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Price expectations in the European Union: is there a consensus?

Emilia Tomczyk[a]

Abstract. This study examines the strength of the consensus on the expected prices across the European Union (EU) countries with respect to various factors: seniority in the EU ('old' vs. 'new' EU Member States, i.e. those that joined the community in 2004), the size of the economy (small vs. large) and currency cohesion (eurozone vs. local-currency countries). The results show that the lowest consensus on expected prices and relatively little variation in such a consensus occur in the 'old' EU countries. Opinions on the direction of the expected price changes vary substantially, but this variation remains stable in time. For almost every EU country, the consensus on the expected prices is higher in the 'regular times' subsample than in the 'pandemic and war' subsample, and for many countries, the differences in the strength of the consensus are larger for the 'pandemic and war' subsample. As far as the correlation with the observed price changes is concerned, the highest correlation coefficients are noted for small economies. Analysing correlation coefficients across subsamples shows that during difficult times of the pandemic and war, seniority in the EU helps the respondents to predict the direction of the expected price changes more in line with the actual price developments.

Keywords: price expectations, consensus, European Union, New Member States
JEL: D84, E31, L16

1. Introduction

Expectations play a major role in determining the behaviour of economic processes, and price expectations in particular attract special interest of both theorists and applied researchers. Numerous studies on price expectations in the European Union (EU) focus on the prices of specific products or services, such as foodstuffs, tobacco, electricity, pharmaceuticals, housing and emissions trading. However, these studies offer no firm conclusions on the speed or even the occurrence of price adjustments. Such mixed results are expected when considering the prices of diverse products and services. Typically, there is a valid reason for adopting a disaggregated approach to price analysis: studies indicate that aggregation bias can be significant (Wolszczak-Derlacz & De Blander, 2009). Measuring price consensus is one area of scientific inquiry on price expectations where an aggregated approach is, by definition, indispensable.

As Krüger and Nolte (2016) assert, consensus is defined as a measure of agreement expressed in surveys, contrasting it with certainty (or rather uncertainty) delineated

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by the conditional variance of future values of macroeconomic variables. To the best of my knowledge, the strength of the consensus on the dynamics of economic processes across EU countries has not been addressed yet in any earlier research, and there is no empirical evidence on whether general uncertainty associated with recent macroeconomic shocks (such as the COVID-19 pandemic and the Russian invasion of Ukraine) correlates with the level of agreement (or disagreement) on the expected economic behaviour.

The paper addresses this issue from the point of view of expected price changes. The purpose of the analysis is to verify whether factors such as the recent macroeconomic shocks, the seniority of a country in the EU or its membership in the eurozone are reflected in the degree of the consensus on expected prices.

Section 2 presents a brief review of literature on the EU price expectations, Section 3 describes the consensus measures and the datasets used for empirical analysis, Section 4 discusses the empirical results and Section 5 presents the conclusions of the study.

2. Literature review

The analysis of price expectations in the EU is a complex task, as evidenced by the extensive body of research on the topic. Since 2004, the majority of studies comparing economies of the EU and the New Member States (NMS) have addressed various aspects of the convergence between the relatively small NMS economies and the much larger one of the whole EU. Analyses of convergence typically focus on long-term productivity, income, foreign direct investment, ecological and energy policy effects and prices. The literature on price adjustments may be broadly classified as studies of nominal price convergence, the synchronisation of inflation across the EU and inflation spillovers, and comparing price dynamics of individual goods or services, particularly those subjected to price controls.

Studies of price convergence constitute perhaps the largest segment of the extensive literature on European price dynamics since the Maastricht Treaty of 1993, and particularly since the accession of 10 new members to the EU in 2004. The convergence of prices among the EU countries can be considered as a result – or even as a purpose – of European integration. With respect to the economic, social and territorial cohesion, the Treaty on the Functioning of the EU reads: ‘In particular, the Union shall aim at reducing disparities between the levels of development of the various regions and the backwardness of the least favoured regions’ (a consolidated version of the treaty on the European Union and the treaty on the functioning of the European Union, Article 174). A comprehensive review of literature on European price convergence can be found in Brož and Kočenda (2018) and a more theory-based approach, focusing on the verification of the Balassa–Samuelson effect and the Engel's Law in Égert (2011), who confirms that the price-convergence process is actually taking place in Europe. However, the process was proven to be nonlinear and dependent on the price differentials (Guerreiro & Mignon, 2013), and its pace differed across EU countries. Hałka and Leszczyńska-Paczesna (2019) found evidence for the 'catching up' effect (faster convergence of countries with price level below the average), but also asserted that for most prices, the convergence process was stalled after 2008. They contributed this result to the decrease in international trade and increase in exchange rates volatility following the 2009–2010 financial crisis. Even within the European Monetary Union (EMU), the pace and consistency of the price-convergence processes differed. Garcia-Hiernaux et al. (2023) determined the relative price convergence for over 80% of the EMU member countries between 2001 and 2011, but observed price divergences after 2012.

Therefore, one can see that empirical results on price convergence quoted in the literature generally support the hypothesis of a long-term price convergence within the EU, albeit pointing out that it is nonlinear, time-varying, and influenced by both universal shocks (e.g. financial crises) and various country-specific factors.

Another branch of the literature focuses on the synchronisation of inflation across EU countries and factors that influence its dynamics; for a comprehensive literature review, see e.g. Szafranek (2021). The wide variety of studies generally confirm the global aspects of inflation but also point to heterogenic and time-dependent factors determining the speed of adjustment and the strength of the connection between the global and the local (country-specific) inflation. Links between the inflation in European countries are also studied and compared across geographical boundaries by means of dynamic econometrics models, especially multivariate generalised autoregressive conditional heteroskedasticity (MV GARCH) models or time-varying parameter vector autoregression (VAR) models with stochastic volatility (which allow the analysis of the spillover of inflation rates). There is a wide range of studies addressing inflation spillover rates for North American and European countries (Bouri et al., 2023), China and European countries (Elsayed et al., 2021), and the eurozone and European small open economies outside the eurozone (Hałka & Szafranek, 2016).

Still another part of the literature analyses the impact of inflation expectations on various economic aggregates such as spending and saving (Premik & Stanisławska, 2017) or households' reactions to business-cycle shocks and policy interventions (Weber et al., 2022). The latter paper belongs to a broader category of studies on policy uncertainty which also include analyses of the role of aggregated expectations (forecasts) in developing indices of the economic policy uncertainty (Baker et al., 2016) and empirical results on interdependencies between the long- and short-term inflation expectations and levels of policy-related uncertainty (Istrefi & Piloiu, 2014).

3. Methods and data

Several measures of the consensus among survey respondents have been proposed in the economic literature; for a review and discussion of their properties, along with the comparison of their application to Polish business survey data, see Tomczyk and Kowalczyk (2023). The study shows that on the basis of their theoretical and empirical properties, two of the measures, i.e. the variance-based and the Tastle-Wierman measures (Tastle & Wierman, 2007) may be considered particularly useful in evaluating the degree of the consensus among survey respondents. However, to ensure easier calculations and the consistency in measuring the variability of consensus in time, the variance-based consensus measure is used in this paper.

Let us define the following:

- P^{inc} is the percentage of respondents expecting increasing prices within the forecast horizon specified in the survey;
- P^{const} is the percentage of respondents expecting no change in prices within the forecast horizon specified in the survey;
- P^{dec} is the percentage of respondents expecting decreasing prices within the forecast horizon specified in the survey.

