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THE LEVEL OF LIVING IN EUROPEAN UNION COUNTRIES IN 2013-2022 BY THE APPLICATION OF TAXONOMIC METHODS

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Purpose: The purpose of this paper is to demonstrate the trend and extent of changes in the level of living in EU countries in 2013-2022.
Design/methodology/approach: Two examination methods were applied for the set of multidimensional objects, namely linear ordering in dynamic terms and grouping by similarity of diagnostic features. Using the linear ordering method, a synthetic variable was determined covering 7 selected indicators describing the level of living, on the basis of which the level of living in EU countries in 2013 and 2022 was compared. Groups of countries having similar values of the adopted indicators were selected on the basis of fuzzy classification, and then the trend and extent of changes in the value of those indicators in the analysed period was compared for the respective groups of countries. The research was carried out on the basis of Eurostat.
Findings: The data confirms gaps in the level of living across EU countries that have persisted for years. Belgium, Luxembourg and the Netherlands significantly outperform the other countries in terms of the level of living. The lowest level of living persists in Bulgaria, Estonia, Greece, Croatia, Latvia, Lithuania and Romania. In all the countries, the level of living indicator grew in the analysed period, but the extent of the change was uneven. Malta and Ireland, followed by Hungary, Czechia, Poland and Slovenia saw the biggest improvement in this respect.
Research limitations/implications: A limitation in the research process is the lack of availability of the full database. If full data availability is obtained, research can be conducted on a wider set of diagnostic variables.
Practical implications: What outcomes and implications for practice, applications and consequences are identified? How will the research impact upon the business or enterprise? What changes to practice should be made as a result of this research? What is the commercial or economic impact? Not all papers will have practical implications.
Social implications: The European Union is made up of countries that vary greatly in terms of the level of living of their populations, and the convergence of those difference is one of the main priorities of the EU policy, which justifies the need for the research discussed in this paper.
Originality/value: Research using two methods, especially the dynamic approach, allowed obtaining a more complete picture of changes in the standard of living in EU countries.

The dynamic approach allows, in addition to creating rankings, quantification of changes in the analysed phenomenon over time.
Keywords: EU countries, level of living, linear ordering method, fuzzy classification.
Category of the paper: Research paper.

1. Introduction

The level of living is a complex notion, affected by many factors, such as the level of economic development, the labour market situation (unemployment rate, poverty risk), the infrastructure level (transport availability), safety and security, living conditions and health protection, environmental protection.

The primary determining factor for the level of living is the economic standing of a given country, with the GDP value (per capita) underlying the improvement in the level of living. Countries with a high GDP enjoy a high level of living, while a low GDP is reflected by a low level of living.

Another important factor in the analysed phenomenon is the labour market situation, since it decides on the income of the population, hence translating into the level of living. Aspects of broadly understood unemployment are among vital topics of each country's social policy. This results both from problems associated with unemployment as such (increase in social dissatisfaction or increased budgetary burden), and problems that may arise from its presence (Kłos, Tomaszewska, 2014).

Poverty means that certain needs cannot be satisfied at a desirable level. In terms of social perception, poverty is understood as the lack of sufficient funds, or the absence of affluence. In most general terms, poverty can be defined as a condition of falling below a certain income level, variable over time, or below a certain threshold of satisfying needs of a person, family, or social group (Biernat-Jarka, Trębska, 2018). Therefore, the poverty indicator is an important component of the synthetic variable describing the level of living of a given country's residents.

An important metric of the level of living of the population is also the number of rooms per person. An apartment purchase is an expensive investment, and so that indicator reflects the affluence level of a given society. Housing conditions affect all citizens at each moment of their lives. An apartment is seen as an asset that satisfies basic needs. It also serves the purpose of satisfying needs of a higher level (security, affiliation, recognition, self-fulfilment).

Another constituent of the population's level of living is the transportation network. Development of an ever-more efficient transportation system and ensuring that it can develop steadily, and improvement in the form and methods of its operation, stimulates the social and economic development of the country, thus significantly affecting the level of living of its citizens.

Another inherent factor in the level of living is the natural environment. That is because the level of living is not only about the quantity of non-perishable consumer goods in one's possession,

but also about clean air, non-polluted water, landscape qualities, etc. (Migała-Warchoł, 2010).

To sum up, constituent metrics were selected for the examination in a purposeful manner, so that they represent various areas of life and possibly faithfully reflect the actual level of living of the population.

The purpose of this paper is to demonstrate the trend and extent of changes in the level of living in EU countries in 2013-2022. The European Union is made up of countries that vary greatly in terms of the level of living of their populations, and the convergence of those difference is one of the main priorities of the EU policy, which justifies the need for the research discussed in this paper.

Two examination methods were applied for for the set of multidimensional objects, namely linear ordering in dynamic terms and the grouping of objects by similarity of diagnostic features. Using the linear ordering method, a synthetic indicator for the level of living was determined, on the basis of which changes in the level of living in EU countries in 2013 and 2022 were compared. Groups of countries having similar values of the indicators describing the level of living were selected on the basis of fuzzy classification, and then the trend and extent of changes in the value of those indicators in the analysed period was compared for the respective groups of countries. The grouping was performed for the data from 2013 and 2022. The outcome of the research is a synthetic picture of the level of living of the EU countries' population in the analysed period. The research was carried out using the EUROSTAT database covering the selected features of the socio-economic development of EU countries in 2013-2022.

