begin{bmatrix} d_{11} & \cdots & d_{1m} \\ \vdots & \ddots & \vdots \\ d_{m1} & \cdots & d_{mm} \end{bmatrix}, \quad (3)$$

where d_{ij} − the distance between *i*-th and *j*-th object, (*i*,*j* = 1, …,*m*) (Matrix D is determined for the relevant year in the analyzed time interval, *t* = 1,…,*n*), respectively: d_{ij} = 0 - the compared objects are identical, $d_{ij} \neq 0$ - the greater the value, the more dissimilar the objects are.

Matrix D allows for individual analysis of objects. The mutual position of objects can be described by means of a similarity or dissimilarity function (Zeliaś, 2004). The subject literature offers various distance measures, and this study applies – Chomątowski-Sokołowski measure (Młodak, 2006; Panek, 2009; Zeliaś, 2004).

6. A distance matrix of the countries under study with respect to the problems examined in the paper - an empirical example

We start the taxonomic analysis by constructing a three-dimensional data matrix $\boldsymbol{X} = [\boldsymbol{x_{ijt}}]$, *k* - the number of variables that make up the final set of variables (k = 11), *m* - the number of objects (*m* = 17), *n* - the number of time units (*n* = 8). Then we determine the normalized matrix according to the previously discussed theory. For each year, we calculate the distance matrix between the surveyed countries. Table 4 presents the distance matrices between the analyzed countries for the years: 2013, 2018, 2019, 2020.

Table 4.
Distance matrix - for the year 2013

	Belgium	Bulgaria	Czechia	Germany	Estonia	France	Italy	Latvia	Lithuania	Hungary	Malta	Austria	Poland	Romania	Slovenia	Slovakia	Finland
Belgium	0	0,026537	0,014061	0,033637	0,018108	0,030361	0,027865	0,019453	0,017801	0,015186	0,023287	0,012579	0,020441	0,0306	0,01999	0,010365	0,016491
Bulgaria	0,026537	0	0,024824	0,05751	0,018617	0,050423	0,050423	0,012754	0,016245	0,017895	0,022963	0,022651	0,019788	0,013373	0,021924	0,018555	0,027505
Czechia	0,014061	0,024824	0	0,042315	0,031284	0,040469	0,040469	0,022696	0,021221	0,012435	0,020824	0,016899	0,020293	0,028774	0,025808	0,01242	0,023754
Germany	0,033637	0,05751	0,042315	0	0,046085	0,018166	0,041659	0,051268	0,049616	0,04349	0,049798	0,038671	0,041924	0,058499	0,046726	0,041639	0,045509
Estonia	0,018108	0,018617	0,019841	0,046085	0	0,03651	0,03651	0,011182	0,014344	0,01107	0,015091	0,010559	0,022217	0,026593	0,015134	0,014137	0,015722
France	0,030361	0,050423	0,040469	0,018166	0,03651	0	0,034436	0,042822	0,045557	0,035168	0,038943	0,029658	0,034701	0,051276	0,033996	0,037547	0,036979
Italy	0,027865	0,021058	0,031284	0,041659	0,032086	0,034436	0	0,02462	0,027458	0,02796	0,036279	0,02862	0,012817	0,01905	0,034378	0,028798	0,039191
Latvia	0,019453	0,012754	0,022696	0,051268	0,011182	0,042822	0,02462	0	0,00597	0,015608	0,018211	0,01526	0,01617	0,017698	0,016065	0,013058	0,020899
Lithuania	0,017801	0,016245	0,021221	0,049616	0,014344	0,045557	0,027458	0,00597	0	0,018836	0,02203	0,016461	0,01835	0,019133	0,017541	0,012687	0,02026
Hungary	0,015186	0,017895	0,012435	0,04349	0,01107	0,035168	0,02796	0,015608	0,018836	0	0,012495	0,012433	0,01845	0,023516	0,018602	0,011253	0,019701
Malta	0,023287	0,022963	0,020539	0,049798	0,015091	0,038943	0,036279	0,018211	0,02203	0,012495	0	0,019812	0,025348	0,030785	0,019009	0,018037	0,025933
Austria	0,012579	0,022651	0,016899	0,038671	0,010559	0,029658	0,02862	0,01526	0,016461	0,012433	0,019812	0	0,016755	0,02631	0,016138	0,010662	0,015281
Poland	0,020441	0,019788	0,020293	0,041924	0,022217	0,034701	0,012817	0,01617	0,01835	0,01845	0,025348	0,016755	0	0,016781	0,023313	0,016949	0,027405
Romania	0,0306	0,013373	0,028774	0,058499	0,026593	0,051276	0,01905	0,017698	0,019133	0,023516	0,030785	0,02631	0,016781	0	0,028267	0,024786	0,03345
Slovenia	0,01999	0,021924	0,025808	0,046726	0,015134	0,033996	0,034378	0,016065	0,017541	0,018602	0,019009	0,016138	0,023313	0,028267	0	0,019354	0,016535
Slovakia	0,010365	0,018555	0,01242	0,041639	0,014137	0,037547	0,028798	0,013058	0,012687	0,011253	0,018037	0,010662	0,016949	0,024786	0,019354	0	0,014186
Finland	0,016491	0,027505	0,023754	0,045509	0,015722	0,036979	0,039191	0,020899	0,02026	0,019701	0,025933	0,015281	0,027405	0,03345	0,016535	0,014186	0