Balance statistic has been traditionally used as an aggregate measure of the respondents' expectations. It is calculated by subtracting the share of respondents who expect a decline from the share of respondents who expect an increase:

$$BAL_t = P_t^{inc} - P_t^{dec}. \tag{1}$$

Generally, positive values of a balance statistic would be interpreted as optimism with respect to the future (i.e. there are more optimists than pessimists) and negative values as pessimism. However, two caveats have to be mentioned here. First, when the expected changes in prices are considered, interpreting the surplus of respondents expecting price increases as 'optimism' is unwarranted; therefore, such value-laden interpretations are not used in this paper. Second, the balance statistic should not be used as an indicator of a consensus, because is constitutes a measure of a central tendency and not of dispersion.

On the basis of Bachmann et al. (2013), the variance-based measure of disagreement can be defined as:

$$Var_t = P_t^{inc} + P_t^{dec} - (BAL_t)^2 = 1 - P_t^{const} - (BAL_t)^2. \tag{2}$$

High values of measure (2) indicate the lack of a consensus due to its variance-based definition. In order to interpret the results in terms of a consensus (agreement), rescaling is needed. Let us define the variance-based consensus measure as

$$Cns\_VAR_t = 1 - Var_t = P_t^{const} + (BAL_t)^2, \tag{3}$$

where $0 \leq Cns_{VAR} \leq 1$. The maximum value of 1 is reached when all respondents' forecasts belong to the same category (that is, perfect consensus that prices will either increase, decrease or remain the same within the next three months). The minimum value of 0 occurs when respondents are divided into two equinumerous and opposing groups expecting increase and decrease in prices (that is, perfect disagreement: $P^{inc} = 0.50, P^{dec} = 0.50$). The Bachmann variance measure has been successfully used in empirical analyses of economic consensus and remains a current 'default' consensus measure in studies on prices (Mattevi & Padellini, 2024).

Let us mention that, contrary to the colloquial understanding of the term, in this paper (following the economic consensus literature), a consensus is measured in degrees: the higher concentration of survey responses, the stronger the consensus.

To evaluate the consensus on price expectations across the EU, the variance-based consensus measure (3) is used. However, just like all the other measures of a consensus, it does not take into account the 'inclination' of the consensus (optimistic versus pessimistic) – this information is missing. To compare a consensus on expected prices with the observed changes in prices, a sign-sensitive version of the variance-based consensus measure is therefore used in this paper:

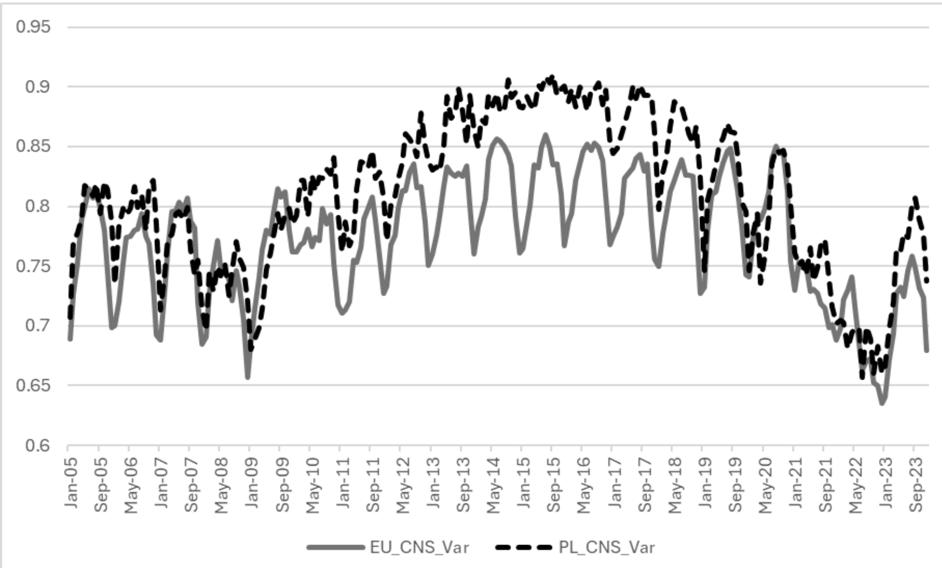
$$Cns\_VAR_t^{sgn} = Cns\_VAR_t \cdot sgn\{BAL_t\}. \tag{4}$$

Data on the expected changes in prices are collected and published by the European Commission, covering all individual EU countries as well as a weighted average for the EU.[1] In monthly questionnaires for retail trade (construction and services sectors excluded), respondents are asked the following question: 'How do you expect your selling prices to change over the next 3 months?' (question Q6) and can choose between the options below: increase, remain unchanged, decrease, refuse to answer/not applicable. They are also instructed to exclude any seasonal variations when answering the questions. However, the effectiveness of the latter is questionable: seasonal variations in expected price changes are clearly visible (although to varying degrees) in

[1] https://economy-finance.ec.europa.eu/economic-forecast-and-surveys/business-and-consumer-surveys/download-business-and-consumer-survey-data/time-series_en#detailed-data-by-answer-category-totals.

all countries. In Figure 1, values of the variance-based consensus measure (3) are presented for Poland and the EU-22 average.

Figure 1. Values of variance-based consensus measure for Poland (PL_CNS_Var) and the average for 22 EU countries (EU_CNS_Var)



Source: author's work based on European Commission data.

Seasonal variations and the absence of long-term trends are characteristic of the variance-based consensus measure across all countries. To preserve the inherently seasonal behaviour of the consensus on expected prices, no attempt was made to correct for the seasonality of the time series.

To compare the subjective price expectations with the objective price changes, Eurostat data is used. Section B-E36 (industry, except for construction, sewerage, waste management and remediation activities), a seasonally unadjusted price index is employed as the closest equivalent to the European Commission survey data. Fixed-base index I21 (2021 = 100) must be transformed to allow comparisons with the price expectations formed three months earlier:

$$PR_t^3 = \frac{I21_t}{I21_{t-3}} - 1, \tag{5}$$

which is interpreted as a percentage change in prices between t and t-3.

To enable meaningful comparisons of the NMSs with their EU economic environment, 2004 was chosen as a starting point for the empirical analysis. Studies show (see Wolszczak-Derlacz & De Blander, 2009) that the integration anchor went into effect in as early as the mid-1990s, long before the date of the official expansion of the EU, and therefore 2004 can be considered as a good starting point for the analysis of economies already integrated to some extent. However, in order to include Denmark, Lithuania and Malta, for which European Commission survey data are not available for 2004, the sample begins in January 2005.

Consensus measures are calculated for the entire sample (January 2005–December 2023) and also for the 'regular times' subsample (January 2005–February 2020). After that date, two macroeconomic shocks occurred, i.e. the COVID-19 pandemic (approximately from March 2020 to May 2022) and then the Russian invasion of Ukraine (February 2022, ongoing), which necessitated considering the post-March 2020 period as a separate 'pandemic and war' subsample. Researchers agree that the global COVID-19 pandemic resulted in major changes in economic relationships, affecting particularly employment and price patterns. A literature review (Anyfantaki et al., 2020; Callegari & Feder, 2022) shows that the economic impact of the COVID-19 pandemic will have extensive, both short- and long-term consequences, making small open economies particularly vulnerable to the risks. Additionally, Tomczyk (2023) demonstrated that the COVID-19 pandemic cannot be seen as just another contraction phase as far as macroeconomic expectations are concerned. While the economic consequences of the pandemic are clearly unfavourable, the statistical properties and the degree of concentration of the answers of survey respondents does not correspond either with the expansion or the contraction phases of the business cycle. For these reasons, the 'regular times' and the 'pandemic and war' subsamples are examined in addition to the entire sample of 2005–2023.

