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A STUDY ON THE DISTANCES BETWEEN COMPANIES IN POLISH PROVINCES WITH RESPECT TO THE USE OF ICT RESOURCES AND COMPETENCIES

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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 Polish provinces during the examined periods (during the Covid-19 pandemic).
Design/methodology/approach: The study examines the use of the Internet and information and communication technologies by enterprises in Polish provinces, with special emphasis placed on the Covid-19 pandemic period. Data were drawn from the Central Statistical Office, taking into account the thematic scope of the study and data availability. The study covered the years 2020-2022, including the time of the Covid-19 pandemic. Selected taxonomic methods were used in the analysis. In the first stage of the study, a synthetic variable was determined. The synthetic variable made it possible to compare the level of development of the phenomenon in selected provinces in 2022, 2021, 2020. Then, a distance matrix was determined. The distance between the level of development of the phenomenon separating Śląskie province from other provinces in the analyzed years was determined. The level of similarity of the Śląskie province to other provinces was examined (similarity matrix). In the last stage, the pace at which the Śląskie province became similar to other provinces in the analyzed period was examined.
Findings: The study analyzes internet and ICT usage by enterprises in the Polish provinces in the years 2020-2022, 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 the inability to collect a set of comparable data over many years. The final diagnostic data set included only 5 variables for two research topics.
Originality/value: The concept of comparative analysis of the phenomenon under consideration presented and implemented in this study can be applied to compare 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. In the beginning, the technologies that digitalization is based on included the use of the computer, laptop and smartphone and later extended to cloud-based technologies, robotization and artificial intelligence (Goban-Klas, Sienkiewicz, 1999). 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. We can observe ongoing advances in IC technologies facilitating data collection, processing and transfer. What is more, the development of these technologies against a background of globalization contributes to the emergence and gradual transformation of an increasingly globalized information society. Globalization impacts on the creation of the information society and its evolution towards more advanced stages.

The literature offers a variety of definitions of the information society. L. Drelichowski defines it as: "… all the people who are able to communicate easily and widely and who have access to the necessary information which enhances living conditions, improves work performance as well as helps fulfill civic duties" (Drelichowski, 2001).

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. (Śledziewska, Włoch, 2020; Gajewski et al., 2016).

The study analyzes internet and ICT usage by enterprises in the selected Poland's provinces in the years 2022-2020 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 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 in Polish provinces, with special emphasis placed on the Covid-19 pandemic period. Data were drawn from the Central Statistical Office, taking into account the thematic scope of the study and data availability. Proper measurement of the development level of the phenomenon in particular provinces of Poland requires selecting appropriate measures. However, there is a lack of universal information on the subject under consideration. The diagnostic variables adopted in the present study are measurable and best describe the development of the analysed 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 (Młodak, 2006; Panek, 2009; Zeliaś, 2004). 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. The following set of variables was adopted in years: 2022, 2021, 2020 with particular focus on the times of the Covid-19 pandemic.

The set of features was composed taking into consideration both the thematic scope of the study and the availability of data. In addition, the features were divided according to the topical themes analysed for Polish provinces.

The first thematic scope - variables related to access to the Internet by enterprises:

x_1 - Number of enterprises with broadband Internet access – [%] (S),

x_2 - Number of enterprises with access to the Internet via DSL or other – [%] (S),

x_3 - Number of enterprises, additional equipment in a mobile device to the Internet (e.g. notebooks, netbooks, tablets, smartphones) [%] (S),

x_4 - Number of employees of enterprises with remote access to business applications, documents, computer programs [%] (S),

x_5 - Number of employees in enterprises with remote access to business e-mail [%] (S).

The second thematic scope - variables related to enterprises with Internet access buying cloud services:

y_1 - Number of Internet-enabled enterprises buying cloud services by type of email access – [%] (S),

y_2 - Number of enterprises with Internet access buying cloud services - office software (e.g. spreadsheet, word processor) – [%] (S),

y_3 - Number of enterprises with Internet access buying cloud services - financial and accounting software [%] (S),

y_4 - Number of enterprises with Internet access buying cloud services - enterprise database hosting [%] (S),

y_5 - Number of Internet-enabled enterprises buying cloud services - file storage [%] (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

	x_1	x_2	x_3	x_4	x_5	y_1	y_2	y_3	y_4	y_5
2022										
Vx	58.3	59.4	119.5	126.1	135	83.6	90.5	83.8	104.5	94.0
$\bar{x}$	6270.5	5360.3	150168.2	151648	121800	1451.3	1185.7	555.6	493.7	768.2
S	3652.5	3181.2	179470.9	191189	165058	1213.8	1073.2	465.8	515.8	722.2
2021										
Vx	20.6	21.1	21.7	29.5	25.8	83.6	90.5	83.8	104.4	94.0
$\bar{x}$	18026.9	15745.8	14372.7	4104.5	3264.4	1451.3	1185.7	555.6	493.7	768.2
S	3715.6	3333.9	3119.4	1213.8	843.6	1213.8	1073.2	465.8	515.8	722.2
2020										
Vx	89.6	132.0	66.0	67.3	68.5	89.6	98.6	101.4	102.5	91.1
$\bar{x}$	1242.9	128040.1	6697.4	5799.2	5320.2	1242.9	1066.3	561.6	876.1	574.8
S	1114.3	169001.6	4423.7	3900.7	3643.2	1114.3	1051.4	569.7	898.6	523.9

Source: based on own research.