Source: based on own research (https://ec.europa.eu/eurostat)

Table 5.
Distance matrix - for the year 2018

	Belgium	Bulgaria	Czechia	Germany	Estonia	France	Italy	Latvia	Lithuania	Hungary	Malta	Austria	Poland	Romania	Slovenia	Slovakia	Finland
Belgium	0	0,030353	0,008763	0,03766	0,020688	0,025452	0,02781	0,021987	0,017047	0,015784	0,024592	0,015084	0,018077	0,029406	0,016346	0,012912	0,019909
Bulgaria	0,030353	0	0,028044	0,055101	0,024133	0,045116	0,045116	0,015293	0,017744	0,018964	0,024313	0,021935	0,022206	0,01047	0,018954	0,021977	0,027639
Czechia	0,008763	0,028044	0	0,037962	0,031035	0,023849	0,023849	0,017628	0,01484	0,009963	0,019338	0,010125	0,017615	0,028277	0,015378	0,01174	0,017499
Germany	0,03766	0,055101	0,037962	0	0,0419	0,019761	0,035	0,045568	0,043034	0,041111	0,042856	0,03735	0,0346	0,05194	0,042617	0,037966	0,041656
Estonia	0,020688	0,024133	0,017575	0,0419	0	0,028897	0,028897	0,009895	0,012275	0,0153	0,014338	0,011369	0,022229	0,029081	0,009754	0,010038	0,008554
France	0,025452	0,045116	0,023849	0,019761	0,028897	0	0,024893	0,032908	0,033871	0,026743	0,033123	0,024464	0,024028	0,041833	0,029926	0,024812	0,030225
Italy	0,02781	0,02226	0,031035	0,035	0,035732	0,024893	0	0,028132	0,026132	0,026932	0,036953	0,025712	0,013503	0,017993	0,028794	0,028256	0,037686
Latvia	0,021987	0,015293	0,017628	0,045568	0,009895	0,032908	0,028132	0	0,008382	0,0114	0,016768	0,009851	0,019907	0,020762	0,010895	0,013368	0,017404
Lithuania	0,017047	0,017744	0,01484	0,043034	0,012275	0,033871	0,026132	0,008382	0	0,01362	0,016398	0,010635	0,01702	0,020247	0,00725	0,012103	0,015074
Hungary	0,015784	0,018964	0,009963	0,041111	0,0153	0,026743	0,026932	0,0114	0,01362	0	0,017991	0,008234	0,016095	0,021618	0,013141	0,010077	0,017983
Malta	0,024592	0,024313	0,019082	0,042856	0,014338	0,033123	0,036953	0,016768	0,016398	0,017991	0	0,017914	0,02566	0,030302	0,014664	0,016707	0,019466
Austria	0,015084	0,021935	0,010125	0,03735	0,011369	0,024464	0,025712	0,009851	0,010635	0,008234	0,017914	0	0,012856	0,021494	0,009631	0,008619	0,01555
Poland	0,018077	0,022206	0,017615	0,0346	0,022229	0,024028	0,013503	0,019907	0,01702	0,016095	0,02566	0,012856	0	0,018063	0,016396	0,014753	0,024534
Romania	0,029406	0,01047	0,028277	0,05194	0,029081	0,041833	0,017993	0,020762	0,020247	0,021618	0,030302	0,021494	0,018063	0	0,022736	0,022771	0,031445
Slovenia	0,016346	0,018954	0,015378	0,042617	0,009754	0,029926	0,028794	0,010895	0,00725	0,013141	0,014664	0,009631	0,016396	0,022736	0	0,009123	0,012049
Slovakia	0,012912	0,021977	0,01174	0,037966	0,010038	0,024812	0,028256	0,013368	0,012103	0,010077	0,016707	0,008619	0,014753	0,022771	0,009123	0	0,010669
Finland	0,019909	0,027639	0,017499	0,041656	0,008554	0,030225	0,037686	0,017404	0,015074	0,017983	0,019466	0,01555	0,024534	0,031445	0,012049	0,010669	0