The separation of a 'financial crisis' subsample was also considered in this study, but the literature generally agrees that the Polish economy stood out as an outlier in the overall global picture, having emerged from the crisis relatively unscathed. Poland was the only EU country that did not experience the economic recession; quite the opposite – it saw economic growth during this period (Allington & Labib, 2015; Drozdowicz-Bieć, 2011; Duszczyk, 2015). Additionally, it would be a very short subsample (from November 2007 to March 2009, i.e. 17 months), which would raise doubts as to the validity of statistical inference.

The initial set of the EU countries consisted of 25 (EU 2004) Member States (i.e. 'old' Member States that joined the UE until 2004 and 'new' Member States that joined the EU in 2004). Countries which joined the EU later, namely Bulgaria (in 2007), Romania (in 2007) and Croatia (in 2013) were not included, because the time frames for the empirical analysis had to be long enough and comparable. Additionally, the following countries were removed from the sample:

- Great Britain (due to Brexit in February 2020);
- Cyprus (due to missing data on expected prices from January 2004 to April 2008 from the European Commission database);
- Ireland (due to missing data on expected prices for 2004–2016 and 2023 from the European Commission database).

Ultimately, the sample begins in January 2005 and covers 22 countries: Austria, Belgium, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain and Sweden.

4. Empirical results

As the first step in the empirical analysis, the values of the consensus measure (3) are calculated for the entire sample (from January 2005 to December 2023, $T = 225$), the ‘regular times’ subsample (from January 2005 to February 2020, $T = 182$), and the ‘pandemic and war’ subsample (from March 2020 to December 2023, $T = 43$). Descriptive statistics for the consensus measures across the EU countries as well as the values of the EU average (for the purpose of comparison) are presented in Table 1.

Table 1. Descriptive statistics for the variance-based consensus measure (3): the entire sample (January 2005–December 2023) and the subsamples

Country	(Sub)sample	Mean	Std dev	Min	Max	Range
EU average	Entire sample	0.7748	0.0509	0.6350	0.8603	0.2253
	Regular times	0.7858	0.0435	0.6572	0.8603	0.2031
	Pandemic & war	0.7312	0.0551	0.6350	0.8500	0.2149
‘Old’ Member States						
Austria	Entire sample	0.7587	0.0675	0.5528	0.8981	0.3453
	Regular times	0.7736	0.0561	0.6117	0.8981	0.2864
	Pandemic & war	0.6998	0.0768	0.5528	0.8829	0.3301
Belgium	Entire sample	0.7548	0.0589	0.5724	0.8910	0.3186
	Regular times	0.7692	0.0471	0.6396	0.8910	0.2514
	Pandemic & war	0.6980	0.0666	0.5724	0.8034	0.2310
Denmark	Entire sample	0.7963	0.0613	0.6026	0.9227	0.3201
	Regular times	0.8024	0.0586	0.6026	0.9227	0.3201
	Pandemic & war	0.7724	0.0664	0.6251	0.9052	0.2801
Finland	Entire sample	0.7098	0.0721	0.4941	0.8509	0.3568
	Regular times	0.7235	0.0630	0.5261	0.8509	0.3248
	Pandemic & war	0.6553	0.0806	0.4941	0.8221	0.3280
France	Entire sample	0.7174	0.0618	0.5294	0.8445	0.3151
	Regular times	0.7145	0.0654	0.5294	0.8445	0.3151
	Pandemic & war	0.7289	0.0432	0.6285	0.8408	0.2122
Germany	Entire sample	0.7790	0.0580	0.6134	0.8790	0.2656
	Regular times	0.7931	0.0469	0.6645	0.8790	0.2145
	Pandemic & war	0.7232	0.0643	0.6134	0.8697	0.2563

Table 1. Descriptive statistics for the variance-based consensus measure (3): the entire sample (January 2005–December 2023) and the subsamples (cont.)

Country	(Sub)sample	Mean	Std dev	Min	Max	Range
Greece	Entire sample	0.7870	0.0628	0.5629	0.9080	0.3451
	Regular times	0.8004	0.0495	0.6609	0.9080	0.2471
	Pandemic & war	0.7340	0.0801	0.5629	0.8940	0.3311
Italy	Entire sample	0.8263	0.0501	0.6882	0.9113	0.2231
	Regular times	0.8391	0.0368	0.7498	0.9113	0.1615
	Pandemic & war	0.7759	0.0628	0.6882	0.8912	0.2029
Luxembourg	Entire sample	0.6972	0.1030	0.3231	0.9132	0.5901
	Regular times	0.7125	0.0892	0.4467	0.9132	0.4665
	Pandemic & war	0.6367	0.1295	0.3231	0.8418	0.5188
The Netherlands	Entire sample	0.8175	0.0593	0.6122	0.9257	0.3135
	Regular times	0.8262	0.0560	0.6122	0.9257	0.3135
	Pandemic & war	0.7827	0.0596	0.6840	0.9001	0.2160
Portugal	Entire sample	0.8036	0.0707	0.5976	0.9248	0.3272
	Regular times	0.8125	0.0700	0.5976	0.9248	0.3272
	Pandemic & war	0.7681	0.0625	0.6828	0.9110	0.2282
Spain	Entire sample	0.7892	0.0601	0.6091	0.9051	0.2960
	Regular times	0.8004	0.0528	0.6523	0.9051	0.2528
	Pandemic & war	0.7451	0.0672	0.6091	0.8926	0.2835
Sweden	Entire sample	0.6996	0.0807	0.4492	0.8616	0.4124
	Regular times	0.6996	0.0817	0.4492	0.8616	0.4124
	Pandemic & war	0.6995	0.0773	0.4629	0.8525	0.3896
'New' Member States						
Czechia	Entire sample	0.7922	0.0647	0.5504	0.9291	0.3787
	Regular times	0.8058	0.0559	0.5897	0.9291	0.3394
	Pandemic & war	0.7384	0.0698	0.5504	0.8622	0.3118
Estonia	Entire sample	0.7605	0.0733	0.4610	0.9010	0.4400
	Regular times	0.7770	0.0585	0.5986	0.9010	0.3024
	Pandemic & war	0.6952	0.0885	0.4610	0.8581	0.3971
Hungary	Entire sample	0.7908	0.0681	0.6040	0.9323	0.3283
	Regular times	0.8053	0.0636	0.6612	0.9323	0.2711
	Pandemic & war	0.7331	0.0537	0.6040	0.8593	0.2553
Latvia	Entire sample	0.7908	0.0762	0.5728	0.9234	0.3506
	Regular times	0.8071	0.0668	0.6136	0.9234	0.3098
	Pandemic & war	0.7263	0.0774	0.5728	0.8582	0.2855
Lithuania	Entire sample	0.7549	0.0663	0.5414	0.9030	0.3616
	Regular times	0.7641	0.0579	0.5820	0.9030	0.3210
	Pandemic & war	0.7183	0.0837	0.5414	0.8662	0.3248
Malta	Entire sample	0.7721	0.0909	0.4820	0.9551	0.4731
	Regular times	0.7695	0.0948	0.4820	0.9551	0.4731
	Pandemic & war	0.7826	0.0729	0.5988	0.9390	0.3402
Poland	Entire sample	0.8100	0.0638	0.6566	0.9100	0.2534
	Regular times	0.8260	0.0559	0.6802	0.9100	0.2298
	Pandemic & war	0.7467	0.0531	0.6566	0.8481	0.1915
Slovakia	Entire sample	0.7768	0.1128	0.3469	0.9501	0.6032
	Regular times	0.7831	0.1128	0.3656	0.9501	0.5845
	Pandemic & war	0.7522	0.1107	0.3469	0.9416	0.5947
Slovenia	Entire sample	0.7959	0.0589	0.6296	0.9121	0.2825
	Regular times	0.8043	0.0513	0.6296	0.9121	0.2825
	Pandemic & war	0.7626	0.0740	0.6450	0.9042	0.2592