3. Measuring distances between Polish provinces with respect to the level of the phenomenon under study

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. Variables which describe a particular phenomenon are usually diverse in character, as there are both stimulants and destimulants among tchem (Mika, 1995).

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; Mika, 1995).

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

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

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):

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

where:

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

$i = 1, \ldots, m; j = 1, \ldots, k; t = 1, \ldots, n.$

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 province in time *t* are: $\boldsymbol{z_{it}}$ (t = 1,…,n, I = 1, …, m).

The analysis covered 16 provinces (m = 16), the time frame was 3 years (n = 3, 2022, 2021, 2020) and the number of variables was 5 (k = 5, variables listed in the previous chapter and two research topics). Table 2 shows the calculated values of the synthetic variable for selected provinces in the years analysed.

Table 2.
Determined values of the synthetic variable - variables related to access to the Internet by enterprises

Province	2020	2021	2022
Dolnośląskie	0.076	0.077	0.079
Kujawsko-pomorskie	0.043	0.048	0.039
Lubelskie	0.033	0.039	0.030
Lubuskie	0.024	0.024	0.019
Łódzkie	0.058	0.064	0.050
Małopolskie	0.092	0.098	0.095
Mazowiecki	0.223	0.156	0.258
Opolskie	0.020	0.020	0.018
Podkarpackie	0.043	0.043	0.037
Podlaskie	0.020	0.024	0.018
Pomorskie	0.067	0.068	0.066
Śląskie	0.118	0.134	0.111
Świętokrzyskie	0.020	0.022	0.020
Warmińsko-mazurskie	0.022	0.024	0.020
Wielkopolskie	0.106	0.120	0.112
Zachodniopomorskie	0.036	0.038	0.027

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.
Ranks of selected provinces during the examined periods - variables related to access to the Internet by enterprises

	Province	2020	2021	2022
1	Dolnośląskie	5	5	5
2	Kujawsko-pomorskie	8	8	8
3	Lubelskie	11	10	10
4	Lubuskie	12	14	14
5	Łódzkie	7	7	7
6	Małopolskie	4	4	4
7	Mazowieckie	1	1	1
8	Opolskie	16	16	16
9	Podkarpackie	9	9	9
10	Podlaskie	14	13	15
11	Pomorskie	6	6	6
12	Śląskie	2	2	3
13	Świętokrzyskie	15	15	13
14	Warmińsko-mazurskie	13	12	12
15	Wielkopolskie	3	3	2
16	Zachodniopomorskie	10	11	11

Source: based on own research.

Analyzing the selected set of variables (the first topic), we can see that Mazowieckie province in the years 2022, 2021, 2020 was always in the first place, and Opolskie province in the last place. The Śląskie province ranked second in terms of the development of the phenomenon in 2020 and 2021, and third in 2022.

Table 4.
Ranks of selected provinces during the examined periods- variables related to enterprises with Internet access buying cloud services

	Province	2020	2021	2022
1	Dolnośląskie	5	5	5
2	Kujawsko-pomorskie	8	8	8
3	Lubelskie	11	11	11
4	Lubuskie	12	12	12
5	Łódzkie	7	7	7
6	Małopolskie	3	4	4
7	Mazowiecki	1	1	1
8	Opolskie	13	13	13
9	Podkarpackie	9	10	10
10	Podlaskie	15	16	16
11	Pomorskie	6	6	6
12	Śląskie	2	2	2
13	Świętokrzyskie	14	15	15
14	Warmińsko-mazurskie	16	14	14
15	Wielkopolskie	4	3	3
16	Zachodniopomorskie	10	9	9

Source: based on own research.

Analyzing the results (second topic), we can see that the results are very similar. The Mazowieckie province is always in first place, and the Śląskie province in second place. The last place is taken by the Warmińsko-mazurskie province in 2020, and in 2021 and 2022 by the Podlaskie province.

5. Analysis of the level of similarity of development of the phenomenon

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):

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

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}≠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).

The distance matrix was used to analyze the similarity of objects. The distance matrix was built, which provided a basis for the construction of the similarity matrix:

$$P = [p_{ij}]\ (i, j = 1, \ldots m),$$

where p_{ij} - measure of similarity between *i*-th and *j*-th object and: $p_{ij} \geq 0$, $p_{ij} = p_{ji}$, $p_{ij} = 1$ for *i* = *j*. This means a measure normalized, $p_{ij} \in < 0, 1 >$.

The similarity meter p_{ij} is determined according to the formula:

$$p_{ij} = \frac{d_{max} - d_{ij}}{d_{max}},\ (i,j = 1, \ldots, m) \tag{4}$$

where:

d_{ij} – the distance between *i*-th and *j*-th object, (*i,j* = 1, …, *m*),

d_{max} – the maximum distance of the Polish provinces from the reference object.