2. Literature review

The level of living is a conceptual category examined from multiple standpoints. Its scope is big, because human needs are very diverse. The literature on the subject provides many definitions covering the respective areas of how the society and individuals function. They are derived from the following definition formulated by a UN Committee of Experts in 1954: "The concept of the level of living covers the entirety of actual conditions of life of the population and the level of material and cultural satisfaction of their needs by the stream of non-gratuitous goods services, and coming from social funds" (UN report, 1954). The key element in all definitions of this category are consumption needs and their "sustainable" satisfaction, which constitutes the primary purpose of economic activity of each household in

microeconomic, or local, scale and the primary purpose of economic activity of each country in macroeconomic, or global, scale (Murawska, 2014).

One of the first researchers dealing with this topic was A. Luszniewicz (Luszniewicz, 1982), who defined the level of living as the degree of satisfaction of material and cultural needs of households fulfilled by the streams of non-gratuitous goods and services and by the streams of collective consumption funds. The researcher also specified seven primary areas of the needs whose satisfaction determines the level of living. These are: nutrition, safety and security, health care, living conditions, transportation, education and culture, and environment.

Teresa Słaby (Słaby, 1990; Czech, Słaby, 2017) defines the level of living as the degree of satisfaction of material and cultural needs with the existing infrastructure enabling such satisfaction. Czesław Bywalec (Bywalec, 2007) defines that category as the degree of satisfaction of the needs resulting from the consumption of material goods and services created by the man. This approach is therefore akin to the position of Luszniewicz. Żekoński (Żekoński, 1974) defines the level of living as the entirety of conditions in which the society, a social-professional group, a household or an individual lives, which express themselves primarily as facilities that relate to the process of satisfying individual and collective needs.

The presented definitions of the level of living reveal a complex and multifaceted nature of that category, which cannot be observed directly, and therefore various socio-economic and economic indicators are employed to describe it, which not so much indicate the level of living, but rather are its manifestation. A comprehensive assessment of the degree of satisfaction of needs should be carried out both in terms of objective and subjective aspects. Objective measures of the level of living refer to phenomena or processes that take place independently of the subjects of consumption, while subjective measures express individual opinions of people about the extent to which their needs are satisfied (Majka, 2015).

Research on the level of living is also carried out by international institutions, and its results are used to diagnose and determine socio-economic policies of the respective countries. Such institutions include for example the United Nations Research Institute for Social Development (UNRISD) which, in the 60s of the 20th century, attempted to implement a new statistical procedure to quantity the population's level of living as a category using the so-called Geneva method (Dąbrowa, 2018) that enabled international comparisons. 1990 saw the launch of the research (still continuing today) on the level of living and development in almost all countries of the world (those that agreed to provide data) by the United Nations Development Programme (UNDP). The agency annually publishes the Human Development Report, which employs the so-called Human Development Index (HDI). It is derived from the aggregation of indicators describing three phenomena comprising the level of living, that is:

- long and healthy life (indicator: life expectancy at birth);
- knowledge – schooling (indicator: mean years of education and expected years of schooling);
- a decent standard of living (indicator: net national income, that is GNI per capita $ PPP) (Bywalec, 2022).

Even though HDI has dominated global social and economic statistics in recent decades, and almost entirely superseded a macroeconomic indicator used previously, that is GDP per capita, it is still not a perfect tool for international comparisons. Research on the level of living is also broadened by European statistics on income and living conditions (EU SILC), providing current and comparable data on income, poverty, social exclusion, and living conditions. The adoption of a harmonised research methodology by all countries conducting EU-SILC research enables data comparison at the EU level and analysis of the phenomena mentioned above at the European level as well (https://badania-ankietowe.stat.gov.pl/kategoria/1/badanie/44). The development of synthetic and objective, to the extent possible, indicatorsallows insight into changes in the level of living of societies at various aggregation levels, and allows to track social and economic development of countries.

3. Methodology

The level of living is a multidimensional phenomenon, described by multiple indicators (features, variables). Research on the subject has most commonly applied the linear ordering method for multidimensional objects in static terms (Kozera, A., Kozera, C., 2011; Murawska, 2014; Wawrzyniak, 2016; Kasprzyk, Wojnar, 2023). That method amounts to constructing a synthetic variable enabling the ranking of objects (for example countries) in terms of the level of the analysed phenomenon in the analysed years. This enables, for example, the identification of units in which the level of living is high or low. If the number of objects is large, in order to generalise the results, a division is typically made into groups marked by a high, medium and low level of the analysed phenomenon. It might then happen that members of the same group are objects where values of the respective features that describe the analysed phenomenon differ significantly. This prompted the authors of this paper to use multicriterial taxonomy, leading to the grouping of objects (countries) having a similar value of the diagnostic features being analysed. The analysis in question was performed in two stages. In the first stage, the level of living in EU countries was analysed using the linear ordering method in dynamic terms and then, on the basis of fuzzy classification method, countries were grouped on the basis of a similar value of the respective features. The analysis was carried out for data from 2013 and 2022. By doing so, a synthetic picture of differences in the level of living in EU countries in the analysed years was obtained, with negligible loss of input information.

The research was carried out using the EUROSTAT database covering the selected features of the socio-economic development of EU countries in 2013-2022.