Note. The missing observation for Italy in April 2020 has been imputed as a mean value of the neighbouring cells, i.e. the observations for March and June 2020.

Source: European Commission database.

Comparing the mean values of the consensus measure show that the lowest average values, signifying low consensus on expected prices, are observed in Luxembourg, Sweden, Finland and France. These are all 'old' EU countries with a long history in the joint European economy, and a low consensus on expected prices suggests substantial dispersion of opinion on which direction the prices are going within a 3-month forecast horizon. On the other hand, the highest mean values are noted in Italy, the Netherlands, Poland and Portugal, in which case there is no apparent reason for this similarity.

Relatively small differences in the consensus, as measured by the standard deviation, characterises Italy, Germany, Greece and Belgium (so again the 'old' EU countries). This finding suggests that the strength of the consensus is relatively stable over time for the 'old' EU in comparison to the 'new' Member States. The highest variation in time, evident in both high standard variation and high maximum values of the consensus measure, are observed for Slovakia, Luxembourg and Malta. In these small economies, the strength of the consensus might vary – i.e. it can go from a relative agreement to a clear disagreement – more dynamically than in big economies.

Unfortunately, there are no previous analyses of the price consensus across EU countries with which these results could be directly compared. However, Wolszczak-Derlacz and De Blander (2009) examine the price dispersion in the EU-15 and three NMSs (Czechia, Hungary and Poland) between 1995 and 2006 on the basis of both aggregate and disaggregate price data. They demonstrate that for each category of goods, the price dispersion is lower in the EU-15 than in all the examined countries together (EU-15 plus 3). The conclusion is that the NMS introduce more variation to the price dynamics. These results cannot be directly compared to the analysis of price expectations presented in this study but both suggest that there are more differences among the NMS regarding prices and price expectations than among the 'old' EU countries.

More patterns emerge across subsamples. The average consensus was higher in the 'regular times' subsample than in the 'pandemic and war' subsample in all EU countries (except France and Malta). One of the possible explanations is that in the untypical subperiods of the pandemic and war, enterprises face much greater difficulties in establishing a consensus over the direction of the expected prices. Also, for most countries, the strength of the consensus as measured by the standard deviation was less uniform during the 'pandemic and war' subsample, with a non-intuitive combination of exceptions including France, Hungary, Malta, Poland, Portugal, Slovakia and Sweden. The general observation that the variation in the consensus is usually greater in wartime or pandemic conditions attests to the difficulties the respondents have in agreeing on the expected behaviour of prices in an anomalous economic environment.

In order to verify whether the differences in the average levels of the consensus between the ‘regular times’ and the ‘pandemic and war’ subsamples were statistically significant, a two-sided test for statistical significance of the difference in means was conducted. Its results (*p* values for the null hypothesis of equality in means) are presented in Table 2.

Table 2. Results of the two-sided test for statistical significance of the difference in means between the subsamples

Country	*p* value
EU average	0.0000
‘Old’ Member States	
Austria	0.0000
Belgium	0.0000
Denmark	0.0068
Finland	0.0000
France	0.0739
Germany	0.0000
Greece	0.0000
Italy	0.0000
Luxembourg	0.0004
The Netherlands	0.0000
Portugal	0.0000
Spain	0.0000
Sweden	0.9945
‘New’ Member States	
Czechia	0.0000
Estonia	0.0000
Hungary	0.0000
Latvia	0.0000
Lithuania	0.0009
Malta	0.3112
Poland	0.0000
Slovakia	0.0966
Slovenia	0.0007

Note. The missing observation for Italy in April 2020 has been imputed as a mean value of the neighbouring cells, i.e. the observations for March and June 2020.

Source: European Commission database.

The null hypothesis of equal mean consensus in the ‘regular times’ and ‘pandemic and war’ subsamples was rejected for the majority of EU countries with the exception of France, Malta, Slovakia and Sweden. France and Malta had already been identified as special cases because they alone form a subset of EU countries in which the average consensus is lower in the 'regular times' subsample than in the 'pandemic and war' subsample, although by a small margin and, as Table 2 shows, statistically insignificant. The remaining countries, Slovakia and Sweden, belong to a small category of countries in which the difference in the strength of the consensus is lower during the 'pandemic and war' subsample than the 'regular times' subsample. Since these countries share no obvious consensus-specific similarities, the explanation for the lack of significance of the differences in means across the subsamples should perhaps be attributed to the characteristics of inflation expectations, which, however, is outside the scope of this paper.

It is interesting to observe that there does not seem to be any pattern in the consensus on price expectations with respect to the eurozone countries (which, since 2024, have been the following countries: Austria, Belgium, Croatia, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Portugal, Slovakia, Slovenia and Spain). The common currency might cause price expectations to be more uniform across the eurozone countries, but this hypothesis is not confirmed by the indicator of the degree of consensus on price expectations of the EU Member States.

As the next step, correlation coefficients of a sign-sensitive consensus measure (lagged three months) with the observed 3-month changes in prices are presented in Table 3 for the entire sample and the two subsamples. It is worth noting that the sizes of the coefficients cannot be meaningfully interpreted in terms of the usefulness of the consensus measure as a leading indicator of the expected changes in prices. Many country-specific factors influence the relationships between the strength of the consensus on the expected price changes and price indices themselves that remain outside the scope of the framework of this analysis (e.g. the degree of political and social stability that impact the precision of price forecasts or ease of access to reliable macroeconomic data across countries). Therefore, correlation coefficients presented in Table 3 should not be evaluated in terms of the usefulness of the variance-based consensus measure as a forecasting tool for prices. They are provided solely for inter-country comparisons of the relative strength of the relationship between the price consensus and price changes.

