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Taxonomic Analysis of Internet and ICT Usage in A Static and Dynamic Perspective in Selected European Countries and US States with Special Focus on The Time of The Covid-19 Pandemic*

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Abstract

The study examines the use of the internet and information and communication technologies by the citizens of the selected country, with special emphasis placed on the Covid-19 pandemic period. In the study, a taxonomic method (Chomątowski, Sokołowski, 1978), (Młodak, 2006) was employed to analyse the level of variation of objects described by selected statistical characteristics and identify clusters of objects sharing a similar level of development of the phenomenon under consideration. (Taxonomic method with modifications proposed by A. Młodak (Młodak, 2006)). The study covered the years 2010-2020, including the time of the Covid-19 pandemic. The analysis included in two stages, i.e. it covered two directions of the structure analysis: the static variant and the dynamic variant. First, Poland was analysed and the groups of voivodeships featuring a homogeneous level of development were identified. In the next step, the analysis was performed for the European countries to see how Poland compares to them. The last stage involved analysing the US states in regard to the phenomenon under study. The study is based on the data sourced from Poland Statistics, US Statistics and Eurostat websites.

Keywords: Econometric Methods, Information Society, Taxonomic Analysis.

Introduction

We live in the times of an ongoing digital revolution. All aspects of our life, the life of the information society that we have turned into, are increasingly dependent on technological innovations. The continuous development of the information society contributes significantly to globalisation and brings about multiple economic changes. Our lives and everyday activities are affected by constant change and take on a new meaning, which results in the emergence of new modes of behaviour in the modern world. Knowledge has been gaining importance in the economy, creating significant interactions between knowledge and various institutions (Goban-Klas, Sienkiewicz, 1999), (Bliźniuk, Nowak, 2005), (Miczka, 1999). One of the major factors dividing the society is the ability to access and use the achievements of the ICT revolution, which impacts greatly on our culture and traditions as well. Our society is becoming, consciously or unconsciously, dependent on the internet - it enables us to transfer some of our social activity to and base it on the digital social space. We have changed our habits and our everyday life by taking advantage of the ICT solutions. In order to avoid digital exclusion, older adults have also adapted to the changes, embracing, as far as possible, mobile devices such as mobile phones, tablets, etc. However, the development of the information society produces some negative consequences too, including cyberterrorism, hacking attacks, etc. Digital exclusion is becoming increasingly noticeable not only among seniors as the gap between the rich, who have access to the latest technologies and the internet, and the poor, who are deprived of them, is widening. The development of

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new information and communication technologies is of vital importance to employment as well as creation of new sources of income. Companies, institutions, public administration try to meet the needs of citizens or institutional and business partners and thus new consumer behaviour patterns emerge. The pandemic and the resultant lockdown have altered our lives dramatically. Enterprises, households and public administration units have been made to increase access to ICTs and broaden the scope of their use. It is true that the expanding scope and availability of e-services require that citizens know how to use and operate modern technologies, but, on the other hand, they offer convenience, e.g. we do not have to submit official documents in person, we can do shopping online. The Covid-19 pandemic, and the consequential restrictions and lockdowns in particular, have rapidly changed our lives, posing a challenge to our everyday functioning. We have experienced problems with distance education and remote work in terms of constant access to the internet and the need for appropriate study and work space at home. The pandemic has changed the access to healthcare services, transportation as well as the way we move around and travel. The study applies the method devised by S. Chomątowski and A. Sokołowski (Chomątowski, Sokołowski, 1978), along with its later modifications proposed by A. Młodak (Młodak, 2006). The analysis is conducted in two stages, i.e. it comprises two directions of structure analysis: a static variant and a dynamic one.