The linear ordering method for multidimensional objects is divided into the following stages: selection of diagnostic variables, determination of importance indexes (weights) for the variables, variable normalisation, construction of a synthetic variable, ranking of objects.

Each stage offers a selection option, starting from the selection of the diagnostic variables, variable normalisation method, or the method of constructing the synthetic variable[1]. The researcher's choices at the respective stages of the research affect its outcome. The problem was discussed by multiple authors (Bąk, Szczecińska, 2015; Bożek, 2002; Dębkowska, Jarocka, 2013; Kukuła, 1999; Jarocka, 2015; Kisielińska, 2016; Pawełek, 2008; Walesiak, 2014).

The first stage involves the selection of a set of diagnostic variables (indicators) describing the phenomenon to be analysed. In practice, the selection of the variables is largely dependent on whether it is possible to gather complete, reliable and comparable statistics. Even though multiple authors deal with the level of living as a phenomenon, at the current stage of the research there is no commonly recognised and applied set of indicators describing it. This paper employs 7 diagnostic variables (indicators) describing the level of living in EU countries (table 1). The merit criterion was used in selecting the diagnostic variables, consisting in the selection of such indicators (features) that are important determinants of the analysed phenomenon, while the other criterion was data availability. (To note, there cannot be too many indicators adopted for the analysis because, in the grouping of objects in terms of a similar level of an indicator, increasing the number of diagnostic variables typically leads to intra-group diversification, resulting in the groups not being homogeneous. Thus, indicators describing objects belonging to those groups markedly differ from the group average, which means the outcome is burdened with a significant error).

The analysis was carried out on the assumption of identical weights for the adopted diagnostic variables.

The data comprise a set *m* of objects (27 countries), each being described by *n* variables (n = 7 for this paper) in $t = 1, \dots, T$ years (in this paper T = 10). It can be described as the observation matrix X:

$$X = \left[x_{ijt}\right] (i = 1, \dots, m; j = 1, \dots n; t = 1, \dots T) \quad (1)$$

where x_{ijt} is the value of *j-th* variable (feature, indicator) in *i-th* object (country) in year *t.*

The next stage is variable normalisation. The Strahl quotient transformation method in dynamic terms is used in this paper. A significant advantage of the Strahl method is the option to interpret results as percentages (Strahl, 1978; Bożek et al., 2022). The dynamic approach allows, next to creating rankings, quantification of changes in the analysed phenomenon over time. Variable normalisation in dynamic terms was employed to quantify changes in the level of development in the following publications: (Bożek, Szewczyk, 2021, Bożek et al., 2021a; Bożek et al., 2021b; Bożek et al., 2022; Lisek, 2023, Sompolska-Rzechuła, Kurdyś-Kujawska, 2022; Stec, 2012; Szewczyk et al., 2021). To note, the Strahl method can be used if all variables take non-negative values and if the maximum (for the stimulant) or the minimum (for the destimulant) is different from zero. This criterion is met for this paper.

[1] the list of publications where the authors apply the linear ordering method for multidimensional objects with different selection variants at the respective stages is given in the paper by (Kisielińska et al., 2021).

Variable normalisation using the Strahl method in dynamic terms is specified by the following formulae (Bożek et al., 2022):

$$z_{ijt}^{d} = \frac{x_{ijt}}{MAX_j} \text{ for stimulants} \tag{2}$$

$$z_{ijt}^{d} = \frac{MIN_j}{x_{ijt}} \text{ for destimulants} \tag{3}$$

where MAX_j – highest value of j-th variable in all analysed years and all analysed objects,
where MIN_j – lowest value of j-th variable in all analysed years and all analysed objects.
The index *d* refers to dynamic approach.

The variable normalised by the Strahl method in dynamic terms (z_{ijt}^{d}) denotes, for the stimulant, what part (and, after multiplying by 100, what %) of the maximum value of j-th diagnostic variable in the entire analysed period constitutes the value of the variable describing i-th object in year t. Normalised variables adopt values from the range $\left[\frac{\mathrm{MIN_j}}{\mathrm{MAX_j}}, 1\right]$.

In the following year, for each *i*-th object (country), the value of the synthetic variable W_{it} and development level indicator P_{it}^{d} is calculated (Bożek, 2002):

$$W_{it}^{d} = \sum_{j=1}^{n} z_{ijt}^{d}, \quad (i = 1,2,\ldots,m; t = 1,2,\ldots,T) \tag{4}$$

$$P_{it}^{d} = \frac{W_{it}^{d}}{n} \tag{5}$$

where: P_{it}^{d} - dynamic development level indicator (DWPR). In this paper, P_{it}^{d} is the dynamic indicator for the level of living.

The indicator P_{it}^{d} adopts values from the range [0,1], where the higher its value, the higher the level of development (living) in year *t*. On the basis of DWPR values, the ranking of objects is created and the extent of changes to object *i* is specified over time from t_1 to t_2 (Bożek et al., 2021a):

$$\Delta DWPR = \Delta P_{i,t_1t_2}^{d} = P_{it_2}^{d} - P_{it_1}^{d} \tag{6}$$

If the reference object is such that the values of its features are maximum (in the analysed period), then the level of development of P_{it}^{d} *i*-th object denotes (after multiplying by 100) what % of the development level of the reference object is the development level of *i*-th object in year *t* (or what % of maximum values of diagnostic variables constitute, on average, variables describing *i*-th object in year t). In turn, indicator $\Delta DWPR$ denotes (after multiplying by 100), by how many percentage points (p.p.) the level of the analysed phenomenon changed in *i*-th object in the period from t_1 to t_2.