Table 3. Correlation coefficients of the consensus measure (4) with the observed changes in prices (5) for the entire sample (January 2005–December 2023) and the subsamples

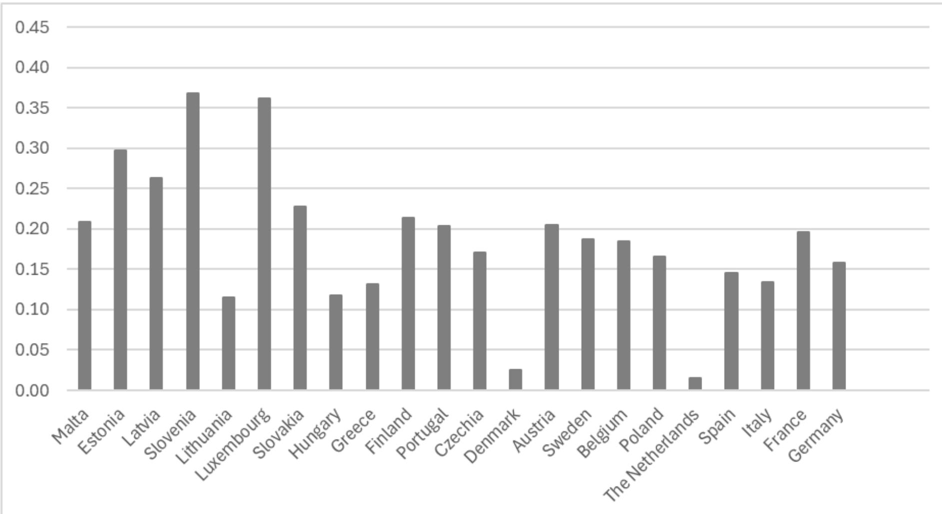
Country	Entire sample	Regular times	Pandemic and war
EU average	0.1601	0.1884	0.1795
'Old' Member States			
Austria	0.2046	0.2815	0.3324
Belgium	0.1850	0.1699	0.2839
Denmark	0.0259	–0.0275	0.1662
Finland	0.2131	0.2253	0.2888
France	0.1959	0.1977	0.1710
Germany	0.1581	0.2370	0.2503
Greece	0.1314	0.1577	0.1486
Italy	0.1346	0.2584	0.1388
Luxembourg	0.3615	0.2796	0.5543
The Netherlands	0.0154	–0.0090	0.1388
Portugal	0.2035	0.2032	0.3000
Spain	0.1460	0.1286	0.0993
Sweden	0.1878	0.1469	0.3352
'New' Member States			
Czechia	0.1708	0.1306	0.2113
Estonia	0.2973	0.4052	0.4688
Hungary	0.1174	0.1258	–0.0009
Malta	0.2086	0.1740	0.2080
Latvia	0.2630	0.3657	0.1944
Lithuania	0.1147	0.1368	0.1961
Poland	0.1663	0.2265	0.0601
Slovakia	0.2275	0.3207	0.0660
Slovenia	0.3686	0.3525	0.5070

Note. The sample for Denmark, Lithuania and Portugal are slightly shorter (price index data for January 2005–March 2005 were not available). The missing observation for Italy in April 2020 has been imputed as a mean value of the neighbouring cells, i.e. the observations for March and June 2020.

Source: European Commission database, Eurostat.

The highest correlation coefficients with the observed price changes were recorded for Estonia, Slovenia and Luxembourg, which are all small economies. It appears that the relatively strong connection between the strength of the price consensus and the actual price changes is easier to achieve in small rather than large economies. The lowest correlation coefficients characterise Denmark, Hungary and the Netherlands. They form a group for which it is difficult to find a common denominator. In Figure 2, values of the correlation coefficients for the entire sample are presented for countries ordered by size of their economies (gross domestic product at current market prices in 2024 as measured by Eurostat, in millions of euro).

Figure 2. Correlation coefficients of the consensus measure with the observed changes in prices for the entire sample, ordered by size of the economy



Source: author's work based on European Commission and Eurostat data.

Smaller countries (in terms of the total GDP) are generally characterised by stronger correlations between the degree of the consensus on the expected prices and the observed changes in prices, but as the size of an economy measured by GDP increases, this pattern disappears. A lack of clear-cut results regarding the interdependence between the consensus and the observed price changes may be partly explained by the absence of an important factor, namely the prevalence of either forward- or backward-looking information in expectations generating processes in individual countries. The Bachmann et al. (2013) paper, in which a variance-based consensus measure is proposed, defines the consensus in terms of the forward-looking behaviour: 'We use these categories to define two forward-looking indices concerning expectations and two indices of current activity' (p. 9). However, the empirical studies on the degree of forward- or backward-lookingness in EU countries yield mixed results. For example, in various studies, Sweden turns out to have a significant backward-looking component in inflation expectations (Łyziak, 2009), but also a high degree of forward-lookingness (Szyszko & Rutkowska, 2019). Further analyses of the influence of the properties of the formation process of expectations on the consensus, along with the impact of other country-specific characteristics, exceeds the scope of this analysis.

As far as subsamples are concerned, a slight majority of countries produce the highest correlation coefficients during the 'pandemic and war' subsample. With the exceptions of Czechia and Slovenia, they are all 'old' EU countries. It follows that during difficult times of the pandemic or war, seniority in the EU helps the respondents to evaluate the direction of expected price changes in line with the actual price developments.

Again, there is no noticeable effect of the fact if a country belongs or not to the eurozone on the size of the correlation coefficients between the consensus measure and the observed price changes.

5. Conclusions

It follows from the variance-based consensus measure that the lowest consensus on the expected prices and relatively little variation in the consensus appear across the 'old' EU countries. Opinions on the direction of expected price changes vary substantially but remain stable in time – i.e. price expectations in the 'old' EU countries do not jump between agreement and disagreement but rather consistently remain in disagreement. Shifting from agreement to disagreement on the expected prices is visible in the small economies of Slovakia, Luxembourg and Malta. For almost every country, the consensus on the expected prices is higher in the 'regular times' subsample than in the 'pandemic and war' one, and for many countries, the differences in the strength of the consensus are larger during the 'pandemic and war' subsample. While it is relatively easy to establish a consensus (presumably of expected increases in prices) in wartime or pandemic conditions, the unpredictability of the political, and thus economic environment increases the differences in the strength of the consensus.

As far as the correlation of the consensus on expected prices with the observed price changes is concerned, the highest correlation coefficients are recorded for the small economies of Estonia, Slovenia and Luxembourg, which suggests that the relationship between the strength of the price consensus and the actual price changes is stronger in small rather than large economies. Analysing the correlation coefficients across the subsamples shows that during difficult times of the pandemic and war, the seniority in the EU helps the respondents to predict the direction of the expected price changes in line with the actual price developments.

There are no recognisable patterns, either in the descriptive statistics of the consensus measure or the sizes of the correlation coefficients with the observed changes in prices, or as far as belonging or not to the eurozone is concerned. Sharing a common currency does not facilitate the consensus on the expected price changes nor does it strengthen the correlation between the price consensus and the observed changes in prices.

The main limitation of the research on the consensus presented in this paper lies in the weakness of the consensus measure itself: its original version (3) does not specify whether the consensus is 'positive' (that is, respondents agree that prices will go up) or 'negative' (where the respondents agree that prices will decrease). A sign-sensitive version (4) used in this paper attempts to combine the strength and the inclination of the consensus, but it does not take into account the size of the balance statistics and therefore does not allow the differentiation between the balance of e.g. +40 (signifying a clear majority of respondents expecting an increase in prices) and +4 (only a small majority of those expecting an increase in prices). However, since the balance statistic is the measure of a central tendency and a consensus measure is the measure of dispersion, combining them in a single index presents a challenge. An important task for further research would be to redefine and improve the sign-specific consensus measure (4).