The method for the classification

A multivariate comparative analysis is closely related to the quantitative disciplines (Pociecha et al., 1988), (Hartigan, 1975), (Edwards, Cavalli-Sforza, 1963). 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 (Grabiński, Wydymus, Zeliaś, 1989), (Panek, 2009), (Lipieta et al., 2000)), (Strahl,1998), (Mika, 1995). The grouping of objects depends on the method selected to measure the distance between the structures (Ward, 1963). The method used in the present study enables structural comparisons. In addition, it is a hierarchical method, whose aim is to obtain disjoint groups of similar objects. The analysis is conducted in two stages, i.e. it comprises two directions of structure analysis: a static variant and a dynamic one. The study applies the method devised by S. Chomątowski and A. Sokołowski (Chomątowski, Sokołowski, 1978), along with its later modifications proposed by A. Młodak (Młodak, 2006). It involves performing a few transformations arranged in a certain order. Based on the collected empirical data, a matrix whose elements are variables describing a particular phenomenon is constructed.

Next, a distance matrix is calculated – it provides a basis for the presentation of structural similarity within the phenomenon:

$$d = \sqrt{\sum_{j=1}^{m}(x_{ji} - x_{jk})^2} \quad (1)$$

The distance matrix is normalised by dividing each row of the matrix by the sum of its elements. The values of the normalised distances serve as a basis for determining the measure of structural similarity of the phenomenon. In the study, the Chomątowski-Sokołowski measure is replaced by the median "Canberra" measure proposed by A. Młodak (Młodak, 2006):

$$MC_{ik} = \underset{j=1,\dots,m}{\text{med}}\left(\frac{|x_{ij}-x_{kj}|}{x_{ij}+x_{kj}}\right) (2)$$

For this purpose, the square similarity matrix P' and then the dissimilarity matrix P are built, using the adopted measure. Matrix P=$[p_{ik}]$, *i, k* = 1,2, ..., *n* is a symmetric matrix, and its elements take values in the range [0, 1]. In the next step, in accordance with Chomątowski-Sokołowski's procedure, the dissimilarity critical threshold α is determined. The authors do not indicate a specific method for calculating the value of α. The study uses the method proposed by A. Młodak (Młodak, 2006), (Nowak, 1981). We assume:

$$\alpha = \mu\alpha_{min} + (1-\mu)\alpha_{max} \quad (3)$$

Where:

$$\alpha_{min} = \min_{\substack{i,k=1,2,\dots,n \\ i\neq k}} p_{ik}$$

$$\alpha_{max} = \max_{i,k=1,2,\dots,n} p_{ik}$$

The value is used to build matrix P*, which is a zero-one matrix. Matrix P* is constructed in accordance with the following formula (4) (Chomątowski, Sokołowski, 1978):

$$P^* = \begin{cases} 0, & p_{ik} < \alpha \\ 1, & p_{ik} \geq \alpha \end{cases} \quad (4)$$

We obtain a zero-one matrix and add to it a new column that is the sum of zeros and ones in each row. A. Młodak (Młodak, 2006) proposed selecting a row and a column in the matrix which:

$$med(p_{i1}, \dots, p_{in}) \leq med(p_{k1}, \dots, p_{kn}) \quad (5)$$

Each time we remove the selected column and row from the matrix we replace it with symbol "*". The process is repeated until the column becomes a zero vector and the objects which have not been removed from the distance matrix form a group of similar objects at a probability level of 1-α. In the next step, we repeat the process and create another matrix by following the adopted procedure for removing rows and columns (Młodak, 2006). The objects aligned to the rows and columns that remain in matrix P form a group of similar objects. For the other rows and columns we produce a new matrix based on the initial matrix P and repeat the process.

In the last stage of the study, the intergroup and intragroup variance of the groups are calculated in order to test whether the groups that have emerged as a result of the process are sufficiently homogeneous and do not require any further delimitation.