Similarity matrices between provinces determine the level of changes in the process of making pairs of provinces more similar or more distant from each other in the years under study.

In the last step of the analysis, the elements of the similarity matrix will be taken into account when examining changes in the level of similarity of provinces to each other.

Indicators of the intensity of changes in the process of provinces becoming similar to each other and to the model province are determined according to the formula:

$$w_{is} = \frac{1}{n}\sum_{t=2}^{n}(p_{is}^{t} - p_{is}^{t-1}) \ (i, s = 1, \ldots, m), \tag{5}$$

$$w'_{is} = \frac{1}{n}\sum_{t=2}^{n}\left|p_{is}^{t} - p_{is}^{t-1}\right| \ (i, s = 1, \ldots, m), \tag{6}$$

$$w''_{is} = \frac{1}{n}\sum_{t=2}^{n}\frac{|p_{is}^{t} - p_{is}^{t-1}|}{p_{is}^{t-1}} \cdot 100\% \ (i, s = 1, \ldots, m). \tag{7}$$

The value of the meter w_{is} with the (+) sign informs that the similarity is increasing, and the value with the (-) sign means that the objects are moving away from each other in the examined years. Small indicator values (w_{is}, w'_{is}) indicate small changes in the level of similarity between objects. The indicator w''_{is} determines the intensity of change.

6. A similarity matrix - 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 = 5), m - the number of objects (m = 16), n - the number of time units (n = 3). Then we determine the normalized matrix according to the previously discussed theory. For each year, we calculate the distance matrix between the surveyed provinces. Table 5-10 presents the distance matrices between the analyzed provinces for the years: 2022, 2021, 2020.

In the first step, the distance matrices for the year 2022 and the two topics under consideration were presented.

Table 5.
Distance matrix - for the year 2022 - variables related to access to the Internet by enterprises

Province	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0.00	0.20	0.25	0.06	0.15	0.08	0.89	0.31	0.21	0.31	0.07	0.16	0.30	0.30	0.16	0.26
2	0.20	0.00	0.05	0.10	0.05	0.28	1.09	0.11	0.02	0.11	0.13	0.36	0.10	0.10	0.36	0.06
3	0.25	0.05	0.00	0.59	0.10	0.33	1.14	0.06	0.04	0.06	0.18	0.40	0.05	0.05	0.41	0.01
4	0.06	0.10	0.59	0.00	0.03	0.38	1.19	0.01	0.09	0.01	0.23	0.46	0.00	0.00	0.46	0.04
5	0.15	0.05	0.10	0.03	0.00	0.05	1.04	0.16	0.07	0.16	0.08	0.30	0.15	0.15	0.31	0.11
6	0.08	0.28	0.33	0.38	0.05	0.00	0.81	0.39	0.29	0.39	0.15	0.08	0.38	0.38	0.08	0.34
7	0.89	1.09	1.14	1.19	1.04	0.81	0.00	1.20	1.11	1.20	0.19	0.74	1.19	1.19	0.73	1.15
8	0.31	0.11	0.06	0.01	0.16	0.39	1.20	0.00	0.10	0.01	0.24	0.46	0.01	0.01	0.47	0.05
9	0.21	0.02	0.04	0.09	0.07	0.29	1.11	0.10	0.00	0.09	0.15	0.37	0.09	0.09	0.37	0.05
10	0.31	0.11	0.06	0.01	0.16	0.39	1.20	0.01	0.09	0.00	0.24	0.46	0.01	0.01	0.47	0.05
11	0.07	0.13	0.18	0.23	0.08	0.15	0.19	0.24	0.15	0.24	0.00	0.22	0.23	0.23	0.23	0.19
12	0.16	0.36	0.40	0.46	0.30	0.08	0.74	0.46	0.37	0.46	0.22	0.00	0.45	0.45	0.05	0.42

Cont. table 5.

13	0.30	0.10	0.05	0.00	0.15	0.38	1.19	0.01	0.09	0.01	0.23	0.45	0.00	0.00	0.46	0.04
14	0.30	0.10	0.05	0.00	0.15	0.38	1.19	0.01	0.09	0.01	0.23	0.45	0.00	0.00	0.46	0.04
15	0.16	0.36	0.41	0.46	0.31	0.08	0.73	0.47	0.37	0.47	0.23	0.05	0.46	0.46	0.00	0.42
16	0.26	0.06	0.01	0.04	0.11	0.34	1.15	0.05	0.05	0.05	0.19	0.42	0.04	0.04	0.42	0.00

Source: based on own research.

Comparing the Śląskie province, we can notice that: the greatest distance separates the Śląskie province from the Mazowieckie province, and the smallest distance separates the Wielkopolskie province.

Table 6.