On the basis of the development level indicator P_{it}^{d}, countries are divided into 5 groups in each analysed year as follows:

group I – very high level of living – $P_{it}^{d} \in (0.8; 1]$

group II – high level of living – $P_{it}^{d} \in (0.6; 0.8]$,

group III – average level of living – $P_{it}^{d} \in (0.4;\ 0.6]$ (7)

group IV – low level of living – $P_{it}^{d} \in (0.2; 0.4]$,

group V – very low level of living – $P_{it}^{d} \in [0; 0.2]$.

In order to identify groups having similar values of the indicators describing the level of living, fuzzy classification was used, relying on the concept of fuzzy sets, then transformed into the traditional classification. In the fuzzy classification, the grouping of objects into a given class is specified by the continuous membership function, adopting values from the range [0,1], whereas in the traditional classification, it is a zero-one function (Zadeh, 1965).

The fuzzy classification can be formulated as follows:

The set of objects $\boldsymbol{\Omega}$ (countries in this case) consisting of n-elements is given: $P_1, P_2, \ldots, P_n$. Each is described by r values of variables: $X_1, X_2, \ldots X_r$. (in this paper, X_l denotes the normalised value of l-th diagnostic variable describing the level of living in a given country. For the set Ω, the family of fuzzy classes $S_1, S_2, \ldots S_K$ $(1 < K < n)$ should be specified, and, for each object P_i, the degree of membership (similarity) in class S_j should be determined, that is the membership function $f_{S_j}(P_i)$ should be created, fulfilling the following conditions:

1. $0 \leq f_{S_j}(P_i) \leq 1 \quad (i = 1, \ldots, n; \quad j = 1, \ldots, K)$, where $f_{S_j}(P_i)$ – degree of membership of object P_i in class S_j,
2. $\sum_{j=1}^{K} f_{S_j}(P_i) = 1 \quad (i = 1, \ldots, n)$,
3. The objects where the degree of membership of the same class reaches a high value are very similar, whereas objects where the degree of membership of different classes reach a high value are dissimilar.

From among the available fuzzy classification methods (Jajuga, 1984), the iterative method was selected, which employs the concept of the fuzzy centre of gravity. In subsequent iterations, changes in the objects' value of the degree of membership of the respective classes are tracked. The procedure continues until the values no longer change significantly.

The fuzzy classification so obtained was then transformed into the traditional classification, assuming that an objectP_i belongs to the class (typological group) S_j if

$$f_{S_j}(P_i) = \max_{l} f_{S_l}(P_i) \tag{8}$$

The presented classification method for multidimensional objects is useful for spatial and temporal research carried out in various thematic areas (Bożek, 2013; Bożek, J., Bożek, B., 2011; Bożek et al., 2020). It allows objective grouping of countries that share the analysed set of features, and a synthetic presentation of the analysed phenomenon over time, with a relatively insignificant loss of input information. Tables, figures and formulas – continuous numbering in the text.

4. Methodology

The paper analyses diagnostic variables described in table 1.

Table 1.
Diagnostic variables describing the level of living in EU countries

Symbol	Name and unit	Nature of the variable
X_1	GDP per capita in EUR	stimulant
X_2	mean equivalent income in PPS	stimulant
X_3	unemployment rate in %	destimulant
X_4	poverty risk in % of the population	destimulant
X_5	number of rooms per person	stimulant
X_6	motorways in km per 100 km^2	stimulant
X_7	emission of PM below 2.5 μm in kg per resident	destimulant

Source: authors' compilation.

Primary characteristics of the variables shows table 2.

Table 2.
Primary characteristics of diagnostic variables describing the level of living in EU countries

Detailing	X_1	X_2	X_3	X_4	X_5	X_6	X_7
Mean							
2013	25 336	15722.7	11.5	8.1	1.6	2.0	4.8
2022	29 354	20094.7	5.9	7.5	1.7	2.2	3.9
Maximum							
2013	82 820	32357.0	27.7	14.3	2.2	7.1	11.7
2022	85 850	36744.0	13.0	16.2	2.3	7.5	9.8
Minimum							
2013	5700	4481.0	5.3	3.2	1	0.0	1.1
2022	7680	10158.0	2.3	3.4	1.1	0.0	0.6
Distance							
2013	78470	27876.0	22.4	11.1	1.2	7.1	10.6
2022	78170	26586.0	10.7	12.8	1.2	7.5	9.2
Coefficient of variation							
2013	68.1	42.3	48.5	42.3	23.6	92.1	58.6
2022	63.9	31.3	43.1	45.5	21.0	84.5	62.9

Source: authors' own compilation based on data (access on 10 January 2023).

The largest variability, between 84.5% and 92.1% is demonstrated by X_6 — motorways per 100 km^2. All variables except X_5 show variability in excess of 30%.

The highest GDP per capita, significantly different from the other countries, was reached by Luxembourg and, in 2013-2021, the indicator demonstrated a continuously growing trend, rising from EUR 82,400 to EUR 86,540. Ireland stands out among the countries in which the value of the indicator improved, as it demonstrated a very significant growth in GDP per capita in 2014, and maintained a growing trend throughout the period. All other countries in 2020 saw a major drop in that indicator, likely related to the start of the COVID-19 pandemic.