The set of diagnostic characteristics of the problems under study

The study attempts to employ the selected taxonomic methods to order Poland's voivodeships (provinces), and next - European countries and the US states, according to the level of their development and to analyse their impact on the overall development in the periods under study as well as to use a taxonomic method to identify homogeneous periods of dynamics variations in the analysed phenomenon in selected countries. The study examines the use of the internet and information and communication technologies by the citizens of the selected country, with special emphasis placed on the Covid-19 pandemic period (Janiga-Ćmiel, 2020), (Janiga-Ćmiel, 2021). Data were drawn from Eurostat and Statistics Poland, 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. The first stage of the analysis involved examining Poland's voivodeships in the years 2020, 2019, 2015. The set of diagnostic characteristics employed in the analysis included data related to the use of ICT by enterprises, public administration, households and individuals as well as digitisation and types and scope of e-services provided by public administration units:

x_1 -Percentage of the public administration units that equip their employees on the devices for mobile connecting from the Internet in business,
x_2 -Percentage of the public administration units that supported the development of digital skills among citizens,
x_3 -Percentage of the public administration units that used the electronic document management system,
x_4 -Percentage of the public administration units that provided services to citizens via the Internet,
x_5 -Number of the public administration entities which used their own electronic mailbox solutions,
x_6 -Percentage of the households of the Internet access,
x_7 -Percentage of the households with broadband internet access,
x_8 -Number of the individuals who the Internet usage - aged 16-74,
x_9 -Percentage of people who have never used the Internet,
x_{10} -Percentage of the enterprises using devices with Internet connection,
x_{11} -Number of the individuals who finding information about goods and services - Internet use,
X_{12} -Number of the individuals who posting messages to social media sites or instant messaging.
X_{13} –Number of the enterprises giving portable devices for a mobile connection to the Internet to their employees.

The second stage of the analysis focused on the European countries in the years 2020, 2019, 2015. The set of the diagnostic characteristics included:

y_1-Percentage of level of Internet access – households,
y_2-Percentage of households without Internet access at home,
y_3 -Percentage of households with broadband access,
y_4- Number of individuals used a portable computer or a handheld device to access the Internet away from home or work,
y_5 - Number of individuals frequently using the Internet (daily),
y_6 - Number of individuals who have never used the Internet,
y_7- Number of individuals using the Internet for participating in social networks,
y_8 - Number of individuals using the Internet for finding information about goods and services,
y_9 - Number of individuals using the Internet for seeking health-related information,
y_{10} - Number of Individuals using the internet for internet banking,
y_{11}- Number of enterprises having received orders online.

During the final stage, an analysis of the US states in the years 2019, 2015 was conducted. The set of the diagnostic characteristics comprised:

z_1 - Number of households with desktop or laptop,
z_2- Number of households without desktop or laptop,
z_3- Number of households with an Internet subscription,
z_4- Number of households with mobile broadband alone or with dialup,
z_5- Number of households without an Internet subscription,
z_6 - Number of households with dial-up alone (no broadband subscription).

The use of taxonomic analysis in a study on the phenomenon under consideration

First, based on the selected set of the diagnostic characteristics, homogeneous groups of Polish voivodeships for the year 2020 were identified. It was done by following the procedure presented in the previous chapter: a distance matrix and next, a matrix of distance structure indicators were built, which provided a basis for the construction of a similarity and dissimilarity matrix ($\alpha = 0.1681$ - for the first stage), (Due to the large number of matrices, their presentation has been omitted). As a result, the following development homogeneous groups of voivodeships formed:

Table 1: The groups of homogeneous development of the phenomenon - voivodeships of Poland -2020 (based on own research)

Group 1	Group 2	Group 3	Group 4
Mazowieckie Śląskie	Podlaskie Świętokrzyskie Warmińsko-mazurskie Zachodniopomorskie Lubuskie Opolskie	Dolnośląskie Wielkopolskie Łódzkie Małopolskie	Pomorskie Kujawsko-pomorskie Lubelskie Podkarpackie

In addition, for the groups, the results are presented graphically (the Excel Map).

Fig 1. The groups of homogeneous development of the phenomenon - voivodeships of Poland - 2020 - the Excel Map (based on own research)

(The voivodeships of the same color belong to one group).