Distance matrix - for the year 2022 - variables related to enterprises with Internet access buying cloud services

Province	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0.00	0.25	0.31	0.06	0.13	0.09	0.74	0.33	0.26	0.35	0.06	0.19	0.34	0.34	0.12	0.25
2	0.25	0.00	0.06	0.08	0.12	0.34	0.98	0.09	0.03	0.11	0.18	0.44	0.10	0.09	0.37	0.01
3	0.31	0.06	0.00	0.56	0.18	0.40	1.05	0.03	0.05	0.05	0.25	0.50	0.03	0.03	0.43	0.06
4	0.06	0.08	0.56	0.00	0.04	0.42	1.06	0.02	0.06	0.03	0.26	0.52	0.02	0.02	0.45	0.07
5	0.13	0.12	0.18	0.04	0.00	0.04	0.87	0.20	0.13	0.23	0.06	0.32	0.21	0.21	0.25	0.12
6	0.09	0.34	0.40	0.42	0.04	0.00	0.65	0.42	0.35	0.45	0.16	0.12	0.43	0.43	0.04	0.34
7	0.74	0.98	1.05	1.06	0.87	0.65	0.00	1.07	1.00	1.09	0.16	0.55	1.08	1.08	0.62	0.99
8	0.33	0.09	0.03	0.02	0.20	0.42	1.07	0.00	0.07	0.02	0.27	0.52	0.01	0.02	0.46	0.08
9	0.26	0.03	0.05	0.06	0.13	0.35	1.00	0.07	0.00	0.09	0.20	0.45	0.08	0.08	0.38	0.03
10	0.35	0.11	0.05	0.03	0.23	0.45	1.09	0.02	0.09	0.00	0.29	0.55	0.01	0.02	0.48	0.10
11	0.06	0.18	0.25	0.26	0.06	0.16	0.16	0.27	0.20	0.29	0.00	0.26	0.28	0.28	0.19	0.19
12	0.19	0.44	0.50	0.52	0.32	0.12	0.55	0.52	0.45	0.55	0.26	0.00	0.53	0.53	0.08	0.44
13	0.34	0.10	0.03	0.02	0.21	0.43	1.08	0.01	0.08	0.01	0.28	0.53	0.00	0.01	0.46	0.09
14	0.34	0.09	0.03	0.02	0.21	0.43	1.08	0.02	0.08	0.02	0.28	0.53	0.01	0.00	0.46	0.09
15	0.12	0.37	0.43	0.45	0.25	0.04	0.62	0.46	0.38	0.48	0.19	0.08	0.46	0.46	0.00	0.38
16	0.25	0.01	0.06	0.07	0.12	0.34	0.99	0.08	0.03	0.10	0.19	0.44	0.09	0.09	0.38	0.00

Source: based on own research.

Comparing the Śląskie province, we can notice that: the greatest distance separates the Śląskie province from the Podlaskie province, and the smallest distance separates the Wielkopolskie province.

Table 7.

Distance matrix - for the year 2021 - variables related to access to the Internet by enterprises

Province	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0.00	0.14	0.19	0.05	0.06	0.10	0.39	0.28	0.17	0.26	0.05	0.28	0.28	0.26	0.21	0.20
2	0.14	0.00	0.04	0.12	0.08	0.25	0.54	0.14	0.03	0.12	0.10	0.43	0.13	0.12	0.36	0.05
3	0.19	0.04	0.00	0.61	0.13	0.29	0.58	0.09	0.02	0.07	0.14	0.47	0.09	0.07	0.40	0.02
4	0.05	0.12	0.61	0.00	0.04	0.37	0.66	0.02	0.09	0.01	0.22	0.55	0.01	0.01	0.48	0.07
5	0.06	0.08	0.13	0.04	0.00	0.03	0.46	0.22	0.11	0.20	0.03	0.35	0.21	0.20	0.28	0.13
6	0.10	0.25	0.29	0.37	0.03	0.00	0.29	0.39	0.28	0.37	0.15	0.18	0.38	0.37	0.11	0.30
7	0.39	0.54	0.58	0.66	0.46	0.29	0.00	0.68	0.57	0.66	0.09	0.12	0.67	0.66	0.18	0.59
8	0.28	0.14	0.09	0.02	0.22	0.39	0.68	0.00	0.11	0.02	0.24	0.57	0.01	0.02	0.50	0.09
9	0.17	0.03	0.02	0.09	0.11	0.28	0.57	0.11	0.00	0.09	0.12	0.46	0.11	0.09	0.39	0.04
10	0.26	0.12	0.07	0.01	0.20	0.37	0.66	0.02	0.09	0.00	0.22	0.55	0.01	0.01	0.48	0.07
11	0.05	0.10	0.14	0.22	0.03	0.15	0.09	0.24	0.12	0.22	0.00	0.33	0.23	0.22	0.26	0.15
12	0.28	0.43	0.47	0.55	0.35	0.18	0.12	0.57	0.46	0.55	0.33	0.00	0.56	0.55	0.07	0.48
13	0.28	0.13	0.09	0.01	0.21	0.38	0.67	0.01	0.11	0.01	0.23	0.56	0.00	0.01	0.49	0.08

Cont. table 7.