If we analyse mean net income per capita expressed in the purchasing power standard (PPS), a growing trend can be observed for most of the countries. The largest level of income in almost the entire analysed period was recorded for Luxembourg, with the exception of 2020, when Germany ranked first. The lowest income from among the analysed countries was recorded for the residents of Romania.

The unemployment rate is an important indicator of the economic standing of a country, indirectly affecting the level of living of its residents. We can see a very clear downward trend in the vast majority of EU countries when we analyse the value of that indicator in the period. That downward trend was reversed in 2020, but the rate began to decrease in most of the countries in the following years. The largest absolute drops in the value of that indicator were recorded for Greece (15.1 p.p.) and Spain (13.2 p.p.), however both countries showed the highest unemployment rates, markedly differing in that respect from the other countries.

An indicator that reflects the financial situation of households in a given country in relative terms, as compared to residents of other countries, is the risk of poverty. It shows the percentage of people in households in which the annual equivalent disposable income is below the poverty risk threshold. In this paper, the threshold is 40% of the mean equivalent income. The poverty risk indicator was the highest for Bulgaria, where the situation further deteriorated (indicator growth by 3.4 p.p.) and Romania, where, however, a falling trend can be seen in the second half of the analysed period. The lowest values of the indicator in the analysed period are observed in Czechia and Finland, and the values are stable over time.

The number of rooms per person is another indicator of the level of living. The variable was very stable in 2013-2022. In most countries, an increase by 0.1 room per person was recorded, with the highest growth recorded for Hungary (0.5 room per person). The lowest value was recorded for Romania, followed by Poland.

The analysed countries vary significantly in terms of motorway density. There are no motorways in Malta and Latvia, while Lithuania and Romania have the fewest of them (but more than zero). The highest motorway density is in the Netherlands, Belgium and Luxembourg, and there is a significant gap between those three countries and the remaining ones, led by Germany.

The highest indicator of the weight of PM below 2.5 μm per resident exists for Denmark and Latvia. The lowest value in the analysed period was recorded for the Netherlands, Malta, Cyprus and Luxembourg. The largest drop in PM emissions per resident was recorded for Estonia, followed by Czechia and Hungary.

According to the formulae given in the methodology section, values of the dynamic development level indicator (DWPR) were calculated for the respective countries for 2013 and 2022. Values of that metric are given in table 3. They are arranged from the highest to the lowest for 2013, thus providing the ranking of countries in terms of the level of living. The division of the countries into groups according to the formulae given in the methodology section (7) is also presented.

Table 3.
Ranking of EU countries in terms of the level of living in 2013 and 2022, values of the dynamic level of living indicator, membership of groups, increase in DWPR in 2013-2022

	2013			2022			ΔDWPR
Country	**Rank**	**$P_{i\ 2013}$**	**Group**	**Rank**	**$P_{i\ 2022}$**	**Group**	
Luxembourg	1	0.6390	II	1	0.7000	II	0.0610
Netherlands	2	0.6028	II	2	0.6808	II	0.0780
Belgium	3	0.5241	III	3	0.6032	II	0.0791
Germany	4	0.4671	III	6	0.5368	III	0.0697
Denmark	5	0.4434	III	7	0.5163	III	0.0729
Austria	6	0.4422	III	9	0.4763	III	0.0341
Cyprus	7	0.4296	III	8	0.5067	III	0.0771
Malta	8	0.4250	III	4	0.5750	III	0.1500
Finland	9	0.4215	III	12	0.4609	III	0.0394
France	10	0.3981	IV	14	0.4127	III	0.0146
Ireland	11	0.3961	IV	5	0.5431	III	0.1470
Sweden	12	0.3920	IV	13	0.4228	III	0.0308
Slovenia	13	0.3547	IV	11	0.4622	III	0.1075
Czechia	14	0.3429	IV	10	0.4733	III	0.1304
Spain	15	0.3380	IV	15	0.3838	IV	0.0458
Italy	16	0.3206	IV	18	0.3609	IV	0.0403
Portugal	17	0.3002	IV	17	0.3666	IV	0.0665
Slovakia	18	0.2468	IV	20	0.3300	IV	0.0832
Hungary	19	0.2467	IV	16	0.3783	IV	0.1317
Estonia	20	0.2400	IV	21	0.3125	IV	0.0725
Lithuania	21	0.2357	IV	22	0.3100	IV	0.0743
Croatia	22	0.2213	IV	23	0.2916	IV	0.0703
Greece	23	0.2168	IV	24	0.2694	IV	0.0526
Poland	24	0.2146	IV	19	0.3440	IV	0.1294
Latvia	25	0.1829	V	26	0.2324	IV	0.0495
Bulgaria	26	0.1813	V	25	0.2652	IV	0.0840
Romania	27	0.1757	V	27	0.2322	IV	0.0565
Mean		0.3481			0.4240		

Source: authors' own calculations based on data https://ec.europa.eu/eurosta (access 10 January 2024).

The calculations confirm differences in the development of the countries, demonstrated by significant differences in DWPR values for the countries with the highest and lowest level of living in the analysed years.