Another limitation of the empirical analysis presented in this paper is the absence of country-specific factors. Prevalence of forward- or backward-looking information in the process of the formation of expectations, dependence of the economy on imported fuel or the degree of fragmentation of the country's industrial sector are just some of the factors to consider. Taking into account the specific characteristics of individual countries that may influence the consensus on price expectations should underline any future research in this field.

Another possible direction for further study could be the search for other measures of consensus, e.g. those rooted in evolutionary biology. One of the key aspects of biodiversity, evenness, is defined as follows: 'A community is perfectly even if every species is present in equal proportions, and uneven if one species dominates the abundance distribution' (Daly et al., 2018, p. 5). The 'abundance distribution' here stands for the distribution of numbers of individual species in a community. There is no straightforward transfer of the biodiversity concepts to economic applications (for example, it would be difficult to find an economic equivalent of one of the key concepts of biodiversity, i.e. the number of species in a community), but the growing role of evolutionary tools in the economic analysis opens a promising path for further research.

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Sustainable development in Poland in quantitative terms – state as of 2022

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Abstract. Sustainable development remains one of the major challenges for contemporary Poland, where dynamic economic growth often collides with social inequalities and environmental degradation. In relation to these challenges, this paper aims to assess the level of sustainable development in voivodships (highest-level administrative division of Poland, equivalent to a province) based on an extended analytical framework that adds an institutional-political dimension to the three core aspects of sustainable development – social, economic and environmental. The study relies on data from 2022 on individual voivodships, from which 20 variables describing the aforementioned aspects of sustainable development are selected. In the extended approach, these aspects are often referred to as 'orders'. For each voivodship, Hellwig's measure is calculated using multidimensional comparative analysis and linear ordering. Based on these calculations, rankings of Polish voivodships are created and visualised by means of cartograms created in R. Additionally, an analysis of the similarity of objects relative to each other is conducted using Euclidean distance matrices. The research shows, among other aspects, which orders of sustainable development constitute the strengths and which represent weaknesses of a given voivodship. The study refers to literature discussing the concept of sustainable development and methods of quantifying it, as well as literature describing the applied research methodology.

Keywords: sustainable development, Hellwig's measure, multidimensional analysis, linear ordering, distance matrix, rankings of Polish voivodships

JEL: C44, Q01, Q5, R5

1. Introduction

Sustainable development is a concept appearing increasingly often in public discourse. Major global organisations such as the United Nations and the European Union, as well as the media, strive to raise public awareness of sustainable development, which is regarded by highly developed countries as the primary direction of development for the future. Nevertheless, achieving sustainable development remains a complex challenge, influenced by factors such as political instability, administrative inefficiency, resource limitations, social and economic disparities across regions and possibly a still

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insufficient level of self-awareness among a large segment of the population regarding sustainable development. Recognising these limitations highlights the need for continuous, multidimensional research and adaptive policy-making. The analysis of sustainable development can be seen as an extension of quality-of-life studies, as it goes beyond the socio-economic aspects commonly used in such research to include other, less obvious dimensions. Consequently, this approach offers a broader perspective on the issue and enables the formulation of more complex conclusions.

The aim of the paper is to evaluate the level of sustainable development across Polish voivodships by incorporating the institutional-political dimension alongside the commonly recognised social, economic and environmental ones. The inclusion of this additional dimension plays a crucial role as it complements the three main aspects and thus offers a broader, more holistic view of sustainable development. For example, a well-trained and non-corrupt administration, supported by non-profit organisations can contribute to making more rational decisions regarding environmental protection (including the management of natural resources), improving economic indicators (for instance, investments are carried out more efficiently when legal regulations and administration support economic activity) and enhancing the situation of the society (e.g. well-educated officials can improve road safety). It is also worth mentioning that in this context, 'dimensions' are often referred to as 'orders' of sustainable development.

Sustainable development, as one of the most popular development concepts, has been widely accepted, at least at the level of general formulations and assumptions. This concept is described as an attempt to holistically integrate humanity, the environment and the economy, standing in opposition to the traditional approach that treats these three categories as separate (Buchard-Dziubińska et al., 2014). The notion of sustainable development is also described as a response to the increasing concerns about the burden placed on our planet's ecosystems and caused by anthropogenic factors. This response takes the form of a strategy aimed at eliminating or reducing the imbalance that may arise between economic and social development, as well as between socio-economic development and the natural environment (Poskrobko, 2009). It is also said that sustainable development most often appears in two contexts. The first is the discussion about development goals and the tools to achieve them. The second context is the perception of sustainable development as a relationship between humans and the environment which must be shaped according to new principles (Trzepacz, 2012). All of the perspectives above boil down to the assumption that humans, as leaders of civilizational (including economic) development, are obligated to strive for a particular harmony with the natural environment.

As regards the formal definition of sustainable development, the most popular one was formulated in 1987 in a report titled *Our Common Future* (also known as the *Brundtland Report*), prepared by the World Commission on Environment and Development. In this report, we read: 'Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs' (United Nations Secretary-General. World Commission on Environment and Development, 1987). Analysing the cited definition, we may conclude that acting in accordance with sustainable development means seeking a vision of civilisation that continuously 'satisfies' humanity while simultaneously caring for the well-being of future generations.

The literature shows that there are several ways that sustainable development may be perceived. One of the basic approaches involves distinguishing its three fundamental dimensions: social, economic and ecological (Atkinson et al., 2014; Baum, 2021; Gupta & Vegelin, 2016; Ilić Krstić et al., 2018; Islam, 2025; Mensah, 2019; Stec et al., 2024). These are interrelated dimensions, with the human at the centre, striving to maintain a balance between them. This perspective is often visualised by means of a Venn diagram, consisting of three circles corresponding to the individual dimensions.

The concept above serves as a starting point for more advanced, comprehensive analyses of sustainable development, where accounting for additional dimensions influencing sustainability often poses a significant challenge. However, this approach may contribute to fulfilling an existing research gap. One of these analyses additionally includes the spatial dimension, according to which development should be characterised by rational methods of land and space use. The human task is to consciously organise their environment, both natural and anthropogenic. Examples of such actions include ensuring proper policies related to nature protection, as well as maintaining appropriate hygiene and cleanliness in areas inhabited by humans, particularly in cities. It is important to emphasise that this approach to sustainable development treats land as a particularly valuable resource due to its limited character and non-reproducibility in production processes (Buchard-Dziubińska et al., 2014).

Another expanded perspective on sustainable development, which this paper is based on, involves highlighting an additional, fourth dimension known as the institutional-political dimension. As mentioned before, in this framework, the dimensions are often called 'orders' of sustainable development. Their mutual integration and maintaining proper balance between them aim to improve the broadly understood quality of life for present and future generations. In practice, these orders are associated with the following actions:

- social order, i.e. combating poverty, fostering cultural development and meeting fundamental human needs, such as access to healthcare and education;
- economic order, i.e. pursuing economic growth that ensures a sufficient supply of goods and services and increasing market innovation;

- environmental order, i.e. developing solutions to reduce the consumption of natural resources, protecting the environment from further degradation and raising public awareness of ecological issues;
- institutional-political order, i.e. shaping efficient and strong public institutions, providing citizens with access to justice and promoting an inclusive society (Drabarczyk, 2017).