14	0.26	0.12	0.07	0.01	0.20	0.37	0.66	0.02	0.09	0.01	0.22	0.55	0.01	0.00	0.48	0.07
15	0.21	0.36	0.40	0.48	0.28	0.11	0.18	0.50	0.39	0.48	0.26	0.07	0.49	0.48	0.00	0.41
16	0.20	0.05	0.02	0.07	0.13	0.30	0.59	0.09	0.04	0.07	0.15	0.48	0.08	0.07	0.41	0.00

Source: based on own research.

Comparing the Śląskie province, we can notice that: the greatest distance separates the Śląskie province from the Opolskie province, and the smallest distance separates the Wielkopolskie province.

Table 8.

Distance matrix - for the year 2021 - variables related to enterprises with Internet access buying cloud services

Province	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	0.00	0.25	0.31	0.06	0.13	0.09	0.74	0.33	0.26	0.35	0.06	0.19	0.34	0.34	0.12	0.25
2	0.25	0.00	0.06	0.08	0.12	0.34	0.98	0.09	0.03	0.11	0.18	0.44	0.10	0.09	0.37	0.01
3	0.31	0.06	0.00	0.56	0.18	0.40	1.05	0.03	0.05	0.05	0.25	0.50	0.03	0.03	0.43	0.06
4	0.06	0.08	0.56	0.00	0.04	0.42	1.06	0.02	0.06	0.03	0.26	0.52	0.02	0.02	0.45	0.07
5	0.13	0.12	0.18	0.04	0.00	0.04	0.87	0.20	0.13	0.23	0.06	0.32	0.21	0.21	0.25	0.12
6	0.09	0.34	0.40	0.42	0.04	0.00	0.65	0.42	0.35	0.45	0.16	0.12	0.43	0.43	0.04	0.34
7	0.74	0.98	1.05	1.06	0.87	0.65	0.00	1.07	1.00	1.09	0.16	0.55	1.08	1.08	0.62	0.99
8	0.33	0.09	0.03	0.02	0.20	0.42	1.07	0.00	0.07	0.02	0.27	0.52	0.01	0.02	0.46	0.08
9	0.26	0.03	0.05	0.06	0.13	0.35	1.00	0.07	0.00	0.09	0.20	0.45	0.08	0.08	0.38	0.03
10	0.35	0.11	0.05	0.03	0.23	0.45	1.09	0.02	0.09	0.00	0.29	0.55	0.01	0.02	0.48	0.10
11	0.06	0.18	0.25	0.26	0.06	0.16	0.16	0.27	0.20	0.29	0.00	0.26	0.28	0.28	0.19	0.19
12	0.19	0.44	0.50	0.52	0.32	0.12	0.55	0.52	0.45	0.55	0.26	0.00	0.53	0.53	0.08	0.44
13	0.34	0.10	0.03	0.02	0.21	0.43	1.08	0.01	0.08	0.01	0.28	0.53	0.00	0.01	0.46	0.09
14	0.34	0.09	0.03	0.02	0.21	0.43	1.08	0.02	0.08	0.02	0.28	0.53	0.01	0.00	0.46	0.09
15	0.12	0.37	0.43	0.45	0.25	0.04	0.62	0.46	0.38	0.48	0.19	0.08	0.46	0.46	0.00	0.38
16	0.25	0.01	0.06	0.07	0.12	0.34	0.99	0.08	0.03	0.10	0.19	0.44	0.09	0.09	038	0.00

Source: based on own research.

Comparing the Śląskie province, we can notice that: the greatest distance separates the Śląskie province from the Podlaskie province, and the smallest distance separates the Wielkopolskie province.

The latest distance matrices for 2020.

Table 9.

Distance matrix - for the year 2020 - variables related to access to the Internet by enterprises

Province	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	0.00	0.16	0.21	0.05	0.09	0.09	0.74	0.28	0.16	0.28	0.05	0.21	0.28	0.27	0.15	0.20
2	0.16	0.00	0.05	0.10	0.07	0.24	0.90	0.12	0.02	0.12	0.12	0.37	0.12	0.11	0.31	0.03
3	0.21	0.05	0.00	0.58	0.12	0.30	0.95	0.07	0.05	0.06	0.17	0.42	0.06	0.06	0.37	0.02
4	0.05	0.10	0.58	0.00	0.03	0.34	1.00	0.02	0.10	0.02	0.21	0.47	0.02	0.02	0.41	0.06
5	0.09	0.07	0.12	0.03	0.00	0.03	0.83	0.19	0.07	0.19	0.05	0.30	0.19	0.18	0.24	0.11
6	0.09	0.24	0.30	0.34	0.03	0.00	0.66	0.36	0.25	0.36	0.13	0.13	0.36	0.35	0.07	0.28
7	0.74	0.90	0.95	1.00	0.83	0.66	0.00	1.02	0.90	1.01	016	0.53	1.02	1.01	0.59	0.93
8	0.28	0.12	0.07	0.02	0.19	0.36	1.02	0.00	0.12	0.01	0.24	0.49	0.01	0.02	0.43	0.08
9	0.16	0.02	0.05	0.10	0.07	0.25	0.90	0.12	0.00	0.11	0.12	0.37	0.11	0.11	0.32	0.04
10	0.28	0.12	0.06	0.02	0.19	0.36	1.01	0.01	0.11	0.00	0.23	0.49	0.00	0.01	0.43	0.08
11	0.05	0.12	0.17	0.21	0.05	0.13	0.16	0.24	0.12	0.23	0.00	0.26	0.23	0.23	0.20	0.15
12	0.21	0.37	0.42	0.47	0.30	0.13	0.53	0.49	0.37	0.49	0.26	0.00	0.49	0.48	0.08	0.41
13	0.28	0.12	0.06	0.02	0.19	0.36	1.02	0.01	0.11	0.00	0.23	0.49	0.00	0.01	0.43	0.08

Cont. table 9.