The highest ranking, in the analysed years, are 3 countries: Belgium, Luxembourg, and the Netherlands, whose DWPR is significantly higher than that of the rest. The lowest level of living was recorded for Romania, Latvia, Bulgaria, Croatia, that is post-communist countries, as well as for Greece. The ranking of countries did not change significantly in the analysed period. Movements by 1-3 places in the ranking were typically observed, notably for countries

from the mid-range of the ranking. Only Ireland moved from place 11 to 5, Malta from 8 to 4, Czechia from 14 to 10, Poland from 24 to 19, while France went four places down, from 10 to 14.

All countries saw the growth in DWPR in the analysed period, which is a positive and desirable development, as it demonstrates the improvement in the indicators describing the level of living. The average value of the level of living in 2013 was 0.3481, growing to 0.4240 in 2022, and so the DWPR increase was 0.08. The pace of that growth was uneven, however, as shown by differences in the value of that indicator $\Delta DWPR$ (table 3). The largest DWPR growth in 2013-2022 was recorded for Malta (0.15) and Ireland (0.15), as well as for Hungary (0.13), Czechia (0.13), Poland (0.13), Slovenia (0.11), Bulgaria (0.08), Slovakia (0.08), that is countries from the bottom positions of the 2013 ranking, where there was the largest need to improve the situation in terms of the adopted set of features. The smallest positive changes occurred for France (0.01), Sweden (0.03), Austria (0.03), Finland (0.04). Despite those positive changes, DWPR of five countries, that is Romania, Latvia, Bulgaria, Croatia, and Greece did not exceed 0.3 in 2022, which means that, on average, the level of living indicators (adopted for the study) constitute less than 30% of their maximum values, which means that there is a still a lot to be improved in those countries in this respect.

The distance between the country with the highest and lowest level of living grew in the analysed period, which is not a favourable phenomenon, in particular in the context of the policy aiming at the convergence of regional differences. In 2013, the smallest value of the development indicator was 0.1757, while the highest was at 0.6390, which means that the distance between the two was 0.4633. The distance further increased to 0.4678 in 2022. When we exclude group two from the comparison, with countries having the highest level of living, the gap is smaller, and shows a slightly downward trend: 0.3484 in 2013 and 0.3046 in 2022.

The improvement in the level of living in EU countries in the analysed period is also reflected by the classification into groups, shown in table 3. In 2013, 3 countries belonged to group V, that is very low development level, for which DWPR did not exceed 0.20, 15 countries were in group IV - low development level, where DWPR did not exceed 0.40, and only 2 countries were in group II, where DWPR was above 0.6. The situation improved in 2022, as there were no more countries in group V, group IV had 13 countries, while there were no significant changes in respect of the ranking leaders, as only 3 countries exceeded 0.6 (group II). However, even for leaders of the ranking, the values describing those countries do not reach the maximum. In no country did the level of living indicator exceed 0.8.

The basis for the ranking shown in table 3 is the value of the synthetic variable, and therefore there are significant differences among objects in terms of the values of the respective features. For example, Ireland and Slovenia are in group III for 2022, whereas GDP in those countries was, respectively, 77,430 and 21,870, and the motorway density was 1.4 km/100km^2 and 3.0 km/100km^2, respectively. Poland and Spain, in turn, belonging to group IV, differ greatly

in terms of the unemployment rate, at 2.9% in Poland, and at 13.0% in Spain. In the second stage of the analysis, on the basis of the fuzzy classification, the countries were grouped by similarity of the values of diagnostic features describing the level of living in EU countries in 2013 and 2022. The calculations were performed in the authors' proprietary software which[2], for a given set of multidimensional objects, determines the centre of gravity for clusters, and calculates the value of the membership function of the clusters for the respective objects.

On the basis of the calculations, 6 multiple member groups and one single member group were created. Members of the groups are shown in table 4.

Table 4.
Groups of EU countries having similar values of the level of living indicators in 2013 and 2022

Group	Group composition	
	2013	**2022**
1	Belgium, Luxembourg, Netherlands	Belgium, Luxembourg, Netherlands
2	Austria, Germany	Austria, Germany, Denmark, Cyprus
3	Denmark, France, Ireland, Sweden	France, Ireland, Sweden, Finland
4	Czechia, Finland, Malta	Czechia, Hungary, Poland, Slovenia, Slovakia
5	Spain, Portugal, Italy, Slovenia	Spain, Portugal, Italy
6	Bulgaria, Estonia, Greece, Croatia, Latvia, Lithuania, Poland, Hungary, Slovakia, Romania	Bulgaria, Estonia, Greece, Croatia, Latvia, Lithuania, Romania
7	Cyprus	Malta

Source: authors' compilation.

In order to present differences in the indicators in the respective groups, average values of the variables in the groups and the average level of living indicator were calculated. For each country group, intra-group variances were calculated: standard deviation – s(x) and variance index – V(x). The groups are characterised in table 5.

