European Research Studies Journal
Volume XXVIII, Issue 1, 2025

pp. 431-458

Comparative Assessment of E-Commerce Market Development in Poland and EU Countries: A Multi-Dimensional Analysis

Submitted 18/12/24, 1st revision 27/01/25, 2nd revision 18/02/25, accepted 28/02/25

Mariusz Pyra[1]

Abstract:

Purpose: *This paper presents a comparative assessment of the development of the e-commerce market in Poland against selected EU countries during 2017-2023. The main aim is to analyse the growth trajectory of the Polish e-commerce sector using the Taxonomic Measure of Development (TMD) and the Model-free Measure of Development (MMD), which allow a comparison of multiple variables between regions.*
Design/Methodology/Approach: *A comprehensive analysis was conducted to identify and analyze the key determinants affecting the development of e-commerce. These determinants include access to digital technologies, economic factors, and the use of the Internet in commercial activities. To construct TMD and MMD indicators, data from Eurostat and the Statista portal were utilized. This analysis enabled the positioning of Poland against other EU countries.*
Findings: *The findings indicate a dynamic development of the Polish e-commerce market from 2017 to 2023, although it still lags behind the leaders in the European Union. The application of taxonomic and model-free methods enabled a comparison of Poland's position with that of other EU countries, thereby identifying areas requiring further support and development.*
Practical Implications: *The article provides practical recommendations for policymakers and businesses, emphasizing pivotal factors influencing the competitiveness of Polish e-commerce within the EU single market. The identification of markets with analogous characteristics facilitates the formulation of strategies to enhance Poland's standing in relation to other nations.*
Originality/Value: *The article introduces a novel approach to the evaluation of e-commerce development in Poland by employing taxonomic and model-free methodologies. It provides a comprehensive set of analytical tools and actionable recommendations. Notably, the implementation of Ward's method facilitates the determination of the domestic market's position in relation to a historical benchmark.*

Keywords: *E-commerce, benchmarking, taxonomic measure, Hellwig's method.*

JEL Classification: *L81, F10, C38.*

Paper type: *Research article.*

[1]*Ph.D., Faculty of Economic Sciences, John Paul II University in Biala Podlaska, Poland, ORCID 0000-0001-8246-851X, m.pyra@dyd.akademiabialska.pl;*

1. Introduction

E-commerce has been instrumental in the digital transformation of the global economy for years, enabling businesses to expand their reach, reduce operating costs, and reach customers more effectively (Żurakowska-Sawa *et al.*, 2023; Pyra *et al.*, 2024; Bhanu Murthy *et al.*, 2021). According to OECD reports and industry publications, e-commerce has become one of the fastest-growing sectors of the digital economy, helping to reshape labor and consumption markets worldwide (OECD, 2022; UNCTAD, 2021; Ahi *et al.*, 2023). The importance of this sector was further accentuated during the course of the pandemic, as e-commerce became a predominant shopping channel in numerous countries (Zwanka *et al.*, 2020; Bâra *et al.*, 2023; Hayakawa *et al.*, 2021; Bhatti *et al.*, 2020).

In the extant literature, e-commerce is defined as the process of selling and buying goods or services via the Internet and other digital technologies. Its relevance is measured at both the microeconomic and macroeconomic levels. The theoretical underpinnings for the analysis of e-commerce development include the concepts of digital infrastructure (Xiao *et al.*, 2011), technology adoption in businesses (Simakov, 2020), and the dynamics of digital consumption (Fan *et al.*, 2018). The increase in the number of internet users, the availability of sales platforms, and the development of logistics services are key determinants of e-commerce market development (Mangiaracina *et al.*, 2015).

The Polish e-commerce market, despite its dynamic growth, lags behind more developed EU economies in terms of market value and share of business turnover. According to Eurostat data, between 2017 and 2022, Poland recorded an increase in e-commerce turnover of more than 148%, making it one of the leaders in terms of dynamics in the CEE region. However, Poland's position falls outside the top five most developed e-commerce markets in the EU, indicating the presence of significant development barriers, including logistics infrastructure, limited digital competence among some segments of the population, and high inflation (Lawrence *et al.*, 2010).

Taxonomic measures for assessing development and synthetic measures, such as the model-free measure of development, are extensively employed in academic literature to comparatively analyze countries' e-commerce positions in a relative manner. The Hellwig method, which serves as the foundation of taxonomic analysis, facilitates the identification of stimulants and destimulants of development by considering a wide range of diagnostic variables (Sompolska-Rzechuła, 2020). This approach finds application in comparative analyses across numerous fields, including e-commerce research.

Analyses performed using the aforementioned metrics have proven to be of considerable value in the study of the development of the e-commerce sector in countries such as Poland. The Polish market is distinguished by dynamic expansion;

however, it is concomitantly beset by challenges including inadequate digital infrastructure and limited capital resources (Levytska *et al.*, 2024).

The present study aims to analyze the development trajectory of the Polish e-commerce market with a view to its position in the rankings of EU countries. It presents comparative results using selected metrics and analyzes the impact of factors such as digital competence, consumer spending, and infrastructure availability. The article contributes to the development of research on e-commerce dynamics, offering both analytical tools and practical recommendations for policymakers and businesses.

The basis of the study is not only to determine a ranking of countries in terms of e-commerce development, but also an attempt to identify groups of markets with similar characteristics. Such a taxonomic analysis is important from the perspective of creating strategies to strengthen Poland's competitiveness within the EU single market. Moreover, the use of clustering methods, such as Ward's method, allows for a deeper understanding of the dynamics and differentiation of market development.

Numerous academic studies have underscored the significance of e-commerce within the digital economy, particularly in terms of its impact on economic growth and market transformation. These studies have highlighted the crucial role of digital infrastructure, technological competence, and regulatory frameworks in shaping the dynamics of this sector. According to Rostow's theory of economic modernization, technological development constitutes a pivotal element in the transition to higher stages of economic growth, a notion corroborated by research on e-commerce (Anwari *et al.*, 2024; Lund *et al.*, 2005; Yang *et al.*, 2023).

Hellwig has proposed the taxonomic measure of development as a benchmarking tool that plays a central role in the evaluation of complex economic systems (Roszkowska, 2024). In the context of e-commerce, this method facilitates the determination of synthetic indicators from multidimensional data, a feature that renders it particularly useful in the study of digital development. Empirical studies on the impact of digital infrastructure on the growth of e-commerce constitute a significant segment of the extant literature. These studies indicate that access to high-speed internet, the level of digitization of businesses, and the development of logistics are pivotal determinants of growth in this sector (Yang *et al.*, 2023; Saeed, 2023; Criveanu, 2023).

Another aspect that has been thoroughly examined in the extant literature is the role of public policy in shaping the e-commerce ecosystem (Viu-Roig *et al.*, 2020). A substantial body of research indicates that regulations pertaining to consumer protection, taxes, and transaction security are pivotal in fostering trust in this sector (Costa *et al.*, 2021; Agrawal *et al.*, 2020; Tofan *et al.*, 2022; Rosário *et al.*, 2021).

Studies that focus on consumer behavior and its impact on market structure are also an integral part of e-commerce research. Research by Brynjolfsson and Smith (2001) suggests that a key reason for the growth of e-commerce is that it is becoming easier for both consumers and businesses to use. Lower transaction costs, the availability of a wide range of products, and the ease of comparing offers encourage faster adoption of e-commerce technology across different social groups. The extant literature also emphasizes the importance of personalization of offers, which enables the use of recommendation algorithms, fostering customer loyalty and increasing their engagement in online shopping (Huang *et al.*, 2013).

Studies on the development of e-commerce on a national scale in Poland use a variety of analysis methods, including synthetic indicators and cluster methods (Wasilewski *et al.*, 2024). Comparative analysis using taxonomic methods enables the identification of key differences in the level of development between regions (Akter *et al.*, 2016; Klóska *et al.*, 2020; Jędrzejczak-Gas *et al.*, 2019). Such studies demonstrate that disparities in regional development across nations, including Poland, are predominantly attributable to the extent of digital infrastructure availability and the engagement of local businesses in the digital transformation process (Luo *et al.*, 2023; Kozlov *et al.*, 2021; Kinal, 2022).

When assessing the evolution of the e-commerce market in Poland in the context of EU countries, it is imperative to refer to several pivotal studies and reports that furnish detailed data and trends in this domain. Specifically, the "Decade of Polish e-commerce" report (2023) highlights the accelerated growth of the Polish e-commerce market, which surpassed PLN 100 billion in the B2C sector in 2020 and reached PLN 850 billion in 2022, encompassing both B2C and B2B (IGE, 2023). This substantial expansion can be attributed to evolving consumer behaviors and the proliferation of m-commerce. Consequently, Poland is positioned as a leader in Europe with regard to the rate of e-commerce development (Polish…, 2024).