Source: based on own research (https://ec.europa.eu/eurostat)

Table 6.
Distance matrix - for the year 2019

	Belgium	**Bulgaria**	**Czechia**	**Germany**	**Estonia**	**France**	**Italy**	**Latvia**	**Lithuania**	**Hungary**	**Malta**	**Austria**	**Poland**	**Romania**	**Slovenia**	**Slovakia**	**Finland**
Belgium	0	0,032049	0,009621	0,034237	0,021529	0,023748	0,028654	0,0239	0,019033	0,01587	0,023278	0,015597	0,018755	0,030448	0,017338	0,014267	0,019931
Bulgaria	0,032049	0	0,029761	0,053914	0,022414	0,04524	0,04524	0,014667	0,018576	0,019269	0,02406	0,022751	0,023486	0,010828	0,017646	0,021361	0,029128
Czechia	0,009621	0,029761	0	0,039234	0,032394	0,025374	0,025374	0,019837	0,01538	0,011066	0,021021	0,011325	0,018527	0,029174	0,017791	0,014749	0,018921
Germany	0,034237	0,053914	0,039234	0	0,041479	0,018318	0,033769	0,045332	0,043158	0,038458	0,04273	0,036285	0,032585	0,049764	0,040014	0,037247	0,041828
Estonia	0,021529	0,022414	0,018224	0,041479	0	0,029917	0,029917	0,008653	0,010012	0,014878	0,015425	0,010447	0,021499	0,027209	0,009587	0,010955	0,011331
France	0,023748	0,04524	0,025374	0,018318	0,029917	0	0,025139	0,033641	0,033581	0,026624	0,033679	0,025858	0,022893	0,041133	0,031221	0,024584	0,031252
Italy	0,028654	0,02324	0,032394	0,033769	0,034345	0,025139	0	0,027488	0,026896	0,026671	0,03697	0,026458	0,014397	0,017894	0,027108	0,027865	0,039007
Latvia	0,0239	0,014667	0,019837	0,045332	0,008653	0,033641	0,027488	0	0,007344	0,013467	0,017913	0,011049	0,019742	0,018836	0,011114	0,011102	0,018127
Lithuania	0,019033	0,018576	0,01538	0,043158	0,010012	0,033581	0,026896	0,007344	0	0,015024	0,016	0,008864	0,01748	0,020612	0,007341	0,011187	0,015068
Hungary	0,01587	0,019269	0,011066	0,038458	0,014878	0,026624	0,026671	0,013467	0,015024	0	0,017454	0,009419	0,013778	0,021065	0,012431	0,009334	0,019263
Malta	0,023278	0,02406	0,02077	0,04273	0,015425	0,033679	0,03697	0,017913	0,016	0,017454	0	0,018349	0,026969	0,029834	0,014725	0,017912	0,019564
Austria	0,015597	0,022751	0,011325	0,036285	0,010447	0,025858	0,026458	0,011049	0,008864	0,009419	0,018349	0	0,014079	0,021347	0,010686	0,008902	0,015991
Poland	0,018755	0,023486	0,018527	0,032585	0,021499	0,022893	0,014397	0,019742	0,01748	0,013778	0,026969	0,014079	0	0,018601	0,014528	0,01402	0,025069
Romania	0,030448	0,010828	0,029174	0,049764	0,027209	0,041133	0,017894	0,018836	0,020612	0,021065	0,029834	0,021347	0,018601	0	0,020674	0,021457	0,032559
Slovenia	0,017338	0,017646	0,017791	0,040014	0,009587	0,031221	0,027108	0,011114	0,007341	0,012431	0,014725	0,010686	0,014528	0,020674	0	0,008096	0,014645
Slovakia	0,014267	0,021361	0,014749	0,037247	0,010955	0,024584	0,027865	0,011102	0,011187	0,009334	0,017912	0,008902	0,01402	0,021457	0,008096	0	0,011854
Finland	0,019931	0,029128	0,018921	0,041828	0,011331	0,031252	0,039007	0,018127	0,015068	0,019263	0,019564	0,015991	0,025069	0,032559	0,014645	0,011854	0