The same set of variables was used to perform analysis for the years 2019 and 2015, which led to the identification of the following groups:

Table 2: The groups of homogeneous development of the phenomenon - voivodeships of Poland - 2019 (based on own research)

Group 1	Group 2	Group 3	Group 4	Group 5
Mazowieckie	Śląskie Wielkopolskie	Lubuskie Podlaskie Świętokrzyskie Zachodniopomorskie Opolskie	Kujawsko-pomorskie Warmińsko-mazurskie Lubelskie Podkarpackie	Dolnośląskie Pomorskie Łódzkie Małopolskie

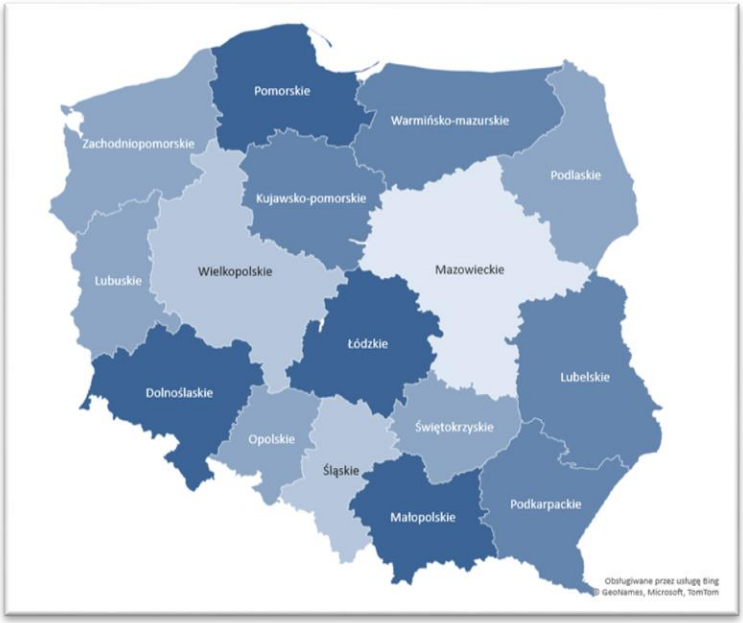

Fig 2. The groups of homogeneous development of the phenomenon - voivodeships of Poland - 2019 - the Excel Map (based on own research)

For the last year, 2015, the final clustering was comprised of five groups.

Table 3: The groups of homogeneous development of the phenomenon - voivodeships of Poland - 2015 (based on own research)

Group 1	Group 2	Group 3	Group 4	Group 5
Mazowieckie	Śląskie	Lubuskie Opolskie Podlaskie Świętokrzyskie Zachodniopomorskie Warmińsko-mazurskie	Kujawsko-pomorskie Podkarpackie Pomorskie	Dolnośląskie Łódzkie Małopolskie Wielkopolskie Lubelskie

Graphical presentation of the results:

Fig 3. The groups of homogeneous development of the phenomenon - voivodeships of Poland - 2015 - the Excel Map (based on own research)

The richest voivodeship in Poland is mazowieckie voivodship due to the capital of Poland. Second place in the ranking of the richest voivodeships is dolnośląskie voivodship with the developing city of Wrocław. The third place belongs to the wielkopolskie voivodeship. The poorest polish voivodships are: lubelskie (agricultural region), podkarpackie and warmińsko-mazurskie.

The analysis was repeated to determine homogeneous periods of dynamics variations in the phenomenon. The following period homogeneous groups were identified:

$G_{1Poland}$ = (2010, 2011, 2012, 2013),

$G_{2Poland}$ = (2014, 2015, 2016),

$G_{3Poland}$ = (2017, 2018, 2019),

$G_{4Poland}$ = (2020).