Another important source is the report "E-commerce in Poland 2024," which analyzes consumer behavior and shopping trends. It is worth noting that the percentage of e-consumers in Poland has stabilized at around 78%, while the popularity of shopping in foreign shops has increased significantly. The report also emphasizes the increasing popularity of BLIK payments and expeditious transfers, which are crucial for understanding the payment preferences of Polish consumers (Gemius, 2024).

Furthermore, the 2024 report, published by Trade.gov.pl, underscores the resilience of the Polish e-commerce market in the face of macroeconomic challenges, such as inflation and economic slowdown. Projections for the ensuing years signal the continuation of this growth trajectory, propelled by the advancement of mobile commerce and intensifying competition (Polish…, 2024). These statistics are pivotal for the evaluation of the competitive landscape of the Polish e-commerce market in relation to other European Union nations.

In the context of analysing the development of the e-commerce market in Poland, it is worth referring to the application of the Taxonomic Measure of Development (TMD) and the Model-free Measure of Development (MMD) in studies on the e-commerce sector. TMD, developed by Hellwig, is often used to assess the level of economic development of regions, which allows a synthetic evaluation of various aspects of development, such as ICT infrastructure or availability of electronic services (Kompa, 2014; Łogwiniuk, 2011). In e-commerce analyses, TMD can be used to compare the level of development of e-commerce plat-forms in different regions of Poland, enabling the identification of areas with the greatest potential for development.

The MMD is an analytical tool that allows linear ordering of objects on the basis of standardised characteristics, which is particularly useful in comparative analyses between different EU countries (Miłek *et al.*, 2021). The MMD enables an objective assessment of the situation of the studied object by unifying the results of the measurement, which is crucial in assessing the competitiveness of the Polish e-commerce market against other EU countries. The synthetic value of the MMD takes values in the range (0,1), where a higher value of the index indicates a more favourable situation of the object. The results of BMR linear ordering are often used to classify objects into homogeneous groups, which allows for a better understanding of the differentiation between the studied entities (Łogwiniuk, 2011).

The literature review indicates that the development of e-commerce is a multifaceted phenomenon, requiring the consideration of both technological and socio-economic factors. Theories of economic development, taxonomic methods and the results of empirical studies provide a solid basis for the analysis and interpretation of data on the Polish e-commerce market in an international context. The use of a variety of research methods in combination with quantitative data and qualitative data makes it possible not only to assess the development to date, but also to forecast future trends in this sector.

2. Materials and Methods

The present study is based on data regarding the development of the e-commerce sector in Poland and selected EU countries from 2017 to 2022. In order to analyse the dynamics and structure of the market, a combination of statistical data from publicly available databases and taxonomic methods and synthetic measures was utilised.

The underlying statistics were sourced from Eurostat databases and the Statista portal, which provided information on key diagnostic variables relating to society, businesses and economic factors. The data set encompassed a range of metrics, including the level of Internet access in households and businesses, the number of individuals utilising the Internet for online purchases and sales, e-commerce

turnover, inflation and unemployment levels, and the structure of household expenditure.

The selection of data was conducted with a focus on the completeness of the sets and the comparability between countries in the years encompassed by the analysis. In instances where missing data were encountered, methodologies such as the utilisation of neighbouring values (e.g., linear interpolation) or the imputation of the preceding year's value were employed.

The selection of diagnostic variables for analysis comprised 17 potential factors, which were categorised as stimulants (factors that exert a positive influence on development) or destimulants (factors that exert a negative influence on development), as illustrated in Table 1.

Table 1. *A list of potential e-commerce development indicators*

Factor	**Name**	**Type of impact**
x1	Persons having used the Internet to purchase goods or services in the last 12 months (% of total)	S
x2	Persons using the Internet to sell goods or services (% of total)	S
x3	People who have never used the Internet (% of total population)	D
x4	Level of Internet access in households (% of total)	S
x5	People with basic or higher general digital skills (% of total)	S
x6	Working people at risk of poverty (% of persons aged 18 and over)	D
x7	Total unemployment	D
x8	Companies that received online orders (at least 1% of turnover) (% of total)	S
x9	E-commerce turnover in total company turnover (%)	S
x10	Internet access by size class of enterprise (1 person employed or more)	S
x11	E-commerce sales of e-commerce businesses (10 employees and more) (% of total)	S
x12	E-commerce sales (total turnover) (10 persons and more) (% of total)	S
x13	Broadband Internet coverage (coverage) by speed (over 30 Mbps) (% of all households)	S
x14	Gross domestic product at market prices (EURO per capita)	S
x15	Household expenditure on consumption related to: housing/home, water, electricity, gas and other fuels (% of total expenditure)	D
x16	Inflation rate (HICP) (%)	D
x17	Percentage of population aged 25-49 (% of total)	S

Source: *Own study.*

The statistical verification of the variables was conducted with respect to the coefficient of variation, with the selection of characteristics for analysis being limited to those where the coefficient of variation, Vx, exceeded a threshold of

10%. However, due to the low value of the coefficient, some variables were subsequently excluded from further analysis:

• x4 - starting in 2018, Vx is below 10%,
• x10 - over the whole analysed time interval Vx of the variable is below 10%,
• x13 - from 2021, Vx is below 10%,
• x17 - over the whole analysed time interval Vx of the variable is below 10%.

From the considered set of potential indicators of e-commerce development, two (x10 and x17) were eliminated from all time periods and a further two (x4 and x13) in selected time periods. This means that the assessments in subsequent years will be based on a variable number of indicators. This should be kept in mind when comparing results. The remaining variables can be regarded as diagnostic variables.

A transformation of destimulants into stimulants was carried out, using the following formula:

$$x_{ij} = \frac{1}{x_{ij}}$$

The next step was to analyse the correlation between the factors that remained in the following years in the group of e-commerce development indicators. Based on this, it was determined that:

1) Data for 2017 (no x1 variables) -> correlation above 0.7 variables: x2 with x4; x3 with x4; x8 with 8x; x8 with x11; x8 with z12; x9 with x11; x9 with x12 (very strong); x11 with x12.
2) Data for 2018 (no variables x1, x5) -> correlation above 0.7 variables: x8 with x9; x8 with x11; x8 with x12; x9 with x11; x9 with x12 (very strong); x11 with x12.
3) Data for 2019 (no variables x1, x5) -> correlation above 0.7 variables: x3 with x4; x4 with x14; x8 with x9, x8 with x11, x8 with x12; x9 with x11, x9 with x12 (very strong); x11 with x12.
4) Data for 2020 (no variables x1, x5) -> correlation above 0.7 variables: x1 with x2, x1 with x4; x8 with x11; x9 with x12.
5) Data for 2021 -> correlation above 0.7 variables: x1 with x4, x1 with x5, x1 with x9, x1 with x12; x2 with x5; x4 with x14, x8 with x11, x9 with x12.
6) Data for 2022 (no variable x5) -> correlation above 0.7 of variables: x1 with x9, x1 with x12; x8 with x11, x9 with x12.
7) Data for 2023 -> correlation above 0.7 variables: x1 with x2; x1 with x5; x1 with x9, x1 with x12; x3 with x4, x3 with x14; x8 with x11, x9 with x12.

The preceding analysis provides a foundation for the assertion that correlations between variables undergo alterations to a certain extent with the passage of time (across successive periods). Nevertheless, certain variables demonstrate a persistent correlation with one another, irrespective of the period under consideration.

This observation lends support to the proposition that these variables should be considered for exclusion from subsequent calculations, as they contribute identical (in the case of strong correlation) or highly similar information. The following proposals have been put forward for the elimination of these variables:

1) x9 or x12 - both variables correlate strongly with each other in all periods (elimination of variable x12).
2) x8 or x11 - variable x8 in a review of all periods appears to have more correlations with other variables than variable x11 (elimination of variable x8).
3) x1 with x2, x4, x5, x9 - this correlation is subject to change from one analysis period to the next. This is because the variable relates to a specific measurement (online shopping in the last 12 months). The x1 variable, which is a candidate for elimination, remains, as it appears to bring additional information relative to the variables with which it correlates.

The above variables are eliminated in all models in each analysis period. Three complementary methods were used for the analysis:

Taxonomic Measure of Development - Hellwig's method to determine synthetic development indicators for each country in a given year based on distance from a benchmark. The benchmark values were based on the maximum values of the variables in the years analysed. It was therefore assumed that the synthetic measure of development in each dimension would be of the form (for each dimension):

$$d_{it} = 1 - \frac{q_{it}}{\bar{q}_t + 2 * S_{qt}}$$

The synthetic measure adopted in this manner will take values in the range (0; 1). The closer its value in a given area is to unity, the more similar the assessed area is to the adopted benchmark.