Source: based on own research (https://ec.europa.eu/eurostat)

Table 7.
Distance matrix - for the year 2020

	Belgium	Bulgaria	Czechia	Germany	Estonia	France	Italy	Latvia	Lithuania	Hungary	Malta	Austria	Poland	Romania	Slovenia	Slovakia	Finland
Belgium	0	0,02998	0,010934	0,031367	0,019634	0,021134	0,026315	0,022467	0,017447	0,012494	0,021909	0,013662	0,018799	0,025395	0,018505	0,013799	0,018268
Bulgaria	0,02998	0	0,026717	0,052523	0,019668	0,040692	0,040692	0,015318	0,01815	0,02212	0,023742	0,022515	0,021223	0,012344	0,017127	0,019855	0,023573
Czechia	0,010934	0,026717	0	0,03836	0,029439	0,024629	0,024629	0,018208	0,013807	0,011888	0,020104	0,010854	0,018502	0,023425	0,017462	0,014996	0,018404
Germany	0,031367	0,052523	0,03836	0	0,040498	0,017358	0,032118	0,043619	0,041998	0,033684	0,043156	0,035703	0,032219	0,04536	0,039422	0,035998	0,039611
Estonia	0,019634	0,019668	0,0182	0,040498	0	0,028234	0,028234	0,005901	0,009909	0,011138	0,013266	0,009837	0,02191	0,022737	0,008216	0,010147	0,009362
France	0,021134	0,040692	0,024629	0,017358	0,028234	0	0,020671	0,030144	0,031758	0,020623	0,03439	0,024202	0,020962	0,035428	0,02844	0,02421	0,028495
Italy	0,026315	0,022719	0,029439	0,032118	0,032354	0,020671	0	0,027577	0,026573	0,02916	0,037225	0,026184	0,011413	0,017571	0,026397	0,026902	0,034295
Latvia	0,022467	0,015318	0,018208	0,043619	0,005901	0,030144	0,027577	0	0,008255	0,01355	0,017386	0,010695	0,019514	0,019775	0,008733	0,011284	0,012602
Lithuania	0,017447	0,01815	0,013807	0,041998	0,009909	0,031758	0,026573	0,008255	0	0,015284	0,015343	0,00858	0,017109	0,017962	0,006156	0,009392	0,013368
Hungary	0,012494	0,02212	0,011888	0,033684	0,011138	0,020623	0,02916	0,01355	0,015284	0	0,015035	0,009208	0,017823	0,021858	0,012273	0,007164	0,010454
Malta	0,021909	0,023742	0,019859	0,043156	0,013266	0,03439	0,037225	0,017386	0,015343	0,015035	0	0,017864	0,02724	0,027305	0,015784	0,015808	0,018825
Austria	0,013662	0,022515	0,010854	0,035703	0,009837	0,024202	0,026184	0,010695	0,00858	0,009208	0,017864	0	0,015002	0,018755	0,008674	0,008821	0,012785
Poland	0,018799	0,021223	0,018502	0,032219	0,02191	0,020962	0,011413	0,019514	0,017109	0,017823	0,02724	0,015002	0	0,015604	0,016261	0,016092	0,023255
Romania	0,025395	0,012344	0,023425	0,04536	0,022737	0,035428	0,017571	0,019775	0,017962	0,021858	0,027305	0,018755	0,015604	0	0,017631	0,017791	0,025227
Slovenia	0,018505	0,017127	0,017462	0,039422	0,008216	0,02844	0,026397	0,008733	0,006156	0,012273	0,015784	0,008674	0,016261	0,017631	0	0,005858	0,010538
Slovakia	0,013799	0,019855	0,014996	0,035998	0,010147	0,02421	0,026902	0,011284	0,009392	0,007164	0,015808	0,008821	0,016092	0,017791	0,005858	0	0,007896
Finland	0,018268	0,023573	0,018404	0,039611	0,009362	0,028495	0,034295	0,012602	0,013368	0,010454	0,018825	0,012785	0,023255	0,025227	0,010538	0,007896	0