The analysis of the European countries led to the detection of the following groups in each period under study:

Table 4: The groups of homogeneous development of the phenomenon – the selected European countries - 2020 (based on own research)

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Belgium	Czechia	Germany	Denmark	Netherlands	Bulgaria	Italy
Cyprus	Austria	Luxembourg	Norway	Finland	Greece	Poland
Hungary	Estonnia	Ireland	Iceland	United	Portugal	
Malta	Latvia	Spain		Kingdom	Croatia	
	Slovakia			Sweden	Lithuania	
	Slovenia				Romania	

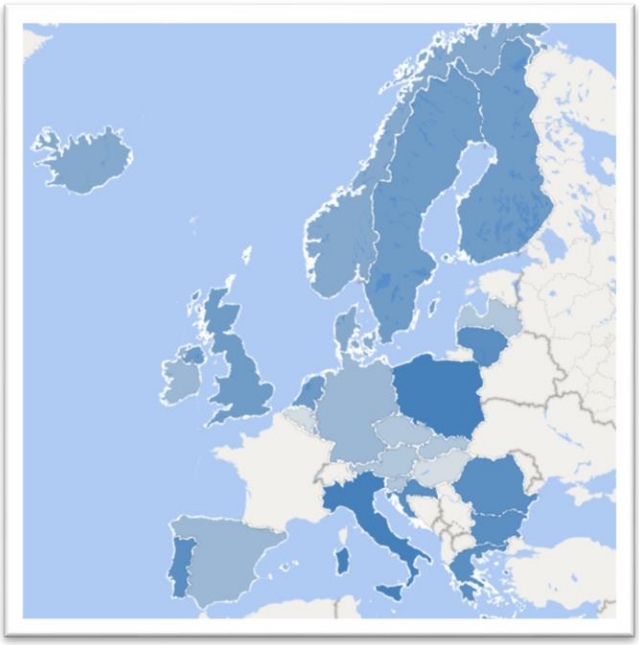

Fig 4. The groups of homogeneous development of the phenomenon - the selected European countries - 2020 - the Excel Map (based on own research)

For the year, 2019, the final clustering was comprised of seven groups.

Table 5: The groups of homogeneous development of the phenomenon – the selected European countries - 2019 (based on own research)

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Belgium Cyprus Malta	Czechia Spain Austria Ireland Estonnia Germany	Denmark Sweden United Kingdom Luxembourg Finland Netherlands	Norway Iceland	Bulgaria Greece Portugal Romania	Croatia Lithuania Slovakia Latvia Hungary	Italy Poland Slovenia

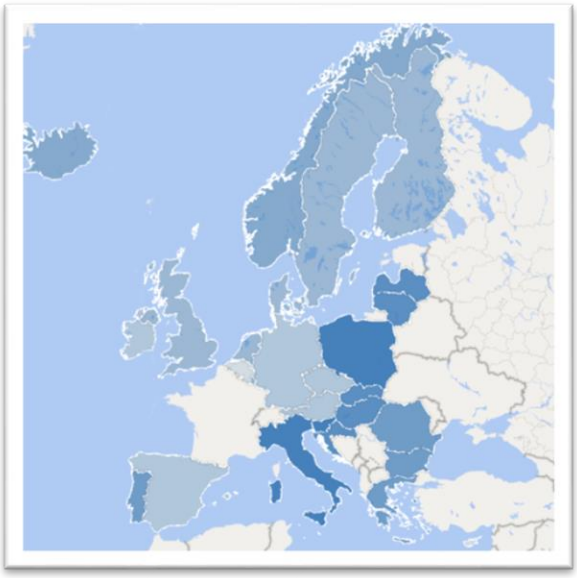

Fig 5*:* The groups of homogeneous development of the phenomenon - the selected European countries - 2019 - the Excel Map (based on own research)

For the last year, 2015, the final clustering was comprised of five groups.