In the case of the Hellwig method, the maximum values of each variable in a given period were used as a benchmark. Consequently, the benchmark presents the best performance among EU countries in a given year in the cross-section for each of the factors analysed.

Consequently, the aforementioned benchmark is regarded as the most optimal 'country' performing within the EU.The ranges for the classification of individual countries on the basis of the values of the taxonomic development index (hi) were determined as the values of the four quantiles (0%, 33.3%, 66.7% and 100% quantiles from the numerical values) for the set of all hi values across all the years analysed.

Model-free Development Measure - a synthetic measure based on the arithmetic mean of standardised variables, allowing for a linear ordering of countries. It is described by the formula:

$$h_i = \frac{1}{p}\sum_{j=1}^{p} x_{ij}$$

The synthetic value of the MMD measure is always in the range (0,1), with higher values indicating a more favourable situation for the object under assessment.

The ranges for the classification of individual countries on the basis of the values of the taxonomic development index (hi) were determined as the values of the four quantiles (0%, 33.3%, 66.7% and 100% quantiles from the numerical values) for the set of all hi values across all the years analysed.

Ward's method - is a technique using analysis of variance that is used to estimate the distance between clusters. The distance between clusters is defined as the modulus of the difference between the sums of the squares of the distances of the points from the centres of the groups to which these points belong, and is described by the following formula:

$$D_{12} = \sqrt{\frac{2.|k|.|l|}{|k|+|l|}}.\|\bar{x}-\bar{y}\|$$

The Ward's method analysis was conducted utilising the R language in conjunction with the requisite libraries. All data were standardised in accordance with the Z-score formula to facilitate the comparability of variables that differed in units of measurement. The standardisation of the variable values was accomplished using the following formula:

$$\mathbf{z_{ij}} = \frac{\mathbf{x_{ij}} - \bar{\mathbf{x}}_\mathbf{j}}{\mathbf{S_j}}$$

Furthermore, a correlation analysis was conducted with the objective of eliminating highly correlated variables, which could result in redundancy within the models.

3. Results

According to Hellwig's concept, the MMD and Ward's method were employed to arrange all countries in a linear sequence according to their degree of e-commerce development (characterised by the emerged characteristics).

3.1 The Taxonomic Measure of Development by Z. Hellwig

The TMD was utilised to ascertain the hi values of all EU countries, with these values serving as a benchmark for the EU27 average. A ranking was established for each year of the analysis, based on the determined values for all years and the year 2023. The country with the highest hi value was assigned the highest ranking, with the lowest value determining the lowest ranking, as illustrated in Table 2.

Table 2. *E-commerce development ranking 2017-2023*

Country	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
European Union	23	23	22	6	4	11	6
Belgium	8	8	8	11	14	15	12
Bulgaria	9	9	9	5	18	12	15
Czech Republic	2	2	5	20	20	4	11
Denmark	6	4	1	19	28	27	28
Germany	24	24	24	18	19	26	23
Estonia	16	20	16	1	11	2	3
Ireland	18	17	20	25	13	13	17
Greece	19	18	19	3	6	3	19
Spain	10	12	11	28	9	23	16
France	28	28	28	17	2	24	4
Croatia	20	16	17	26	23	21	21
Italy	11	11	12	9	26	14	26
Cyprus	14	13	13	12	3	16	5
Latvia	3	3	4	10	10	17	8
Lithuania	5	5	3	23	15	6	9
Luxembourg	27	27	26	22	21	28	14
Hungary	15	19	15	14	27	19	27
Malta	17	15	18	2	17	1	22
Netherlands	22	22	23	24	8	5	1
Austria	13	14	14	8	22	9	10
Poland	26	26	27	15	7	25	20
Portugal	21	21	21	16	12	22	18
Romania	7	6	7	27	1	20	2
Slovenia	12	10	10	4	24	7	24
Slovakia	1	1	2	7	25	8	25
Finland	4	7	6	13	5	18	7
Sweden	25	25	25	21	16	10	13

Source: *Own study.*

The resulting ranking indicates that Poland was not among the top three countries in any of the analysed periods. In 2017 and 2018, it ranked 26th, and in 2019, it ranked 27th, falling below the EU average and achieving the lowest rank. However, in 2020, there was a notable improvement, with Poland ranking 15th, an improvement of 12 positions from the previous year. A further improvement in 2021 saw Poland achieve 7th position.

However, between 2022 and 2023, Poland's position in the ranking declined once more, with a 25th-place ranking in 2022 and a 20th-place ranking in 2023.It is important to note that the aforementioned ranking is conducted within the context of a group of EU countries, with the average ranking for the entire EU serving as a reference point. This relative ranking indicates that fluctuations in the ranking do not necessarily imply a deterioration in the situation of e-commerce development in Poland in absolute terms; rather, they signify a relatively weaker rating within the group of EU countries.

3.2 The Model-Free Measure of Development

The MMD was utilised to ascertain the di values for all EU countries, with the EU27 average serving as a benchmark. The values for all years included in the analysis, along with the year 2023, were considered in the determination of a ranking for each year. The country with the highest di value was assigned the highest ranking, with the lowest value determining the lowest ranking, as illustrated in Table 3.

Table 3. *E-commerce development ranking 2017-2023*

Country	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
European Union	12	13	14	13	14	14	15
Belgium	10	12	7	9	11	11	11
Bulgaria	25	23	25	28	28	28	28
Czech Republic	19	17	19	10	9	7	7
Denmark	4	3	5	1	1	1	2
Germany	2	2	4	4	7	9	8
Estonia	11	9	12	11	13	12	12
Ireland	13	8	11	8	3	4	4
Greece	28	27	28	24	23	22	23
Spain	17	19	16	16	15	15	16
France	5	11	8	7	8	10	9
Croatia	6	7	10	21	22	23	22
Italy	23	22	24	26	26	26	26
Cyprus	26	28	26	23	24	25	24
Latvia	22	21	23	20	19	20	20
Lithuania	24	24	22	22	21	21	21
Luxembourg	14	15	15	5	5	5	5
Hungary	20	20	18	19	16	13	14
Malta	3	4	3	15	17	16	17
Netherlands	1	1	1	2	2	2	1

Austria	16	18	20	12	18	17	13
Poland	15	16	17	18	20	18	19
Portugal	21	25	21	25	25	24	25
Romania	27	26	27	27	27	27	27
Slovenia	9	14	13	14	12	19	18
Slovakia	18	10	9	17	10	8	10
Finland	7	5	2	6	6	6	6
Sweden	8	6	6	3	4	3	3

Source: *Own study.*

Utilising a synthetic measure of development devoid of a benchmark, Poland does not feature within the top three in any of the analysed periods, including 2023.In the ranking based on the MMD method, Poland's position appears to be more stable in the analysed period (there is minimal change).

In 2017, Poland is ranked 15th, and in the subsequent four years its position undergoes a gradual deterioration. In 2018, it was ranked 16th, and in 2019, it was ranked 17th. Finally, in 2020, it was ranked 18th, and in 2021, it was ranked 20th, which is the lowest reading in the entire analysis period. In 2022, Poland's position in the ranking was 18th, and in 2023 it was 19th. Throughout the analysis period, Poland's ranking was below the EU average.

3.3 Comparison of TMD and MMD Rankings

The subsequent stage of the research will involve an analysis of the alterations in ranking positions that have been caused by the method that has been utilised to ascertain the level of e-commerce development.In the context of 2017, the smallest discrepancy in ranking position was 3, and the largest was 23. In this context, the most notable countries were the Netherlands (TMD (22) vs. MMD (1)), Germany (TMD (24) vs. MMD (2)), and France (TMD (28) vs. MMD (5)).

In the 2018 rankings, the difference in ranking position was reduced to 1, with the largest disparity remaining at 22. In this context, the most outstanding countries were Germany TMD (24) vs MMD (2), the Netherlands TMD (22) vs MMD (1) and Romania TMD (6) vs MMD (26).The example of Romania demonstrates that discrepancies between TMD and MMD can also occur in the other direction (i.e. TMD is not always higher than MMD).

A similar observation was made when comparing rankings for the period 2019-2020, during which the smallest observed difference in ranking position was 1 and the largest was 22. In this context, the most notable countries were the Netherlands TMD (23) vs. MMD (1), Germany TMD (24) vs. MMD (4), and France TMD (28) vs. MMD (8).

In 2020, the smallest observed difference in ranking position was 1, while the largest was 23. In this context, the most notable cases were Bulgaria TMD (5) vs. MMD (28), the Netherlands TMD (24) vs. MMD (2), and Greece TMD (3) vs. MMD (24).

It is evident that several countries stand out for the significant disparity between their positions in the two rankings, a phenomenon that is replicated in subsequent years (Germany, France, the Netherlands).An analysis of subsequent years will substantiate this observation.