Source: based on own research (https://ec.europa.eu/eurostat)

Tables 4-7 present the determined distance matrices between the analyzed countries for selected years from 2013-2020. Analyzing the results obtained, we can conclude that in 2013 for Poland and the countries studied:

- the largest distance in terms of the level of the phenomenon analysed was between Poland and Germany, followed by Malta, France and Finland.
- the smallest distances are between Poland and Italy, also Lithuania, Austria, Romania.

In 2018:

- the largest distance separates Poland from: Germany, Malta, Finland, France.
- Poland was the closest to the level of development of the phenomenon to Austria, Italy, Slovakia.

Then in 2019 the largest distance for Poland occurs between Germany, followed by Malta and Finland. A similar level of development of the phenomenon studied for Poland is also observed for Hungary, Italy and Slovakia. The year 2020 was included in the study, which includes the beginning of the covid pandemic. During this period of time, we notice the greatest distance between Poland and Germany, Malta and Finland. The countries with the most similar level of the phenomenon to Poland are: Italy, Austria, Romania.

The analysis of the distances between Poland and the other countries allowed identifying the fields where Poland lags far behind as well as the countries in relation to which it managed to shorten the distance in the years under study.

7. Conclusion

The aim of the paper was to employ the proposed taxonomic distance methods to investigate the level of the use of information and communication technology by enterprises in Poland and in selected European countries during the examined periods.

The study covered the years 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, including the time of the Covid-19 pandemic. Selected taxonomic methods were used in the analysis. In the first step of the study, a synthetic variable was determined.

In 2013, the value of the synthetic variable for Poland was 0. 0511. In the years 2014-2016, the value of the synthetic variable increased to 0.0567. In 2020, it was 0.0553. The level of the phenomenon analysed for Poland is not increasing rapidly. The distance to countries with a higher level of development of the phenomenon is not diminishing rapidly. The analyzed countries can be divided into two groups. The first group consists of countries that have a higher value of the synthetic variable in 2020 (the beginning of the Covid-19 pandemic) than in 2013. The second group consists of countries presenting the opposite situation (the value of the variable decreased). Poland belongs to the second group. The values of the synthetic variable additionally allowed for ranking the countries from the best to the worst in terms of the studied phenomenon. Germany had the highest level throughout the period under study. This country has a highly developed IT sector. The IT sector is one of the basic industries of the German economy and constitutes the basis for the assumptions of Industry 4.0. The last places of Romania and Bulgaria are due, among other things, to their late accession to the European Union.

Then the distance matrix was determined. The distance of the level of development of the phenomenon that separates Poland from the studied countries has been determined. The analysis of the distance matrix for Poland confirmed that the greatest distance separates Poland from Germany in terms of the level of the phenomenon under study.

The distance matrices also contain information on the distances between each of the selected European countries in the analysis. For example, we can check the distance between Germany and other countries in the analyzed years. In 2013, 2018, 2019, 2020, Germany is very far away from countries such as Romagna and Bulgaria. However, the level of development of the phenomenon was closest to: France.

To sum up, it can be said that digital transformation is implemented by enterprises, public administration, society and the national economy. Digitization has a significant impact on consumer behavior, changes the rules of competition in the market and creates new economic models.

In summary, today's organizations, businesses, society and economy must respond quickly to the changing environment and implement appropriate, effective solutions to survive.

References

1. Anderberg, M.R. (1973). *Cluster Analysis for Applications*. New York/London: Academic Press.
2. Bolch, B.W., Huang, C.J. (1974). *Multivariate statistical methods for business and economics*. Englewood Cliffs, NY: Prentice Hall.
3. Chomątowski, S., Sokołowski, A. (1978) Taksonomia struktur. *Przegląd Statystyczny*. *25(2)*.
4. Cole, A.J. (1969). *Numerical Taxconomy*. New York: Academic Press.
5. Edwards, A.W.F., Cavalli-Sforza, L.L. (1963). A method for cluster analysis. *Biometrics, 21*.
6. Everitt, B. (1974). *Cluster Analysis*. London: Heinemann.
7. Fisher, M.M. (1978). Regional Taxonomy: *A Comparison of Some Hierarchic and Nonhierarchic Strategies*. Regional Conference of the International Geographical Union, Capos.
8. Gajewski, J., Paprocki, W., Pieriegud, J. (2016). *Cyfryzacja gospodarki i społeczeństwa. Szanse i wyzwania dla sektorów infastrukturalnych*. Instytut Badań nad Gospodarką Rynkową – Gdańska Akademia Bankowa.
9. Goban-Klas, T., Sienkiewicz, P. (1999). *Społeczeństwo informacyjne. Szanse, zagrożenia, wyzwania*. Kraków: Wydawnictwo Fundacji Postępu Telekomunikacji.
10. Gordon, A.D. (1981). *Classification*. London: Chapman and Hall.