14	0.27	0.11	0.06	0.02	0.18	0.35	1.01	0.02	0.11	0.01	0.23	0.48	0.01	0.00	0.42	0.07
15	0.15	0.31	0.37	0.41	0.24	0.07	0.59	0.43	0.32	0.43	0.20	0.08	0.43	0.42	0.00	0.35
16	0.20	0.03	0.02	0.06	0.11	0.28	0.93	0.08	0.04	0.08	0.15	0.41	0.08	0.07	0.35	0.00

Source: based on own research.

Comparing the Śląskie province, we can notice that: the greatest distance separates the Śląskie province from the Mazowieckie province, and the smallest distance separates the Wielkopolskie province.

Table 10.

Distance matrix - for the year 2020 - variables related to enterprises with Internet access buying cloud services

Province	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0.00	0.22	0.27	0.06	0.13	0.09	0.88	0.33	0.23	0.35	0.07	0.16	0.34	0.35	0.04	0.25
2	0.22	0.00	0.06	0.08	0.08	0.30	1.10	0.11	0.04	0.13	0.14	0.37	0.12	0.14	0.25	0.04
3	0.27	0.06	0.00	0.57	0.13	0.35	1.15	0.06	0.04	0.08	0.19	0.42	0.07	0.09	0.30	0.04
4	0.06	0.08	0.57	0.00	0.03	0.38	1.18	0.03	0.07	0.05	0.22	0.45	0.04	0.06	0.33	0.05
5	0.13	0.08	0.13	0.03	0.00	0.04	1.02	0.20	0.10	0.21	0.07	0.29	0.20	0.22	0.17	0.12
6	0.09	0.30	0.35	0.38	0.04	0.00	0.80	0.41	0.31	0.43	0.15	0.08	0.42	0.43	0.08	0.33
7	0.88	1.10	1.15	1.18	1.02	0.80	0.00	1.21	1.11	1.23	0.19	0.72	1.22	1.23	0.85	1.13
8	0.33	0.11	0.06	0.03	0.20	0.41	1.21	0.00	0.10	0.02	0.26	0.49	0.02	0.02	0.36	0.08
9	0.23	0.04	0.04	0.07	0.10	0.31	1.11	0.10	0.00	0.12	0.16	0.39	0.10	0.12	0.27	0.05
10	0.35	0.13	0.08	0.05	0.21	0.43	1.23	0.02	0.12	0.00	0.27	0.50	0.01	0.01	0.38	0.09
11	0.07	0.14	0.19	0.22	0.07	0.15	0.19	0.26	0.16	0.27	0.00	0.23	0.26	0.28	0.11	0.18
12	0.16	0.37	0.42	0.45	0.29	0.08	0.72	0.49	0.39	0.50	0.23	0.00	0.49	0.51	0.12	0.41
13	0.34	0.12	0.07	0.04	0.20	0.42	1.22	0.02	0.10	0.01	0.26	0.49	0.00	0.02	0.37	0.08
14	0.35	0.14	0.09	0.06	0.22	0.43	1.23	0.02	0.12	0.01	0.28	0.51	0.02	0.00	0.39	0.10
15	0.04	0.25	0.30	0.33	0.17	0.08	0.85	0.36	0.27	0.38	0.11	0.12	0.37	0.39	0.00	0.29
16	0.25	0.04	0.04	0.05	0.12	0.33	1.13	0.08	0.05	0.09	0.18	0.41	0.08	0.10	0.29	0.00

Source: based on own research.

Comparing the Śląskie province, we can notice that: the greatest distance separates the Śląskie province from the Mazowieckie province, and the smallest distance separates the Małopolskie province.

In the next step of the analysis, similarity matrices were determined.

Table 11.