In 2021, the smallest observed difference in ranking position was 0, while the largest was 27, indicating the widest range of disparities to date. In this context, the most outstanding countries were Denmark - TMD (28) vs MMD (1), Romania TMD (1) vs MMD (27) and Cyprus TMD (3) vs MMD (24).

In the context of 2022, the smallest difference in ranking position was 2 and the largest was 26. In this context, the most outstanding countries were Denmark TMD (27) vs MMD (1), Luxembourg TMD (28) vs MMD (5) and Greece TMD (3) vs MMD (22).

The last year included in the analysis was 2023, in which the smallest difference in ranking position was 0 and the largest difference was 26. The most distinguished countries were Denmark TMD (28) vs. MMD (2), Romania TMD (2) vs. MMD (27), and Cyprus TMD (5) vs. MMD (24).

The observation of repeated countries with the highest divergence in rankings was not confirmed, and the TOP 3 countries with the largest difference in rankings changed over the period of analysis, especially in the last years. However, there is some repetition over a 2-year period (e.g. 2022 and 2023 or 2017-2018).

The results of ordering the EU countries by degree of e-commerce development according to the selected variables (usually 13), using both linear methods, proved to be divergent.

A further comparison within the context of Poland itself is that of its position in the TMD and MMD rankings in relation to the EU27 average. In the context of both the TMD and MMD rankings, Poland ranked above the EU27 ranking. However, a correlation of changes in ranking positions between the EU27 and Poland can be observed in subsequent years of analysis.

This indicates that a change in the EU17 ranking position was accompanied by a corresponding change in Poland's ranking position. While both rankings show that, in the period 2017-2019, changes seem to preserve the proportion, in subsequent periods, changes in Poland's ranking position were more dynamic, especially in the context of the TMD ranking.

Between 2017 and 2019, Poland exhibited a similar reaction to the EU27 (EU average) in terms of changes in its ranking position, suggesting that the proportion in the context of changes (in this case, improvement) in the values of the examined factors shaping e-commerce development is analogous to the analogous changes for the EU27.

However, subsequent years witnessed an augmentation in the proportion, as Poland exhibited a more gradual decline in its position within the TMD ranking when compared to the EU27 (wherein one or more countries demonstrated a more expeditious enhancement in their factor values than Poland).Notably, in 2021, the scenario mirrored that of 2017, with regard to the extent of divergence between the EU27 and Poland's ranking positions. However, between 2022 and 2023, the divergence between the rankings of Poland and the EU27 increased, though the overall convergence of the trend was maintained.

In the context of the MMD ranking, only the period 2019-2022 saw a slight widening of the gap between Poland's and the EU27's ranking positions. However, the direction of these changes remained consistent throughout the observed period.

The aforementioned observations suggest that Poland's position in the TMD and MMD rankings generally mirrors that of the EU27, with the exception of a delay in the improvement or deterioration of its ranking. Consequently, it can be concluded that Poland, in terms of the analysed factors that shape e-commerce development, exhibits a behaviour akin to that of the entire EU27. However, given the levels of these indicators, it exhibits a lag in comparison to the EU27, consequently resulting in an average performance that is below the EU average.

3.4 Grouping Based on Synthetic Measure Values

The subsequent phase of the analysis entailed the establishment of groups, predicated on the values of the synthetic indicators of the degree of e-commerce development, as determined by the TMD and MMD methodologies.

Table 4. *Number of countries in each class based on synthetic TMD index (hi) for 2017-2023*

Class boundaries				2017	2018	2019	2020	2021	2022	2023
Class 3	0,277	<= hi <	0,309	7	5	6	15	10	11	12
Class 2	0,31	<= hi <	0,379	8	10	9	7	10	11	10
Class 1	0,38	<= hi <	0,605	13	13	13	6	8	6	6

Source: *Own study.*

As illustrated in Table 4, the classification criterion (ranges of values of the calculated hi indicator within the TMD) is presented, along with the number of facilities included in the class in the subsequent years of analysis. The first group contained the sites with the highest values of the synthetic measure of development

(TMD) of e-commerce in the entire group of countries studied. During the 2017-2019 period, this group constituted the largest, comprising 13 countries each, as illustrated in Table 5.However, from 2020 onwards, a discernible shift in the size of this group becomes evident, characterised by a decline, thereby favouring a more equitable distribution of numbers across the remaining groups.

This observation provides a compelling rationale for concluding that a substantial shift in the development of e-commerce has occurred in certain countries in 2020 and beyond. This shift is characterised by the influence of specific factors that have contributed to this development. Some countries have enhanced the values of the examined factors to a considerable extent, resulting in a significant outperformance of others and a subsequent relegation to lower groups.

Table 5. *Country classification into synthetic TMD index (hi) groups for 2017-2023*

Country	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
European Union	Class 3	Class 2	Class 2	Class 1	Class 1	Class 2	Class 1
Belgium	Class 1	Class 1	Class 1	Class 2	Class 2	Class 2	Class 2
Bulgaria	Class 1	Class 1	Class 1	Class 1	Class 2	Class 2	Class 2
Czech Republic	Class 1	Class 1	Class 1	Class 3	Class 3	Class 1	Class 2
Denmark	Class 1	Class 1	Class 1	Class 3	Class 3	Class 3	Class 3
Germany	Class 3	Class 3	Class 3	Class 3	Class 3	Class 3	Class 3
Estonia	Class 2	Class 2	Class 2	Class 1	Class 2	Class 1	Class 1
Ireland	Class 2	Class 2	Class 2	Class 3	Class 2	Class 2	Class 3
Greece	Class 2	Class 2	Class 2	Class 1	Class 1	Class 1	Class 3
Spain	Class 1	Class 1	Class 1	Class 3	Class 2	Class 3	Class 2
France	Class 3	Class 3	Class 3	Class 3	Class 1	Class 3	Class 1
Croatia	Class 2	Class 2	Class 2	Class 3	Class 3	Class 3	Class 3
Italy	Class 1	Class 1	Class 1	Class 2	Class 3	Class 2	Class 3
Cyprus	Class 2	Class 1	Class 1	Class 2	Class 1	Class 2	Class 1
Latvia	Class 1	Class 1	Class 1	Class 2	Class 2	Class 2	Class 2
Lithuania	Class 1	Class 1	Class 1	Class 3	Class 2	Class 1	Class 2
Luxembourg	Class 3	Class 3	Class 3	Class 3	Class 3	Class 3	Class 2
Hungary	Class 2	Class 2	Class 2	Class 3	Class 3	Class 3	Class 3
Malta	Class 2	Class 2	Class 2	Class 1	Class 2	Class 1	Class 3
Netherlands	Class 3	Class 2	Class 3	Class 3	Class 1	Class 1	Class 1
Austria	Class 1	Class 2	Class 2	Class 2	Class 3	Class 2	Class 2
Poland	Class 3	Class 3	Class 3	Class 3	Class 1	Class 3	Class 3
Portugal	Class 2	Class 2	Class 2	Class 3	Class 2	Class 3	Class 3
Romania	Class 1	Class 1	Class 1	Class 3	Class 1	Class 3	Class 1
Slovenia	Class 1	Class 1	Class 1	Class 1	Class 3	Class 2	Class 3
Slovakia	Class 1	Class 1	Class 1	Class 2	Class 3	Class 2	Class 3
Finland	Class 1	Class 1	Class 1	Class 2	Class 1	Class 3	Class 2
Sweden	Class 3	Class 3	Class 3	Class 3	Class 2	Class 2	Class 2

Source: *Own study.*

An analogous classification was carried out for the synthetic indicators of the e-commerce development measure according to the MMD method. The class ranges are summarised in Table 6, together with the size of the groups in the following years.

Table 6. *Number of countries in each class based on synthetic MMD index (di) for 2017-2023*

Class boundaries				2017	2018	2019	2020	2021	2022	2023
Class 3	0	<= di <	0,363	13	14	13	6	5	6	9
Class 2	0,364	<= di <	0,645	9	4	9	12	11	11	9
Class 1	0,646	<= di <	1	6	10	6	10	12	11	10

Source: *Own study.*

The size of class one for MMD fluctuated between 6 and 10 countries between 2017 and 2020, representing the second most numerous class during this period. In contrast, following 2020, there was an increase in class size, with it eventually reaching a level of 10. A similar increase in class 2 was observed between 2020 and 2023, as illustrated in Table 7.

Consequently, all available evidence suggests that 2020 was a pivotal year in the assessment of e-commerce development in EU countries. The findings indicate a substantial increase in both class 1 and class 2, suggesting an enhancement in the degree of e-commerce development as measured by the variables studied and the methods employed.