Table 6: The groups of homogeneous development of the phenomenon – the selected European countries - 2015 (based on own research)

Group 1	Group 2	Group 3	Group 4	Group 5
Belgium	Czechia	Bulgaria	Denmark	Norway
Malta	Croatia	Romania	Sweden	Iceland
Ireland Spain	Slovenia	Greece	United	Luxembourg
Austria	Cyprus	Portugal	Kingdom	
Estonnia	Latvia	Lithuania	Netherlands	
Germany	Hungary	Italy	Finland	
	Slovakia	Poland		

Graphical presentation of the results:

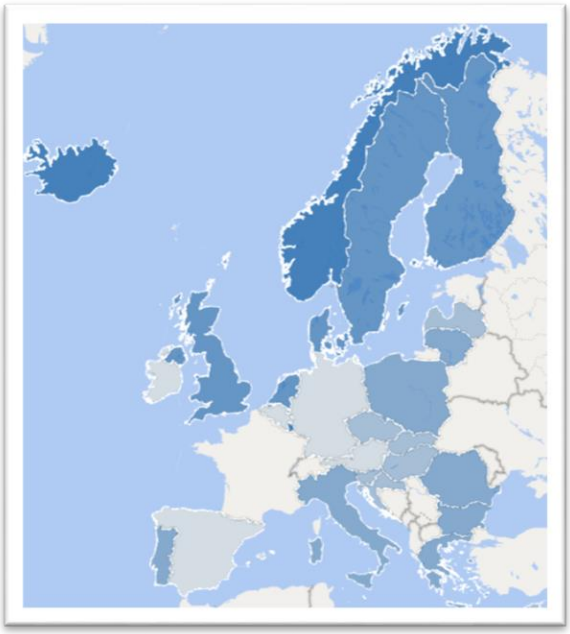

Fig. 6: The groups of homogeneous development of the phenomenon - the selected European countries - 2015 - the Excel Map (based on own research)

As far as the economic growth in the European countries is concerned, the fastest and the highest growth is observed in the Scandinavian countries. The richest European countries include Denmark, the Netherlands, Sweden, Luxembourg and Belgium. The poorer countries include Croatia, Bulgaria, Romania and Poland. In recent years, countries like Luxembourg, Denmark, Sweden, Germany and Finland had the highest percentage of households with Internet access. The group of countries with the lowest level of internet access includes Bulgaria, Greece, Romania.

The period homogeneous groups among the European countries are as follows (variables for Europe):

G_{1E}=(2010, 2011, 2012)

G_{2E}=(2013, 2014, 2015)

G_{3E}=(2016, 2017, 2018)

G_{4E}=(2019, 2020)

The last stage involved identifying development homogeneous groups for the US states in the selected years: 2019, 2015 (no data available for 2020).

Table 7: The groups of homogeneous development of the phenomenon – groups for the US states - 2019 (based on own research)

Group 1	Group 2	Group 3	Group 4	Group 5
Georgia	California	District of Columbia	Alaska	Alabama
Illinois	Florida	Hawaii	Arizona	Connecticut
Michigan	New York	Maine	Colorado	Arkansas
New Jersey	Texas	Montana	Indiana	Iowa
North Carolina		Nebraska	Maryland	Kansas
Ohio		New Hampshire	Massachusetts	Kentucky
Pennsylvania		New Mexico	Minnesota	Louisiana
Washington		North Dakota	Missouri	Mississippi

Virginia		Rhode Island	Tennessee	Nevada
		South Dakota	Wisconsin	Oklahoma
		Vermont Delavare		South Carolina
		West Virginia		Oregon
		Wyoming		Utah
		Idaho		