Table 5.
Average, values, standard deviation s(x), variance index V(x) of the level of living indicators in 2013 and 2022. Average development level indicator

	GDP per capita in EUR	**Mean equivalent income in PPS**	**Unemploy-ment rate**	**Poverty risk**	**Number of rooms per person**	**Motorways in km per 100 km²**	**Emission of PM below 2.5 µm**	**Indicator DWPR**
Group 1in 2013								
Mean	**51 356.7**	**24 963.3**	**7.2**	**5.0**	**2.1**	**6.2**	**2.1**	
s(x)	22 034.3	5 228.4	1.1	1.0	0.1	0.6	0.5	0.5886
V(x)	42.9%	20.9%	14.7%	19.2%	4.6%	10.1%	25.3%	
Group 1in 2022								
Mean	**55 563.3**	**30 061.7**	**4.6**	**5.4**	**2.1**	**6.5**	**1.5**	
s(x)	21 593.0	4 756.8	0.9	1.3	0.0	0.7	0.4	0.6613
V(x)	38.9%	15.8%	18.8%	23.5%	2.2%	11.1%	24.6%	
Group 2 in 2013								
Mean	**34 55.0**	**22 713.5**	**5.4**	**6.6**	**1.7**	**2.8**	**2.1**	
s(x)	1 425.0	361.5	0.1	0.5	0.1	0.8	0.1	0.4547
V(x)	4.1%	1.6%	0.9%	6.9%	5.9%	27.6%	4.5%	

[2] software in C++ calculates values of the membership functions of fuzzy classes for objects according to the algorithm presented in Bożek J., Bożek B. (2011).

Cont. table 5.

Group 2 in 2022								
Mean	**38 307.5**	**25 841.8**	**4.9**	**5.7**	**1.8**	**3.0**	**3.5**	
s(x)	8 672.6	1 797.8	1.3	1.0	0.2	0.6	3.6	0.5090
V(x)	22.6%	7.0%	27.4%	16.9%	8.8%	19.5%	102.4%	
Group 3 in 2013								
Mean	**38 292.5**	**21 345.8**	**10.0**	**5.8**	**1.9**	**1.6**	**5.6**	
s(x)	4 861.6	1 061.9	2.5	0.4	0.1	0.9	3.6	0.4074
V(x)	12.7%	5.0%	25.1%	7.2%	7.9%	54.0%	65.1%	
Group 3 in 2022								
Mean	**48 585.0**	**23 060.5**	**6.6**	**5.5**	**1.9**	**1.0**	**2.5**	
s(x)	17 296.9	482.2	1.2	1.4	0.1	0.6	0.5	0.4737
V(x)	35.6%	2.1%	18.1%	25.2%	6.8%	64.0%	19.9%	
Group 4 in 2013								
Mean	**22 500.0**	**16 855.3**	**7.2**	**3.8**	**1.8**	**0.4**	**4.3**	
s(x)	8 659.7	3 731.9	0.9	0.7	0.3	0.4	2.8	0.3965
V(x)	38.5%	22.1%	12.1%	18.1%	16.4%	102.8%	65.5%	
Group 4 in 2022								
Mean	**17 128.0**	**15 088.0**	**3.8**	**4.4**	**1.4**	**1.8**	**5.1**	
s(x)	2 788.9	3 710.7	1.3	0.9	0.2	0.8	1.6	0.3976
V(x)	16.3%	24.6%	34.9%	20.4%	16.8%	43.1%	31.2%	
Group 5 in 2013								
Mean	**20 170.0**	**15 263.3**	**16.5**	**9.9**	**1.6**	**2.9**	**4.7**	
s(x)	3 826.2	2 101.9	6.1	3.0	0.2	0.4	1.4	0.3284
V(x)	19.0%	13.8%	37.3%	30.7%	11.7%	13.5%	30.1%	
Group 5 in 2022								
Mean	**24 156.7**	**18 495.0**	**9.2**	**10.2**	**1.7**	**2.6**	**3.4**	
s(x)	3 688.4	2 793.4	2.8	1.2	0.2	0.9	0.7	0.3704
V(x)	15.3%	15.0%	30.8%	12.2%	14.4%	33.4%	21.5%	
Group 6 in 2013								
Mean	**10 635.0**	**8 618.9**	**13.4**	**10.8**	**1.2**	**0.8**	**6.3**	
s(x)	2 989.6	1 782.1	5.5	2.9	0.1	0.7	2.2	0.2162
V(x)	28.1%	20.7%	41.1%	26.6%	12.5%	83.6%	35.3%	
Group 6 in 2022								
Mean	**13 661.4**	**14 500.1**	**7.0**	**11.9**	**1.3**	**0.9**	**5.6**	
s(x)	3 468.5	2 845.8	2.5	2.4	0.2	0.8	2.0	0.2733
V(x)	25.4%	19.6%	35.3%	19.8%	13.8%	85.0%	35.1%	
Single-element group in 2013								
Cyprus	20450	21006	16.1	7.4	2	2.8	1.2	0.4490
Single-element group in 2022								
Malta	24560	24338	3	6.6	2.3	0	0.6	0.6043

Source: authors' own calculations based on data https://ec.europa.eu/eurosta (access: 10 January 2023).

Group 1 is composed of three countries with the highest level of living: Belgium, Luxembourg, the Netherlands Those countries are markedly outperform the remaining groups in terms of GDP, mean income by PPS, motorway density, and show the lowest PM pollution. The average GDP for those countries was EUR 51,357 in 2013, growing to 55,563 in 2022. The mean equivalent net income grew from 24,963 PPS in 2013 to 30,061 PPS in 2022. The densest (from among the other groups) motorway network, at 6.2 km/100km^2 in 2013, grew even denser, to 6.5 km/100km^2 in 2022. PM emission was the lowest, at 1.5 kg/person (2.1 kg/person in 2013). The level of living indicator grew from 0.61 to 0.68.