11. Grabiński, T., Wydymus, A., Zeliaś, A. (1989). *Metody taksonomii numerycznej w modelowaniu zjawisk społeczno-gospodarczych.* Warszawa, PWN.
12. Greencare, M.J. (1984). *Theory and Applications of Correspondence Analysis*. London: Academic Press.
13. Harrison, P.J. (1968). A Method of Cluster Analysis and Some Applications. *Applied Statistics, Vol. 17*.
14. Hartigan, J.A. (1975). *Clustering Algorithms.* New York: J. Wiley.
15. Hartigan, J.A. (1985). Statistical Theory in Clustering. *Journal of Classifications, Vol. 2.*
16. Hellwig, Z. (1972*).* A method for the selection of a compactset of variables. In: *Social indicators. Report and Paper in the Social Sciences, 30,* Unesco.
17. https://ec.europa.eu/eurostat
18. Jardine, N., Sibson, R. (1971). *Mathematical Taxsonomy.* New York: Wiley.
19. Johnson, S.C. (1967). Hierarchical Clustering Schemes. *Psychometrica, Vol. 32*.
20. Malina, A., Zeliaś, A. (1998). On Building Taxsonometric Measures on Living Conditions. *Statistics in Transition, Vol. 3(3).*
21. Malina, A. (2008). *Przestrzenno-czasowa analiza rynku pracy w Polsce i krajach Unii Europejskiej.* Kraków: Wydawnictwo Uniwersytetu Ekonomicznego w Krakowie.
22. Mika, J. (1995). *Analiza statystyczna Polski na tle krajów Unii Europejskiej*. Katowice: Śląsk.
23. Młodak, A. (2006). *Analiza taksonomiczna w statystyce regionalnej*. Warszawa: Difin.
24. Narayan, G. (2004). *Multivariate Statistical Analysis.* USA: Marcel Dekker.
25. Panek, T. (2009) *Statystyczne metody wielowymiarowej analizy porównawczej*. Warszawa: Oficyna Wydawnicza Szkoły Głównej Handlowej w Warszawie, pp. 58-114.
26. Pociecha, J., Podolec B., Sokołowski, A., Zając, K. (1988). *Metody taksonomiczne w badaniach społeczno-ekonomicznych.* Warszawa: PWN.
27. Śledziewska, R., Włoch, R. (2020). *Gospodarka cyfrowa. Jak nowe technologie zmieniają świat*. Warszawa: Wydawnictwo Uniwersytetu Warszawskiego.
28. Sneath, P.H.A., Sokal, R.R. (1973). *Numerical taxonomy.* San Francisco: W.H. Freeman.
29. Strahl, D. (1990). *Metody programowania rozwoju społecznego-gospodarczego*. Warszawa: PWE.
30. Strahl, D. (1998). *Taksonomia struktur w badaniach regionalnych.* Wrocław: Wydawnictwo Akademii Ekonomicznej im. Oskara Langego we Wrocławiu.
31. Szczotka, F. (1972). On a method of ordering and clustering of objects. *Zastosowania Matematyki, nr 13*.
32. Tryon, R.C. Bailey, D.E. (1970). *Cluster Analysis*. New York: McGraw-Hill.
33. Ward, J.H. (1963). Hierarchical grouping to optimize an objective function. *Journal of the American Statistical Association*', *Vol. 58*.
34. Wishart, D. (1969). An Algorithm for Hierarchical Classification. *Biometrics, Vol. 22(1).*
35. Zeliaś, A. (2004). *Poziom życia w Polsce i krajach Unii Europejskiej*. Warszawa: PWE.