Table 7. *Country classification into synthetic MMD index (di) groups for 2017-2023*

Country	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
European Union	Class 2	Class 2	Class 2	Class 2	Class 2	Class 2	Class 2
Belgium	Class 2	Class 2	Class 2	Class 1	Class 1	Class 1	Class 2
Bulgaria	Class 3	Class 3	Class 3	Class 3	Class 3	Class 3	Class 3
Czech Republic	Class 3	Class 3	Class 3	Class 1	Class 1	Class 1	Class 1
Denmark	Class 1	Class 1	Class 1	Class 1	Class 1	Class 1	Class 1
Germany	Class 1	Class 1	Class 1	Class 1	Class 1	Class 1	Class 1
Estonia	Class 2	Class 1	Class 2	Class 2	Class 2	Class 2	Class 2
Ireland	Class 2	Class 1	Class 2	Class 1	Class 1	Class 1	Class 1
Greece	Class 3	Class 3	Class 3	Class 3	Class 2	Class 2	Class 3
Spain	Class 3	Class 3	Class 3	Class 2	Class 2	Class 2	Class 2
France	Class 1	Class 2	Class 2	Class 1	Class 1	Class 1	Class 1
Croatia	Class 1	Class 1	Class 2	Class 2	Class 2	Class 3	Class 3
Italy	Class 3	Class 3	Class 3	Class 3	Class 3	Class 3	Class 3
Cyprus	Class 3	Class 3	Class 3	Class 3	Class 3	Class 3	Class 3
Latvia	Class 3	Class 3	Class 3	Class 2	Class 2	Class 2	Class 3
Lithuania	Class 3	Class 3	Class 3	Class 2	Class 2	Class 2	Class 3
Luxembourg	Class 2	Class 3	Class 2	Class 1	Class 1	Class 1	Class 1
Hungary	Class 3	Class 3	Class 3	Class 2	Class 2	Class 2	Class 2
Malta	Class 1	Class 1	Class 1	Class 2	Class 2	Class 2	Class 2

Netherlands	Class 1	Class 1	Class 1	Class 1	Class 1	Class 1	Class 1
Austria	Class 3	Class 3	Class 3	Class 2	Class 2	Class 2	Class 2
Poland	Class 2	Class 3	Class 3	Class 2	Class 2	Class 2	Class 2
Portugal	Class 3	Class 3	Class 3	Class 3	Class 3	Class 3	Class 3
Romania	Class 3	Class 3	Class 3	Class 3	Class 3	Class 3	Class 3
Slovenia	Class 2	Class 2	Class 2	Class 2	Class 1	Class 2	Class 2
Slovakia	Class 3	Class 1	Class 2	Class 2	Class 1	Class 1	Class 1
Finland	Class 2	Class 1	Class 1	Class 1	Class 1	Class 1	Class 1
Sweden	Class 2	Class 1	Class 1	Class 1	Class 1	Class 1	Class 1

Source: *Own study.*

The findings of the study, which were grouped by TMD and MMD-based methods, revealed a marked increase in the domain of e-commerce development in EU countries following 2020. However, the analysis indicated that this growth was not uniformly distributed across all EU countries, with some nations demonstrating faster development than others. This has resulted in a comparatively disadvantaged position for the remaining countries in both the ranking and the comparisons.

A comparison of the TMR-based and MMD-based groupings reveals a lower abundance of the top class in the former, thereby confirming the earlier observation of a more dynamic development in certain countries, relatively more than the rest of the EU. This suggests that not all countries have taken full advantage of the opportunities created by the COVID-19 pandemic for e-commerce.

The final element is a comparison of the affiliation to the specified classes of individual countries across the years analysed and the method used to synthetically measure the degree of e-commerce development. In 2017, 25 differences in class affiliations were recorded, but only for Denmark (class 1), Estonia (class 2) and Ireland (class 2), classification according to TMD and MMD values gave analogous class affiliations. For the remaining countries, the affiliations were quite different, often reversed. In 2018, there were slightly fewer differences in class affiliations, with 22.

This time, the group of countries with unchanged class affiliations included: EU27 (class 2), Denmark (class 1), Luxembourg (class 3), Poland (class 3), Slovakia (class 1) and Finland (class 1). For the remaining countries, the affiliations were quite different, sometimes reversed. In 2019, 21 differences in class affiliations were recorded. The group of countries with unchanged class affiliations included: EU27 (class 2), Denmark (class 1), Estonia (class 2), Ireland (class 2), Poland (class 3) and Finland (class 1).

A similar situation to that in 2018 was observed in 2020, when the number of discrepancies was more than 21; this time, it was 23. The group of countries with unchanged class membership included Latvia (class 2), Austria (class 2), Portugal (class 3), Romania (class 3) and Slovakia (class 2).In 2021, the number of changes was

19. The group of countries with unchanged class membership included: Estonia (class 2), Spain (class 2), France (class 1), Italy (class 3), Lithuania (class 2), Malta (class 2), the Netherlands (class 1) and Finland (class 1).

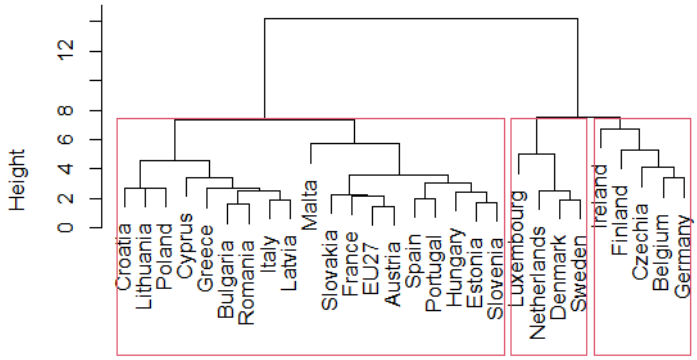
In 2022, the number of changes was also 19, and the group of countries with unchanged class membership included: EU27 (class 2), the Czech Republic (class 1), Croatia (class 3), Latvia (class 2), the Netherlands (class 1), Austria (class 2), Portugal (class 3), Romania (class 3), and Slovenia (class). In 2023, the number of discrepancies between classification into one of the three groups, based on TMD and MMD values, was also 19. The group of countries with unchanged class membership included: Belgium (class 2), Greece (class 3), Spain (class 2), France (class 1), Croatia (class 3), Italy (class 3), the Netherlands (class 1), Austria (class 2) and Portugal (class 3).

3.5 The Ward Method

The Ward method is a distinct clustering technique that falls under the category of agglomerative methods. It is widely regarded as the most efficacious approach for generating homogeneous clusters, and in this context, it is employed to form groups. To ensure the comparability of this method with the preceding ones, the clustering process is undertaken under the premise of delineating three distinct groups.

As illustrated in Figure 1, the Ward method's grouping dendrogram for the year 2017 highlights these three groups. The first group (counting from the left) is designated group A, the second group is group B, and the last group is group C. These have been compared with the classification (classes) derived from the TMD and MMD methods. It is evident that in 2017, the classification by Ward's method does not coincide with the classes groups of the TMD and MMD methods. Group A is the most numerous, comprising 19 countries, and thus outnumbering the most numerous TMD and MMD classes. Furthermore, even in terms of content, groups B and C do not overlap with the less numerous TMD and MMD classes.

Figure 1. *E-commerce market clusters of EU countries in 2017*



Source: *Own study.*

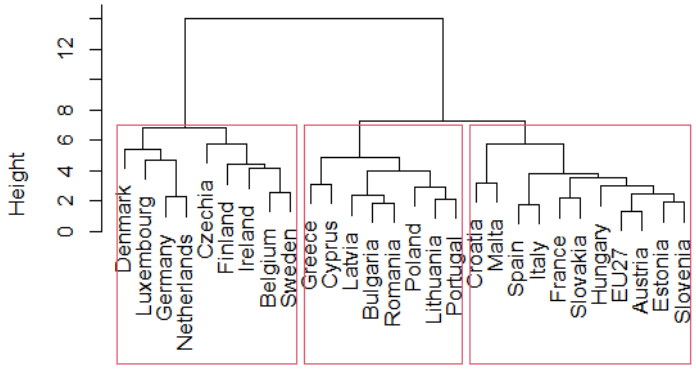
Ward's classification system places Poland in group A, which comprises Croatia and Lithuania (the two countries are deemed to be most similar to each other). Conversely, Poland is positioned in TMD class 3, which encompasses countries such as France and the EU27, who are also classified in Ward's group A. The remaining countries in TMD class 3 fall outside of Ward's group 1, yet are situated within their respective subgroups (e.g., Ward's group B and subgroup: Netherlands - Denmark/Sweden). This finding indicates that Ward's grouping exhibits a higher level of focus on similarities, as compared to the TMD-based grouping, which is believed to be the root cause of the observed discrepancies in the assessments.

Within the context of MMD-based grouping, disparities between this method and Ward's are also evident. Poland is categorised in MMD-based grouping as class 2, which encompasses countries falling within Ward's group A, such as the EU27, Estonia, and Slovakia. This finding indicates that the level of similarity is comparable to that observed in the TMD and Ward comparison.