When discussing sustainable development from the perspective of the four orders, it is important to precisely define the concept of order. According to Sztumski (2006, p. 74), 'It is an organisation of a system that enables the harmonious functioning of its elements in such a way that the system as a whole can effectively fulfil its purpose and carry out the tasks for which it is intended'. A conventional division of the system into parts can correspond to the individual orders of sustainable development, depending on the specific domain.

The result of sustainable development is the achievement of an 'integrated order'. This is interpreted as a target state that ensures the cohesive and simultaneous attainment of the four specified orders (Balas & Molenda, 2016). In Borys (2011), we can read that 'Integrated order is the target state of sustainable development, a reference point for developmental changes characterized by the quality of sustainability. This implies that sustainable development cannot be equated with integrated order because the first one is a process, and the second one is the target state of developmental changes'. As a result, achieving all orders simultaneously guarantees entry onto the path of sustainable development, which is considered as a (potentially long-term) process. Remaining on this path, in turn, enables the establishment of certain developmental patterns, which collectively contribute to the formation of an integrated order.

The remaining part of this paper is organised as follows. Section 2 describes the methods used to conduct the study, along with their main assumptions and the applied formulas. This section is also dedicated to the 20 variables used in the study. Section 3 presents a multidimensional comparative analysis which contains all necessary calculations for the construction of rankings and classifications aiming to quantify sustainable development in each voivodship. Finally, in Section 4, the study results are summarised and interpreted.

2. Methodology

In this paper, an attempt is made to quantify sustainable development based on multidimensional comparative analysis. This notion is associated with a group of mathematical methods used to analyse objects in terms of certain complex phenomena that require multiple (at least two) variables for their characterisation. The term 'object' refers to the examined units subject to classification or grouping (Ulmann, 2020). With regards to the previous chapter, the extended concept of sustainable development boils down to distinguishing its four main dimensions called orders (social, economic, environmental and institutional-political). To conduct a multidimensional comparative analysis, the individual orders must be associated with specific sets of objects and variables that describe these objects. Due to the chosen topic, the set of objects is formed by voivodships in Poland. The variables are divided into four equal groups corresponding to the different dimensions of sustainable development. All characteristics pertain to the year 2022, and their selection is based on the report of the Statistical Office in Katowice titled *Sustainable Development Indicators for Poland* (Pol. *Wskaźniki zrównoważonego rozwoju Polski;* Urząd Statystyczny w Katowicach, 2015). Although the aforementioned report includes a broad set of variables (e.g. public expenditure on education as a percentage of GDP or energy intensity of the economy), not all of them are suitable for regional-level analysis due to the lack of complete or comparable data across voivodships. Owing to the extensive number of indicators presented in the report, a more selective approach is adopted in this study. The variables are selected to ensure diversity and to represent various aspects of each of the examined dimensions – social, economic, environmental and institutional-political. This approach allows maintaining a balance between comprehensiveness and clarity. The data sources include Statistics Poland, Office of Rail Transport (Urząd Transportu Kolejowego) and the Polish National Police Portal (Portal Polskiej Policji).

The study applies methods such as Hellwig's measure of development and distance matrix construction. The first one is a well-known multi-objective procedure used in various fields such as banking or social sciences due to its ability to assess and compare objects based on multiple criteria. Hellwig's method has also undergone various modifications presented in Roszkowska (2024) and Roszkowska et al. (2024). Other methods are also commonly applied in the multidimensional analysis of sustainable development, such as TOPSIS, weighted sum and ELECTRE (Lindfors, 2021). The choice of Hellwig's method is guided by its computational simplicity and clarity of interpretation. Unlike TOPSIS, it does not require the identification of an anti-pattern, which reduces the complexity of the procedure. It is important to underline that each method is based on different assumptions. While both Hellwig's measure and TOPSIS rely on reference points, ELECTRE operates on an outranking relation, which makes direct comparisons between such techniques challenging. The selection of a method therefore depends on the preferences of the decision-maker and the purpose of the analysis. For instance, if the goal is to create a ranking relative to reference values, pattern-based methods like Hellwig's measure are appropriate. On the other hand, if the analyst questions the influence of extreme reference values, methods such as ELECTRE may be more suitable.

In general, the set of objects studied in relation to a certain complex phenomenon can be represented as:

$$\Omega = \{O_1, O_2, O_3, \dots, O_N\}, \tag{1}$$

where $O_1, O_2, O_3, \dots, O_N$ describe objects examined due to some complex phenomenon and N represents the total number of objects in the study.

The set of variables (sustainable development indicators) can be expressed as:

$$X = \{X_1, X_2, X_3, \dots, X_K\}, \tag{2}$$

where $X_1, X_2, X_3, \dots, X_K$ indicate variables describing the objects and K is the total number of variables.

The objects and variables defined in this way form an observation matrix (realisations of variables) with dimensions $N \times K$ in the following form:

$$X_{N \times K} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1K} \\ x_{21} & x_{22} & \cdots & x_{2K} \\ \cdots & \cdots & \cdots & \cdots \\ x_{N1} & x_{N2} & \cdots & x_{NK} \end{bmatrix}, \tag{3}$$

where x_{ik} denotes the value of the k-th variable for the i-th object ($i = 1, \dots, N$; $k = 1, \dots, K$).

Based on matrix $X_{N \times K}$, the following procedure is applied to calculate Hellwig's measure of development:

1. Identification of the nature of the variables (divided into stimulants, destimulants, nominants);
2. Unifying the nature of the variables (bringing the variables into the form of stimulants);
3. Normalisation of units and scales of variables through unitarisation using the following formula:

$$z_{ik} = \frac{x_{ik} - x_k^{min}}{x_k^{max} - x_k^{min}}, \tag{4}$$

where x_k^{max} (x_k^{min}) denotes the maximum (minimum) value of the k-th variable and z_{ik} represents the normalised value of the k-th variable for the i-th object, corresponding to value x_{ik}.

Normalisation can also be performed in other ways. Example formulas can be found in studies such as Gaspars-Wieloch (2012), Roszkowska (2011) and Vafaei et al. (2018), but the normalisation procedure applied in this research is quite universal, as it can be used for both positive and negative data. Moreover, it allows assigning a zero value to the worst object in the group and a unit value to the best object.

The choice of any normalisation technique affects the scaling of the variables, which, in turn, impacts the synthetic measure. In the case of unitarisation, the main factor determining the normalised value is outliers recorded for a given variable. Therefore, if these values differ significantly from the intermediate values, the results obtained through unitarisation may not be fully useful when determining the synthetic measure. This issue does not occur with other methods, such as standardisation. In this study, the authors conduct a statistical analysis of the source data (available in the following link: https://docs.google.com/spreadsheets/d/1W5vt9DYqITRxGaoaCd18DJzJ7Qn9F7Wb /edit?usp=sharing&ouid=116594861186276178752&rtpof=true&sd=true) and conclude that, although some variables exhibit significant asymmetric outliers, unitarisation remains a justified choice due to its widespread use in the literature (Kukuła & Bogocz, 2014; Leń et al., 2016; Radzka et al., 2015). Nevertheless, in cases of excessive asymmetry, this issue can be addressed by applying alternative techniques that limit the influence of extreme values in statistical data (Łuczak et al., 2025; Łuczak & Just, 2020a, 2020b; Łuczak & Just, 2021). Hence, future research could compare the results with those derived from other normalisation methods in order to assess the stability of the results.