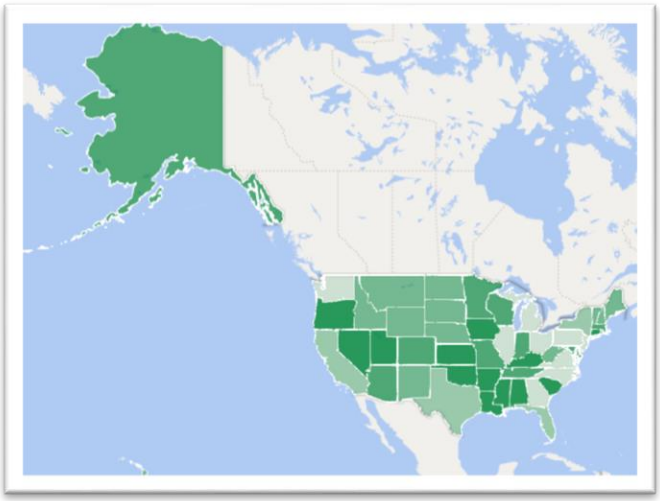

Fig. 7 The groups of homogeneous development of the phenomenon - groups for the US states -2019 - the Excel Map (based on own research)

For the last year, 2015, the final clustering was comprised of nine groups.

Table 8: The groups of homogeneous development of the phenomenon – groups for the US states - 2015 (based on own research)

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
Ohio	Virginia	New York	California	West Virginia	Hawaii	Maryland	Connecticut	Alabama
Pennsylvania	New Jersey	Texas		Nebraska	Rhode Island	District of Columbia	Mississippi	Arkansas
Illinois	Massachusetts	Florida		New Mexico	Montana	Missouri	Arizona	Oregon
	North Carolina			Idaho	Wyoming	Tennessee	Indiana	Louisiana
	Georgia			New Hampshire	Vermont	Alaska	Oklahoma	Kentucky
	Washington			Maine	North Dakota	Minnesota	Utah	South Carolina
	Michigan				South Dakota	Colorado	Nevada	
					Delavare	Wisconsin	Kansas	
							Iowa	

Graphical presentation of the results:

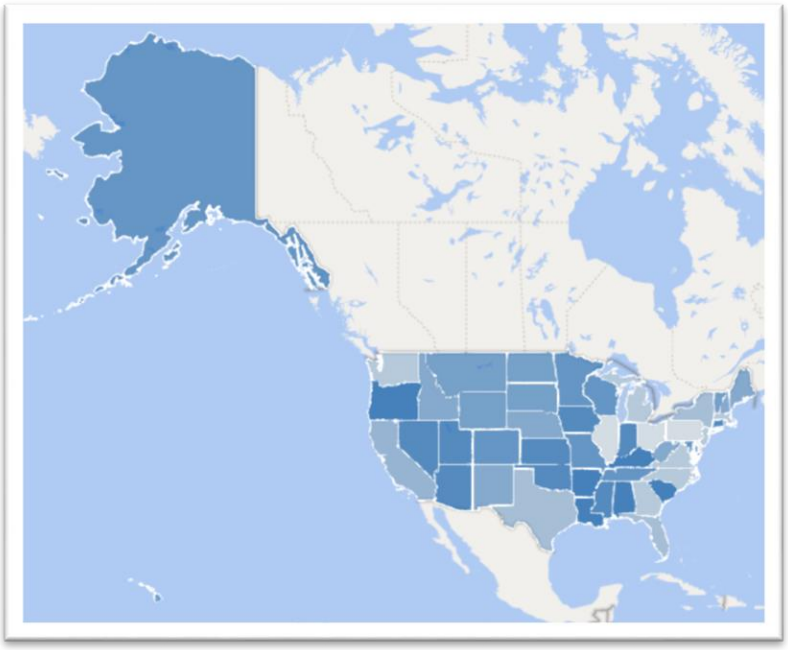

Fig 8. The groups of homogeneous development of the phenomenon - groups for the US states -2015 - the Excel Map (based on own research)