Figure 2 presents the Ward clustering dendrogram for 2018, with the three groups highlighted. It is evident that the groups appear to be more balanced in terms of object abundance. A subsequent comparison with the classification (classes) derived from the TMD and MMD methods will be made. This comparison reveals that, according to Ward's classification, Poland was placed in group B, which includes Lithuania and Portugal as the closest countries, as well as Romania, Bulgaria, Latvia, Cyprus and Greece. Group B thus contains a total of eight countries.

In the TMD classification, Poland was placed in group 3, and none of the countries included in this group were in Ward's group B. On the other hand, in the case of the classification based on the TMD, Poland was placed in class 3 with 13 other countries. The recurring countries from Ward's classification (group B) are: Greece, Cyprus, Lithuania, Latvia, Bulgaria, Romania, and Portugal. It is evident that there is a substantial overlap between MMD group 3 and Ward's group B.

Figure 2. *E-commerce market clusters of EU countries in 2018*

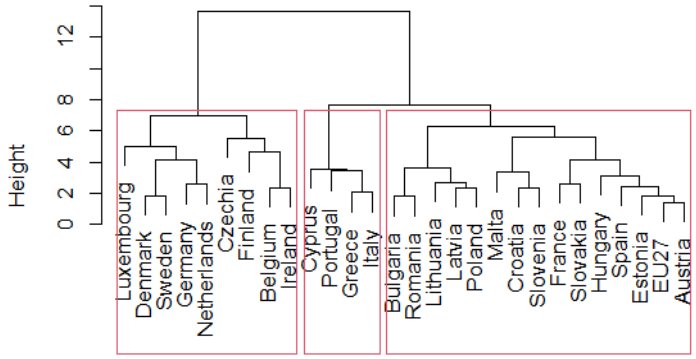


Source: *Own study.*

As illustrated in Figure 3, Poland's 2019 classification places it in group C, alongside 14 other countries. This group constitutes a direct subgroup, with Latvia being the immediate predecessor, followed by Lithuania, Bulgaria and Romania. A comparison with the TMD-based classification, in which Poland is positioned in group 3 with five other countries, reveals a clear divergence in the two classifications.

France is the only member of the TMD group 3 that appears in Ward's group C.In contrast, when the classification is based on the MMD, where Poland is in group 3 with 12 other countries, the discrepancy is reduced.The countries in Ward's group C and in MMD group 3 are Bulgaria, Spain, Lithuania, Latvia, Hungary, Austria and Romania. This finding indicates a persistent discrepancy between the Ward classification and both the TMD and MMD classifications.

Figure 3. *E-commerce market clusters of EU countries in 2019*

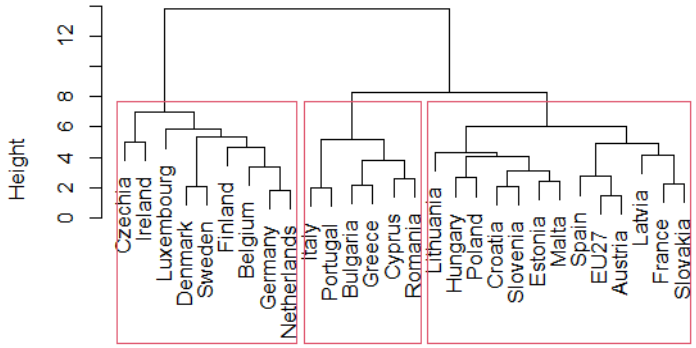


Source: *Own study.*

As illustrated in Figure 4, Poland's 2020 classification places it in group C, alongside 12 other countries. This group constitutes a direct subgroup with Hungary, followed by Croatia, Slovenia, Estonia and Malta. In comparison to the TMD-based classification, in which Poland is positioned in group 3 with 14 countries, the disparities between the classifications appear to be less pronounced than in previous years. The TMD group 3 includes Spain, France, Croatia, Lithuania and Hungary, and these countries are also part of Ward's group C.

A comparison of the classification based on MMD reveals that Poland is in group 2 with 11 other countries, indicating reduced discrepancies. Ward's group C and MMD group 2 consist of the EU27, Estonia, Spain, Croatia, Lithuania, Latvia, Hungary, Malta, Austria, Slovenia and Slovakia, indicating an overlap between the groups. For both the Ward method and the MMD method, Poland is positioned in the same group.

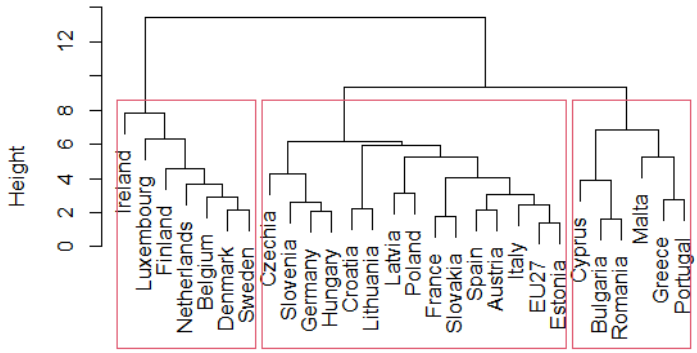
Figure 4. *E-commerce market clusters of EU countries in 2020*



Source: *Own study.*

Ward's classification for 2021 is illustrated in Figure 5, where Poland is positioned in group B with 14 other countries. This group constitutes a direct subgroup with Lithuania, followed by France, Slovakia, Spain, Austria, Italy, EU27 and Estonia. In comparison to the TMD-based classification, where Poland is in group 1 with 7 countries, the discrepancy between the classifications appears to be significant once more. The TMD group 1 includes EU27 and France, which are part of Ward's group B.

Figure 5. *E-commerce market clusters of EU countries in 2021*



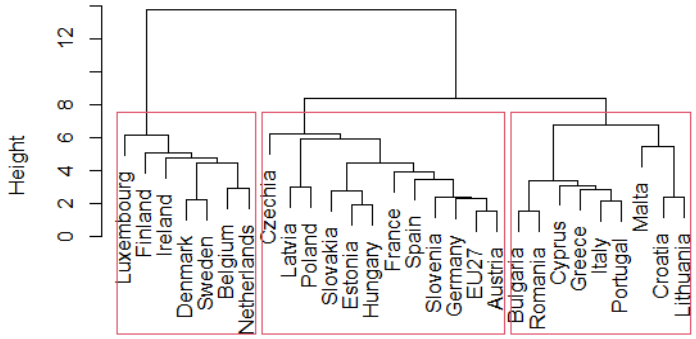
Source: *Own study.*

A comparison of the classification based on MMD, in which Poland is positioned in Group 2 with 10 other countries, reveals reduced discrepancies. Within Ward's group B and MMD group 2, the countries include the EU27, Estonia, Spain, Croatia, Lithuania, Latvia, Hungary, and Austria. There is substantial overlap between these groups. For the Ward method and the MMD method in the group encompassing Poland, the disparities are minimal.

The Ward classification for 2022 is illustrated in Figure 6, where Poland is designated group B with 11 other countries. It forms a direct subgroup with

Lithuania, followed by the Czech Republic and the other countries in the group. In comparison to the TMD-based classification, in which Poland is in group 3 with 10 countries, significant discrepancies in the classifications occur. Notably, within the TMD group 3, Germany, Spain, France and Hungary are positioned in Ward's group B.

Figure 6. *E-commerce market clusters of EU countries in 2022*



Source: *Own study.*

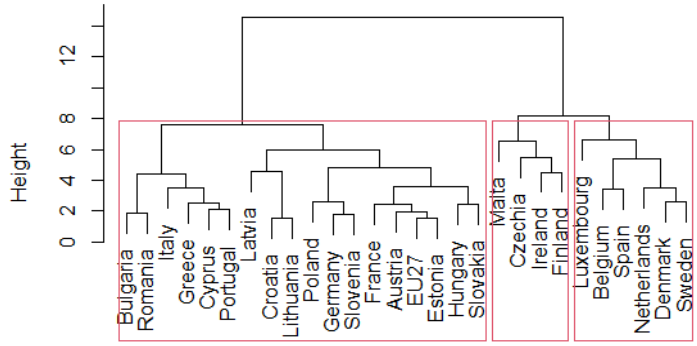
A comparison of the classification based on MMD, in which Poland is positioned in Group 2 alongside 10 other countries, reveals reduced discrepancies. Within Ward's Group B and MMD Group 2, the countries include the EU27, Estonia, Spain, Latvia, Hungary, Austria, and Slovenia, indicating substantial overlap between these groups. Notably, the differences between the Ward method and the MMD method in the aforementioned group are minimal.