Similarity matrix - for the year 2022 - variables related to access to the Internet by enterprises

Province	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.00	0.91	0.89	0.97	0.93	0.96	0.60	0.86	0.91	0.86	0.97	0.93	0.87	0.87	0.93	0.88
2	0.91	1.00	0.98	0.96	0.98	0.88	0.51	0.95	0.99	0.95	0.94	0.84	0.96	0.96	0.84	0.97
3	0.89	0.98	1.00	0.74	0.95	0.85	0.49	0.97	0.98	0.97	0.92	0.82	0.98	0.98	0.82	0.99
4	0.97	0.96	0.74	1.00	0.99	0.83	0.47	1.00	0.96	1.00	0.90	0.80	1.00	1.00	0.79	0.98
5	0.93	0.98	0.95	0.99	1.00	0.98	0.54	0.93	0.97	0.93	0.96	0.87	0.93	0.93	0.86	0.95
6	0.96	0.88	0.85	0.83	0.98	1.00	0.64	0.83	0.87	0.83	0.93	0.96	0.83	0.83	0.96	0.85
7	0.60	0.51	0.49	0.47	0.54	0.64	1.00	0.46	0.51	0.46	0.91	0.67	0.47	0.47	0.67	0.48
8	0.86	0.95	0.97	1.00	0.93	0.83	0.46	1.00	0.96	1.00	0.89	0.79	1.00	0.99	0.79	0.98
9	0.91	0.99	0.98	0.96	0.97	0.87	0.51	0.96	1.00	0.96	0.93	0.84	0.96	0.96	0.83	0.98
10	0.86	0.95	0.97	1.00	0.93	0.83	0.46	1.00	0.96	1.00	0.89	0.79	1.00	1.00	0.79	0.98
11	0.97	0.94	0.92	0.90	0.96	0.93	0.91	0.89	0.93	0.89	1.00	0.90	0.90	0.90	0.90	0.91
12	0.93	0.84	0.82	0.80	0.87	0.96	0.67	0.79	0.84	0.79	0.90	1.00	0.80	0.80	0.98	0.81
13	0.87	0.96	0.98	1.00	0.93	0.83	0.47	1.00	0.96	1.00	0.90	0.80	1.00	1.00	0.79	0.98

Cont. table 11.

14	0.87	0.96	0.98	1.00	0.93	0.83	0.47	0.99	0.96	1.00	0.90	0.80	1.00	1.00	0.79	0.98
15	0.93	0.84	0.82	0.79	0.86	0.96	0.67	0.79	0.83	0.79	0.90	0.98	0.79	0.79	1.00	0.81
16	0.88	0.97	0.99	0.98	0.95	0.85	0.48	0.98	0.98	0.98	0.91	0.81	0.98	0.98	0.81	1.00

Source: based on own research.

Table 12.

Similarity matrix - for the year 2022 - variables related to enterprises with Internet access buying cloud services

Province	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	1.00	0.89	0.86	0.97	0.94	0.96	0.67	0.85	0.88	0.84	0.97	0.91	0.85	0.85	0.94	0.89
2	0.89	1.00	0.97	0.97	0.95	0.85	0.56	0.96	0.98	0.95	0.92	0.80	0.96	0.96	0.83	0.99
3	0.86	0.97	1.00	0.75	0.92	0.82	0.53	0.99	0.98	0.98	0.89	0.78	0.99	0.99	0.81	0.97
4	0.97	0.97	0.75	1.00	0.98	0.81	0.52	0.99	0.97	0.99	0.88	0.77	0.99	0.99	0.80	0,97
5	0.94	0.95	0.92	0.98	1.00	0.98	0.61	0.91	0.94	0.90	0.97	0.86	0.90	0.90	0.89	0.94
6	0.96	0.85	0.82	0.81	0.98	1.00	0.71	0.81	0.84	0.80	0.93	0.95	0.81	0.81	0.98	0.85
7	0.67	0.56	0.53	0.52	0.61	0.71	1.00	0.52	0.55	0.51	0.93	0.76	0.52	0.52	0.72	0.56
8	0.85	0.96	0.99	0.99	0.91	0.81	0.52	1.00	0.97	0.99	0.88	0.77	0.99	0.99	0.80	0.96
9	0.88	0.98	0.98	0.97	0.94	0.84	0.55	0.97	1.00	0.96	0.91	0.80	0.96	0.96	0.83	0.99
10	0.84	0.95	0.98	0.99	0.90	0.80	0.51	0.99	0.96	1.00	0.87	0.76	0.99	0.99	0.79	0.95
11	0.97	0.92	0.89	0.88	0.97	0.93	0.93	0.88	0.91	0.87	1.00	0.89	0.88	0.88	0.92	0.92
12	0.91	0.80	0.78	0.77	0.86	0.95	0.76	0.77	0.80	0.76	0.89	1.00	0.76	0.76	0.97	0.80
13	0.85	0.96	0.99	0.99	0.90	0.81	0.52	0.99	0.96	0.99	0.88	0.76	1.00	1.00	0.79	0.96
14	0.85	0.96	0.99	0.99	0.90	0.81	0.52	0.99	0.96	0.99	0.88	0.76	1.00	1.00	0.79	0.96
15	0.94	0.83	0.81	0.80	0.89	0.98	0.72	0.80	0.83	0.79	0.92	0.97	0.79	0.79	1.00	0.83
16	0.89	0.99	0.97	0.97	0.94	0.85	0.56	0.96	0.99	0.95	0.92	0.80	0.96	0.96	0.83	1.00

Source: based on own research.

(The determined matrices take up many pages of the article, which does not allow presenting all of them, therefore the values of the measures of similarity of the Śląskie province to other provinces in the examined years are presented) The designated matrices make it possible to examine changes in the process of provinces becoming similar or moving away from similarity in the examined years.