In group 2, covering only 2 countries in 2013, that is Austria and Germany, the level of living indicator was at 0.48 on average, so much less than for group 1. The group was joined by Denmark (from group 3) and Cyprus in 2022. Differences between group 1 and 2 are very significant. GDP per capita in group 2 countries was, on average, EUR 38,308 in 2022 (EUR 34,755 in 2013), with the mean equivalent net income growing from 22,713 PPS to

25,842 PPS, and the unemployment rate falling from 5.4% to 4.9%, and the poverty risk from 6.6% to 5.7%. DWPR grew to 0.51, and so the distance between group 1 and 2 increased from 0.1812 to 0.1876 in the analysed period.

In 2013, group 3 included 4 countries: Denmark, France, Irlandia, Sweden. In 2022, Denmark moved to group 2, and Finland to group 3 (it was in group 4 in 2013). As compared with the previous group, DWPR here is lower (0.43 in 2013 and 0.48 in 2022), even though GDP is higher in those countries: EUR 38,293 in 2013 and EUR 48,585 in 2022 on average). However, the above does not translate into the mean equivalent net income, lower in group 2, at 21,346 PPS in 2013, and 23,061 PPS in 2022. Similarly to the previous group, the situation improved in terms of the unemployment rate and PM emissions, with significant drops for both indicators: unemployment dropped from 10% to 6.6%, and PM emission was cut by nearly one half: from 5.6 kg/person to 2.5 kg/person.

Group 4 was made up of 3 countries in 2013: Czechia, Finland i Malta. In 2022, Finland moved to group 3, and Malta remained as the only member of the group. In 2022, group 4 was composed of: Czechia, Slovenia, Hungary, Poland, and Slovakia, with the latter 3 in group 6 in 2013, showing the lowest level of living. In group 4, mean net equivalent income and GDP per capita are markedly lower than for group 3 countries. In 2022,-the average GDP of group 4 countries was at EUR 17,128, which is less than one half of the average for group 3. The average for that indicator was lower only for group 6.

Group 5 was made up of 4 countries in 2013: Spain, Slovenia, Portugal, and Italy. The development indicator in those countries was 0.33 on average in 2013, growing to 0.37 in 2022. The unemployment rate (9.2% in 2022) and poverty risk at 10.2% are the highest among the remaining groups. In 2022, Slovenia moved to group 4 following positive changes.

Group 6 comprises countries with the lowest level of living. There were 10 members of the group in 2013: Bulgaria, Estonia, Greece, Croatia, Latvia, Lithuania, Poland, Hungary, Slovakia, Romania, so the group comprised nearly all of the post-communist countries (except for Czechia and Slovenia). DWPR in the group was at 0.22, almost 3 times less than for group 1 (highest level of living), and GDP in those countries was, on average 5 times smaller (10,635), and the mean income almost 3 times less, at 8,619 PPS. The situation improved significantly in Hungary, Poland and Slovakia in the analysed period, as a result of which those 3 countries joined group 4, where DWPR in 2022 was at 0.42 on average. Some level of living indicators also improved in the remaining group 6 countries: GDP grew from EUR 10,635 to EUR 13,661, the unemployment rate dropped from 13.4% to 7%, PM emissions fell from 6.3 kg/person to 5.3 kg/person, and the mean equivalent income increased from 8,619 PPS to 14,500 PPS. As a result of those changes, DWPR increased to 0.2733, which, however, still shows a low level of living and an urgent need for improvement in those countries.

5. Conclusion

The research confirms the persisting gap in the level of living in EU countries. In the analysed period, 3 countries: Belgium, Luxembourg and the Netherlands significantly outperformed the other countries in terms of the level of living. The lowest level of living persists in Bulgaria, Estonia, Greece, Croatia, Latvia, Lithuania and Romania. The synthetic level of living indicator (DWPR) grew in all countries in the analysed period, but the extent of the changes was uneven, while the smallest DWPR increase was recorded for France (1.4 p.p.), and the highest for Malta (15 p.p.). High increases of the value of that indicator were recorded for Ireland, Hungary, Czechia, Poland, and Slovenia.

In addition to France, low DWPR increases were recorded for Finland, Austria, and Sweden. Low increases are typically shown by countries where the level of living is relatively high, whereas the highest growths of the indicator are recorded mostly for post-communist countries (with the exception of Malta and Ireland).

All countries demonstrated largely positive trends for the adopted indicators, that is GDP and income, number of rooms per person, motorway density, unemployment rate drop, percentage of people at risk of poverty, and air pollution level. A slight disruption of those positive trends was observed in 2020, when most of the countries recorded a drop in GDP per capita, and the unemployment rate growth. However, the gaps between the countries remain very significant, as reflected by the grouping of countries in terms of similar values of the level of living indicators. 6 groups were created and one isolated object. There were differences in terms of group membership at the start and end of the analysed period, resulting from the uneven extent of changes in the respective countries. One of the factors showing the greatest difference among the countries was GDP, which, for the respective groups in 2022, was at: EUR 55,6k, EUR 38.3k, EUR 48.6k, EUR 17.1k, EUR 24.1k, EUR 13.7 k, which clearly shows the gaps among the countries.

The methods used for the research are complimentary and offer a synthetic picture of differences in the level of living in European Union countries.

The results of the research demonstrate the need for appropriate actions and development of new solutions (strategies) to improve and cause the convergence of the level of living in the respective EU countries.

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