The Ward classification for 2023 is illustrated in Figure 7, where Poland is positioned in Group A alongside 17 other countries. This group constitutes a direct subgroup, with Germany and Slovenia, followed by France, Austria, the EU27, Estonia, Hungary and Slovakia. In comparison to the TMD-based classification, in which Poland is placed in Group 3 with 11 countries, the discrepancy between the two classifications is minimal.

Notably, within TMD group 3, Germany, Greece, Croatia, Italy, Hungary, Portugal, Slovenia and Slovakia are classified in Ward's group B. The disparities between the Ward method and the TMD-based approach are marginal in both the group containing Poland and the group comprising TMD group 3.

A comparison of the classification based on MMD reveals that Poland is in group 2 with eight other countries, thus demonstrating greater discrepancies. Within Ward's group A and MMD group 2, the countries EU27, Estonia, Hungary, Austria and Slovenia are included. It is evident that in the group where Poland is located, the differences are medium and larger than in the TMD vs Ward case.

Figure 7. *E-commerce market clusters of EU countries in 2023*



Source: *Own study.*

4. Discussion

A study of the development of the e-commerce market in Poland between 2017 and 2022 indicates dynamic growth in this sector, although this growth remains below the average for the European Union. Similar observations have been made in the literature, which emphasises that, despite intensive development, the Polish e-commerce market still has potential for further expansion (Pyra *et al.*, 2024).

The employment of TMD in the study facilitated a comparison of Poland's position with that of other EU countries, with the results indicating that Poland occupies the lowest rank in the ranking. This finding is consistent with earlier analyses that emphasised the challenges confronting the Polish e-commerce market, such as the necessity to develop logistics infrastructure and to enhance consumer confidence in online shopping (Pieczarka, 2019).

The MMD analysis confirmed that Poland, despite a significant improvement in e-commerce indicators, is still in the group of countries with an average level of development. These results are consistent with previous studies on e-commerce in EU countries, which showed that the markets of Central and Eastern Europe are characterised by high growth rates, but their overall level of development still lags behind leaders such as Germany, the Netherlands or France.

An analysis by CMI shows that in 2020, the e-commerce market in Eastern Europe grew at a rate of 36%, and in Central Europe at 28%, which is significantly higher than in Western Europe, where the growth rate was only 4% (Analysis…, 2023). Notwithstanding this observed momentum, certain Central and Eastern European countries, including Poland, Romania and the Czech Republic, continue to exhibit a relative underperformance in terms of their overall development levels when benchmarked against more advanced Western markets (European…, 2023).

Additionally, a report by Autopay underscores that Europe's most substantial e-commerce markets, such as those in the UK, France and Germany, are estimated to possess an aggregate value of €93 billion, thereby signifying a notable competitive edge for these nations over their CEE counterparts (What…, 2019). It is important to note that Central and Eastern European markets, despite their dynamic growth, continue to face challenges related to low levels of competition and limited local product availability, which negatively impacts their competitiveness against more developed markets (Analysis…,2023).

5. Conclusions

A further comparison of the synthetic assessments of the development of Polish e-commerce in 2017-2022 can be made by summarising them. However, it is first necessary to convert Ward's grouping results into numerical groups, as in the case of TMD and MMD.For this purpose, the following assumption is made:

1) Group A corresponds to class 1;
2) Group B corresponds to class 2;
3) Group C corresponds to class 3.

Utilising the aforementioned approach, the results of the Ward method grouping were transformed and compared on one graph with the scores in the TMD and MMD methods. It is evident that the initial and final periods exhibit analogous situations in terms of the classification of the degree of development by individual methods.

During the period of the most dynamic development of Polish e-commerce (in terms of turnover value dynamics), Poland generally falls into class 3, which is not the highest rating. From 2020 to 2022, Poland appears to have stabilised its rating, maintaining class 2. The MMD method appears to offer greater stability in Poland's classification, as it is less subject to change. Furthermore, a transition to a 'superior class' appears to be associated with the growth of the e-commerce market in terms of turnover value.

The TMD classification appears to be more responsive to environmental changes (i.e. among the compared countries) in the case of Poland from the perspective of its classification based on the value of the synthetic measure of development thus determined. The dynamic growth of e-commerce in Poland resulted in its swift ascent to the 'best class', followed by a rapid reversion to its original position in class 3.

The MMD classification exhibited a stronger correlation with the Ward method than with the TMD method. This renders it challenging to ascertain a clear winner among the methods. None of the employed classifications or approaches demonstrated a clear advantage over the others. Furthermore, the results obtained do not converge to such an extent as to warrant recommending one approach over another as the most

advantageous, i.e. incorporating the strengths of each and additional benefits (informational or efficiency from the point of view of calculation and data collection). All the approaches used appear to be interlinked and therefore to some extent complementary, a statement that is most valid especially in the context of a classification based on the Ward method.

The method complements the outcomes of the TMD and MMD techniques by not indicating the absolute distance from the objects being compared, but rather highlighting the closest similar objects and identifying the most similar entities. This may be particularly significant in the context of historical 'success case' analyses of e-commerce markets, which are currently more developed than the Polish market and, for specific reasons (structure, regulations, efficiency, etc.), may be regarded as a model to emulate.

Ward's method facilitates the determination of the temporal discrepancy between the home market and the historical benchmark market. This, in turn, enables the identification of the actions taken by the benchmark market that led to its current level of development. These actions can then be replicated in an adapted form within the domestic market.

It is imperative to acknowledge that both the TMD and MMD methods yield remarkably substantial insights concerning the relative advancement of the domestic market. The TMD method appears particularly adept at facilitating comparisons that prioritise ranking, focusing on a limited timeframe or a circumscribed context. This is due to its capacity to provide a compelling comparison to current peak performance in specific domains (maximum values of variables within a designated group of comparator countries).

Nevertheless, it should be noted that the TMD method does not engage in direct comparison with real entities, but rather with an ideal benchmark. This highlights inequalities between entities, which may be attributed to the inherent characteristics of each market. In contrast, the MMD method appears to be more beneficial in long-term perspectives, such as Poland's position in the EU internal market. By comparing entities within a given group, it focuses on competitive advantages from the perspective of the examined variables. Consequently, it may provide the foundation for formulating plans and actions with a longer timeframe.

It is important to note that none of the methods used can constitute a stand-alone basis for ranking or strategy. At most, it can be an element of the procedures for controlling the effects of the applied strategy or be an element of diagnostics. The application of methods based on the TMD or MMD approach is derived from the choice of diagnostic data (the variables under study). Consequently, methods should invariably be contemplated within the purview of the variables encompassed within the assessment, with greater import placed on the selection of variables than on the method itself.

References:

Agrawal, D.R., Fox, W.F. 2017. Taxes in an e-commerce generation. International Tax and Public Finance, 24, 903-926. https://doi.org/10.1007/s10797-016-9422-3.

Ahi, A.A., Sinkovics, N., Sinkovics, R.R. 2023. E-commerce Policy and the Global Economy: A Path to More Inclusive Development? Management International Review, 63, 27-56. https://doi.org/10.1007/s11575-022-00490-1.

Akter, S., Wamba, S.F. 2016. Big data analytics in E-commerce: a systematic review and agenda for future research. Electron Markets, 26, 173-194. https://doi.org/10.1007/s12525-016-0219-0.

Analysis of E-commerce in Central and Eastern Europe. 2023. Available: https://www.logistyczny.com/aktualnosci/glos-z-rynku/item/8018-analiza-e-commerce-w-europie-srodkowo-wschodniej.

Anwari, R.D., Norouzi, D. 2016. The impact of e-commerce and R&D on economic development in some selected countries. Procedia - Social and Behavioral Sciences, 229, 19, 354-362. https://doi.org/10.1016/j.sbspro.2016.07.146.

Bâra, A., Oprea, S.V., Bucur, C., Tudorică, B.G. 2023. Unraveling the Impact of Lockdowns on E-commerce: An Empirical Analysis of Google Analytics Data during 2019-2022, J. Theor. Appl. Electron. Commer. Res., 18(3), 1484-1510. https://doi.org/10.3390/jtaer18030075.

Bhanu Murthy, K.V., Kalsie, A., Shankar, R. 2021. Digital economy in a global perspective: is there a digital divide? Transnational Corporations Review, 13, 1, 1-15. https://doi.org/10.1080/19186444.2020.1871257.

Bhatti, A., Akram, H., Basit, H.M., Khan, A.U., Naqvi, S.M.R., Bilal, M. 2020. E-commerce trends during COVID-19 Pandemic. International Journal of Future Generation Communication and Networking, 13, 2, 1449-1452.

Costa, J., Castro, R. 2021. SMEs Must Go Online-E-Commerce as an Escape Hatch for Resilience and Survivability, J. Theor. Appl. Electron. Commer. Res., 16, 3043-3062. https://doi.org/10.3390/jtaer16070166.