Table 13.

Similarity matrix for Ślaskie province - 2022, 2021, 2020 - variables related to access to the Internet by enterprises

Province	**2022**	**2021**	**2020**
	Śląskie		
Dolnośląskie	0.930	0.873	0.906
Kujawsko-pomorskie	0.841	0.808	0.834
Lubelskie	0.819	0.788	0.811
Lubuskie	0.796	0.754	0.790
Łódzkie	0.865	0.845	0.865
Małopolskie	0.962	0.920	0.943
Mazowieckie	0.670	0.944	0.764
Opolskie	0.793	0.746	0.781
Podkarpackie	0.836	0.796	0.833
Podlaskie	0.794	0.755	0.782
Pomorskie	0.901	0.852	0.886
Śląskie	1.000	1.000	1.000
Świętokrzyskie	0.797	0.749	0.782
Warmińsko-mazurskie	0.797	0.755	0.785

‚cont. table 13.

Wielkopolskie	0.977	0.969	0.966
Zachodniopomorskie	0.814	0.785	0.818

Source: based on own research.

The highest level of similarity of Śląskie province is to Wielkopolskie province in the analyzed years. The Śląskie province became more and more similar to the Wielkopolskie province in terms of the analyzed characteristics (the value of the measure systematically increases).

The lowest values occur for the Mazowieckie province in the level of similarity to the Śląskie province.

To assess the level of changes in the process of resemblance of Śląskie province to other provinces, the following indicators have been established:

Table 14.
Indicators of the intensity of changes in the level of similarity of the Śląskie province to other provinces - variables related to access to the Internet by enterprises

Province	**w_{is}**	**w'_{is}**	**w''_{is}(%)**
Dolnośląskie	0.0121	0.0454	5.1338
Kujawsko-pomorskie	0.0037	0.0293	3.5828
Lubelskie	0.0043	0.0270	3.3922
Lubuskie	0.0031	0.0387	5.0283
Łódzkie	-0.0001	0.0209	2.4403
Małopolskie	0.0097	0.0329	3.5434
Mazowieckie	-0.0470	0.2270	26.2915
Opolskie	0.0060	0.0409	5.3737
Podkarpackie	0.0013	0.0383	4.7089
Podlaskie	0.0058	0.0331	4.3192
Pomorskie	0.0075	0.0416	4.8069
Śląskie	0.0000	0.0000	0.0000
Świętokrzyskie	0.0074	0.0405	5.3128
Warmińsko-mazurskie	0.0062	0.0360	4.6932
Wielkopolskie	0.0056	0.0056	0.5789
Zachodniopomorskie	-0.0020	0.0313	3.9030

Source: based on own research.

The value of the meter w_{is} with the sign (+) indicates an increase in the similarity of the analyzed provinces (in 2022, 2021, 2020). For the Mazowieckie province the value of the indicator is negative and amounts to 26.3%. This means that there is no process of becoming similar to the analyzed phenomenon. For Zachodniopomorskie and Łódzkie provinces the indicators are negative and values are very small and amount to 3.9%, 2.4% (w''_{is}) (A negative sign for these provinces may mean that their process of becoming similar to the model province was faster than that of the Śląskie province). The highest value of the indicator (w''_{is}) determining the rate of change in the Śląskie province becoming similar to the Opolskie province, and the lowest rate of change in the Śląskie province becoming similar to Wielkopolskie province in 2022, 2021, 2020.

7. Conclusion

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

The study covered the years 2022, 2021, 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 can present a complex phenomenon by means of one variable. Variables which describe a particular phenomenon are usually diverse in character, as there are both stimulants and destimulants. The synthetic variable presented the level of development of the analyzed phenomenon in Polish provinces in selected years. The values of the synthetic variable additionally allowed for ranking the provinces from the best to the worst in terms of the studied phenomenon. The Mazowieckie province had the highest level throughout the period under study (The richest province in Poland is Mazowieckie province due to the capital of Poland).

Then the distance matrix was determined in 2022, 2021, 2020 for two research topics. The distance of the level of development of the phenomenon that separates Śląskie province from the studied provinces has been determined.

The distance matrices also contain information on the distances between each of the selected Polish provinces in the analysis. Distance matrices determined the distance in the development of the phenomenon that separates the selected province from other subsequent provinces.

Then, a similarity matrix was determined to examine the level of similarity of the Śląskie province to other provinces for the analyzed years (for two research topics).

Taking into account the similarity matrix, it was possible to determine the indicators of the rate of similarity in the development of the phenomenon over the entire period of time considered.

To sum up, the taxonomic analysis tools selected in the analysis made it possible to study the phenomenon both in one year and for three years in total. The synthetic variable presented the level of development of the phenomenon in each province individually and assigned ranks for provinces. The distance matrix presented the distance in the development of the phenomenon of the Śląskie province from other provinces. And the similarity matrix allowed for the determination of measures of the pace of development of the Śląskie province becoming more similar to the remaining provinces in the period under study.

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

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