Alaska, Maryland, Calivornia, Massachusetts and New Jersey were classified in recent years as belonging to the wealthiest US states. Washington, for example, is the seat of big companies, such as Microsoft, Starbucks and Amazon. In California there are companies: Google and Facebook. The state of Maryland is famous for the development of the electrical industry. North Dakota, where shale gas and oil are extracted, is becoming a state with the lowest unemployment rate. The other rich US states are the District of Columbia, Connecticut, Hawaii, New Hampshire, Virginia, Minnesota, Washington, Utah, Colorado, Delaware, New York, Wyoming, Illinois, North Dakota, Rhode Island, Vermont, Pennsylvania, Wisconsin, and Texas. The poorest states are Maine, Montana and Arkansas, Idaho, Kentucky. Another state classified as a poor one is Alabama. Although it boasts a high rate of economic growth, resulting i.a. from the fact that three international auto companies, Honda, Hyundai and Mercedes-Benz, have located their factories there, Alabama still has a high unemployment rate. Rapid economic growth was recorded in Colorado, famous for marijuana cultivation.

The period homogeneous groups among the US states are as follows (variable for the US, years: 2015, 2016, 2017, 2018, 2019):

G_{1USA}=(2015, 2016, 2017)

G_{2USA} = (2018, 2019)

In the last step of the analysis, for each set of groups the intergroup and intragroup variance were calculated. Next, the differences between the intergroup and intragroup variance were calculated - each difference for particular groups was positive. The statistical significance of the differences was examined and thus it was confirmed that the groups are homogeneous and there is no need to further divide them.

Conclusions

In the present study, the taxonomic method discussed in the works of S. Chomątowski and A. Sokołowski (Chomątowski, Sokołowski, 1978), (Młodak, 2006), (Nowak, 1981) which estimates the level of variation of objects described by selected statistical characteristics and groups the objects according to the similarity of development of the examined phenomenon, to conduct an analysis of the internet and ICT use in the years 2010-2020, with special focus on the time of the Covid-19 pandemic. In the first stage of the analysis, Polish voivodeships were examined with regard to the phenomenon in question.

The groups of homogeneous development were identified for the years 2020, 2019 and 2015. The membership of groups G_1, G_2, G_3 did not change significantly in the period 2019, 2015 under study.

In the next step, the method was used again to compare Poland and the European countries, which involved determining groups of homogeneous development among the latter. In the years covered by the study, the Nordic countries always formed a separate group. They display a high level of the internet and ICT use.

The last stage of the analysis focused on the US states 2015, 2019. In the years considered, the groups include similar elements (states), but the number of groups is larger. Group 4 in 2015 is one-element (California), and in 2019 it formed Group 2 - (Florida, New York, Texas, California).

Next, the method was used to identify groups displaying homogeneous periods of development of the examined phenomenon for Poland, European countries and the USA. Among the groups that formed as a result of the analysis, there is a one-element group for the year 2020 or a two-element group for the years 2020, 2019. The groups include the time of the pandemic, which triggered an increase in the internet and ICT use. This is the time when remote work and online education entered our lives on a massive scale and a lot of people had to buy PCs or computer hardware, etc.

To sum up, the results of the analysis show that the homogeneous groups of Polish voivodeships with the highest level of the internet and ICT use form around the capital and big cities, which offer ample employment and educational opportunities. The lowest level can be observed in the groups comprising mainly rural areas. The analysis of the countries and the US states reveals that another factor affecting the level of internet and ICT use is economic development. Rich countries and states can afford to invest in new technologies, ensuring their citizens access to such solutions while companies and investors provide them with job opportunities. Efforts are made to advance medicine and allow access to new drugs, to protect the environment, which exerts an enormous influence on human health as well as to provide all kinds of facilities to the elderly and the people with disabilities. This leads to a society's improved standard of living, extended life span and successful fight against poverty and hunger. Obviously, it has to be remembered that although the internet and modern communication technologies are generally of benefit to the society, they present some inherent risk as well.

In sum, it can be said that the proposed method enabled comparison of the analysed phenomenon in selected countries. The results of this analysis allowed assessing similarity between the countries (for Polish provinces, the US states). Thus, they proved to be an effective tool to research the problem this article addresses.

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