Criveanu, M.M. 2023. Investigating Digital Intensity and E-Commerce as Drivers for Sustainability and Economic Growth in the EU Countries. Electronics, 12, 2318. https://doi.org/10.3390/electronics12102318.

European E-commerce market overview 2023. 2023. Available: https://autopay.pl/baza-wiedzy/blog/ecommerce/przeglad-europejskiego-rynku-ecommerce-2023.

Fan, J., Tang, L., Zhu, W., Zou, B. 2018. The Alibaba effect: Spatial consumption inequality and the welfare gains from e-commerce. Journal of International Economics, 114, 203-220. https://doi.org/10.1016/j.jinteco.2018.07.002.

Gemius, E-commerce in Poland 2024. Available: https://gemius.com/documents/66/RAPORT_E-COMMERCE_2024.pdf.

Hayakawa, K., Mukunoki, H., Urata, S. 2021. Can E-commerce mitigate the negative impact of COVID-19 on international trade? The Japanese Economic Review, 74, 215-232. https://doi.org/10.1007/s42973-021-00099-3.

Huang, Z., Benyoucef, M. 2013. From e-commerce to social commerce: A close look at design features. Electronic Commerce Research and Applications, 12, 4, 246-259. https://doi.org/10.1016/j.elerap.2012.12.003.

IGE. 2023. A decade of Polish e-commerce. E-Izba Report 2013-2023. Available: https://eizba.pl/wp-content/uploads/2023/02/Raport_e-Izby_Dekada_polskiego-e-commerce_2023.pdf.

Jędrzejczak-Gas, J., Barska, A. 2019. Assessment of the Economic Development of Polish Regions in the Context of the Implementation of the Concept of Sustainable Development - Taxonomic Analysis. European Journal of Sustainable Development, 8, 5, 222. https://doi.org/10.14207/ejsd.2019.v8n5p222.

Kinal, J. 2022. Peculiarities of e-commerce development: a case of Poland. Entrepreneurship and Sustainability Issues, 9, 3, 50-63. https://doi.org/10.9770/jesi.2022.9.3(3).

Klóska, R., Ociepa-Kicińska, E., Czyżycki, R., Szklarz, P. 2020. Regional Development in Poland in Taxonomic Terms. Sustainability, 12, 4780. https://doi.org/10.3390/su12114780.

Kompa, K. 2014. Application of taxonomic measures to evaluation of the European stock exchanges financial efficiency. Quantitative Methods in Economics, XV, 4, 52-61.

Kozlov, A., Kankovskaya, A., Teslya, A., Kalkowska, J., Vlodarkievicz-Klimek, H. 2021. The dynamics of the level of regional business digitalization: comparative study of Russia and Poland, DTMIS' 20: Proceedings of the International Scientific Conference - Digital Transformation on Manufacturing. Infrastructure and Service, 34, 1-5. https://doi.org/10.1145/3446434.344652.

Lawrence, J.E., Usman, A.T. 2010. Barriers to e-commerce in developing countries. Information, Society and Justice, 3, 1, 23-35. https://doi.org/10.4018/978-1-4666-2791-8.ch010.

Levytska, S., Demianiuk, R. 2024. E-commerce in Poland and Ukraine: development and challenges. Management and Administration Journal, 60, 133. https://doi.org/10.34739/zn.2023.60.06.

Lund, M.J.F., McGuire, S. 2005. Institutions and development: electronic commerce and economic growth, Organization Studies, 26, 12, 1743-1763. https://doi.org/10.1177/0170840605059149.

Luo, C., Wei, D., Su, W., Lu, J. 2023. Association between Regional Digitalization and High-Quality Economic Development, Sustainability, 15, 1909. https://doi.org/10.3390/su15031909.

Łogwiniuk, K. 2011. The use of taxonomic methods in the comparative analysis of the access to the ICT infrastructure by schoolchildren in Poland. Economy and Management, 1, 7-23.

Mangiaracina, R., Marchet, G., Perotti, S., Tumino, A. 2015. A review of the environmental implications of B2C e-commerce: a logistics perspective. International Journal of Physical Distribution & Logistics Management, 45, 6, 565-591. https://doi.org/10.1108/IJPDLM-06-2014-0133.

Miłek, D., Nowak, P. 2021. Development of public analysis services in Poland against the background of the European Union. Social Inequalities and Economic Growth, 65. DOI:10.15584/nsawg.2021.1.3.

OECD. 2022. Digital Economy Outlook. Paris, OECD Publishing.

Pieczarka, K. 2019. Conditions of the Development of Electronic Commerce in Poland. Research Papers of Wroclaw University of Economics and Business, 7, 63, 92-102. DOI:10.15611/pn.2019.7.08.

Polish e-commerce market in 2024-2028. 2024. Available: https://www.trade.gov.pl/wiedza/polski-rynek-e-commerce-w-latach-2024-2028.

Pyra, M., Skruibyte, I., Kaspariene, J. 2024. Development of the Polish E-Commerce Market in Comparison to Selected EU Countries. European Research Studies Journal, vol. XXVII, issue 4, 571-583. DOI: 10.35808/ersj/3535.

Rosário, A., Raimundo, R. 2021. Consumer Marketing Strategy and E-Commerce in the Last Decade: A Literature Review. J. Theor. Appl. Electron. Commer. Res., 16, 3003-3024. https://doi.org/10.3390/jtaer16070164.

Roszkowska, E. 2024. A Comprehensive Exploration of Hellwig's Taxonomic Measure of Development and Its Modifications - A Systematic Review of Algorithms and Applications. Appl. Sci., 14, 10029. https://doi.org/10.3390/app142110029.

Saeed, S. 2023. A Customer-Centric View of E-Commerce Security and Privacy. Appl. Sci., 13, 1020. https://doi.org/10.3390/app13021020.

Simakov, V. 2020. History of formation of e-commerce enterprises as subjects of innovative entrepreneurship. Three Seas Economic Journal, 1, 1, 84-90. https://doi.org/10.30525/2661-5150/2020-1-12.

Smith, M.D., Brynjolfsson, E. 2001. Consumer Decision-making at an Internet Shopbot: Brand Still Matters, The Journal of Industrial Economics, 49, 4, 541-558. https://doi.org/10.1111/1467-6451.00162.

Sompolska-Rzechuła, A. 2020. Application of linear object ordering to assess economic activity of the population by provinces. The Polish Statistician, 65, 3, 46-61. DOI: 10.5604/01.3001.0014.0456.

Tofan, M, Bostan, I. 2022. Some Implications of the Development of E-Commerce on EU Tax Regulations. Laws, 11, 13. https://doi.org/10.3390/laws11010013.

UNCTAD. 2022. E-commerce and Digital Economy Programme Year in Review 2021: Bridging the digital readiness divide. UNCTAD Publications.

Viu-Roig, M., Alvarez-Palau, E.J. 2020. The Impact of E-Commerce-Related Last-Mile Logistics on Cities: A Systematic Literature Review. Sustainability, 12, 6492. https://doi.org/10.3390/su12166492.

Wasilewski, A., Juszczyszyn, K., Suryani, V. 2024. Multi-factor evaluation of clustering methods for e-commerce application. Egyptian Informatics Journal, 28. https://doi.org/10.1016/j.eij.2024.100562.

What does the e-commerce market look like in Europe? - Emerging markets. 2019. Available: https://blog.arvato.pl/wschodzace-rynki-e-commerce-w-europie.

Xiao, B., Benbasat, I. 2011. Product-Related Deception in E-Commerce: A Theoretical Perspective. MIS Quarterly, 35, 1, 169-195. https://doi.org/10.2307/23043494.

Yang, Y., Chen, N., Chen, H. 2023. The Digital Platform, Enterprise Digital Transformation, and Enterprise Performance of Cross-Border E-Commerce-From the Perspective of Digital Transformation and Data Elements, J. Theor. Appl. Electron. Commer. Res., 18, 777-794. https://doi.org/10.3390/jtaer18020040.

Yang, L. Liu, J., Yang, W. 2023. Impacts of the Sustainable Development of Cross-Border E-Commerce Pilot Zones on Regional Economic Growth. Sustainability, 15, 13876. https://doi.org/10.3390/su151813876.

Zwanka, R., Buff, C.L. 2020. COVID-19 Generation: A Conceptual Framework of the Consumer Behavioral Shifts to Be Caused by the COVID-19 Pandemic. Journal of International Consumer Marketing, 33, 1, 58-67. https://doi.org/10.1080/08961530.2020.1771646.

Żurakowska-Sawa, J., Pyra, M. 2023. Conditions for the Growth of Cross-Border E-commerce in Poland. European Research Studies Journal, vol. XXVI, issue 3, 496-508. DOI: 10.35808/ersj/3227.