The result of the transformation is a matrix of a normalised observation:

$$Z_{N\times K} = \begin{bmatrix} z_{11} & z_{12} & \cdots & z_{1K} \\ z_{21} & z_{22} & \cdots & z_{2K} \\ \cdots & \cdots & \cdots & \cdots \\ z_{N1} & z_{N2} & \cdots & z_{NK} \end{bmatrix}; \tag{5}$$

4. Finding the pattern in the cross-section of each variable according to the following formula:

$$z_0 = [z_{01} \dots z_{0K}], \text{where } z_{0k} = \max_i(z_{ik}); \tag{6}$$

5. Calculating the distance between the i-th object and the pattern:

$$d_i = \sqrt{\sum_{k=1}^{K} (z_{0k} - z_{ik})^2}, \tag{7}$$

Higher values of d_i indicate a lower similarity of the i-th object to the hypothetical pattern;

6. Calculating the values of Hellwig's measure of development. For the i-th object, we compute:

$$H_i = 1 - \frac{d_i}{d_0}, \tag{8}$$

where $d_0 = \overline{d} + 2s_d$, for $\overline{d} = \frac{1}{N}\sum_{i=1}^{N} d_i$, $s_d = \sqrt{\frac{1}{N-1}(d_i - \overline{d})^2}$.

The highest possible value of Hellwig's measure is one, which represents an extreme case where the i-th object corresponds to the ideal object, where it is identical to the pattern. Smaller values of the measure indicate a worse realisation of the studied complex phenomenon. If there are objects in the data set that are significantly worse and deviate from the others, the measure can take values below zero (Appenzeller & Jurek, 2018);

7. Ranking of the objects according to descending H_i;
8. Classification of objects into classes based on the value of Hellwig's measure. To facilitate interpretation, the following additional notation is introduced:
   $\overline{H}$ – the average value of Hellwig's measure in the set of the analysed objects,
   s_H – the standard deviation of Hellwig's measure in the set of the analysed objects.
   The classification rules are presented in Table 1:

Table 1. Classification of objects based on the value of Hellwig's measure

Two-class	Three-class	Four-class
Above average $H_i > \overline{H}$	Good $H_i > \overline{H} + s_H$	Very good $H_i > \overline{H} + s_H$
Below average $H_i \leq \overline{H}$	Average $\overline{H} - s_H \leq H_i \leq \overline{H} + s_H$	Good $\overline{H} < H_i \leq \overline{H} + s_H$
	Poor $H_i < \overline{H} - s_H$	Average $\overline{H} - s_H < H_i \leq \overline{H}$
		Poor $H_i \leq \overline{H} - s_H$

Source: Appenzeller and Jurek (2018).

In the present analysis, a four-class division is applied;

9. Calculating the Sustainable Development Index (SDI) as the arithmetic mean of Hellwig's measure values for each order, assuming equal importance for all dimensions. This provides a single aggregated value for each voivodship;
10. Repeating the ranking and classification procedure based on SDI values.

The next step of the study involves calculating the distance matrix, which allows for the examination of the similarity between objects. The distance between the i-th object and j-th object satisfies four conditions: non-negativity, symmetry, reflexivity and triangle inequality. To calculate the discussed distances, one of the most basic measures, the Euclidean distance, given by (9), is used:

$$d_{ij} = \sqrt{\sum_{k=1}^{K} (z_{ik} - z_{jk})^2}, \tag{9}$$

where z_{ik} and z_{jk} denote the normalised values corresponding to observations x_{ik} and x_{jk}.

The distances calculated in this way include all pairs of objects. The minimum value of the matrix (excluding the main diagonal, where values are zero due to the symmetry condition) identifies the pair of objects that are the most similar, while the maximum value indicates the pair of objects that are the most different.

According to the extended concept of sustainable development, the four main dimensions (orders), are distinguished: social, economic, environmental and institutional-political. This conceptual framework guides the selection of diagnostic variables used in the empirical study. As a result, 20 variables are selected and equally divided among the four orders, with five indicators assigned to each. This approach aligns with the fundamental idea of sustainable development, which emphasises the balanced and harmonious advancement of all orders. While this symmetrical structure highlights the equal importance of each order, the selection of variables is not random. Only indicators that demonstrate sufficient variability and low mutual correlation are included. To enhance the information value of the indicators, only variables with a coefficient of variation of at least 10% are considered. Although Appenzeller and Jurek (2018) recommend a higher threshold of around 20%, the authors lowered it due to data availability constraints.

The first five variables used in the study, i.e., $X_1, \ldots, X_5$, are assigned to the social order. Their names and types (stimulant, destimulant, nominant) are presented in Table 2 below.

Table 2. Indicators connected with the social order

Indicator	Name	Type
X_1	At-risk-of-poverty rate after considering social transfers in income	Destimulant
X_2	Road traffic fatalities per 100,000 population	Destimulant
X_3	Number of housing units put into use per 1,000 population aged 25–34	Stimulant
X_4	Share of adults participating in education or training aged 25–64	Stimulant
X_5	Number of doctors (personnel working in total) per 10,000 population	Stimulant

Source: authors' work.

The next group of variables pertains to the economic order of sustainable development. This group consists of variables $X_6, \dots, X_{10}$, which are presented in Table 3.

Table 3. Indicators connected with the economic order

Indicator	Name	Type
X_6	Labour productivity in the industrial sector	Stimulant
X_7	Voivodships budget revenues *per capita*	Stimulant
X_8	Share of railway lines adapted for speeds of 120 km/h and above in the total length of operational railway lines	Stimulant
X_9	Registered unemployment rate	Destimulant
X_{10}	Investment expenditures *per capita*	Stimulant

Source: authors' work.

Variables $X_{11}, \dots, X_{15}$ used in the study cover the environmental order. Their description is provided in Table 4.

Table 4. Indicators connected with the environmental order

Indicator	Name	Type
X_{11}	Share of renewable energy in total electricity production	Stimulant
X_{12}	Forest cover	Stimulant
X_{13}	Annual water consumption *per capita*	Destimulant
X_{14}	Municipal waste generated *per capita*	Destimulant
X_{15}	Share of legally protected areas in the total area	Stimulant

Source: authors' work.

The last order of sustainable development called institutional-political is described using variables $X_{16}, \dots, X_{20}$ (Table 5).

Table 5. Indicators connected with the institutional-political order

Indicator	Name	Type
X_{16}	Share of public administration units providing training for employees in telecommunications and information technology	Stimulant
X_{17}	Number of active non-profit organisations per 10,000 population	Stimulant
X_{18}	Number of corruption crimes per 100,000 population	Destimulant
X_{19}	Number of public administration employees per 10,000 population	Nominant
X_{20}	Share of women in the legislative bodies of local government units	Nominant

Source: authors' work.

3. Results

Using formula (8), the values of Hellwig's measure were calculated for each voivodship across the four orders of sustainable development. These values are presented in Table 6. Based on these values, as well as their descriptive statistics such as mean and standard deviation, rankings of voivodships were created. The objects in the rankings were divided into four groups: very good, good, average and poor. Each group reflects the qualitative level of the studied complex phenomenon. Due to the fact that the calculated aggregate variables are stimulants, voivodships characterised by higher values of Hellwig's measure occupy higher positions in the rankings. The visualisation of the analysis results is presented in Cartograms 1–4.

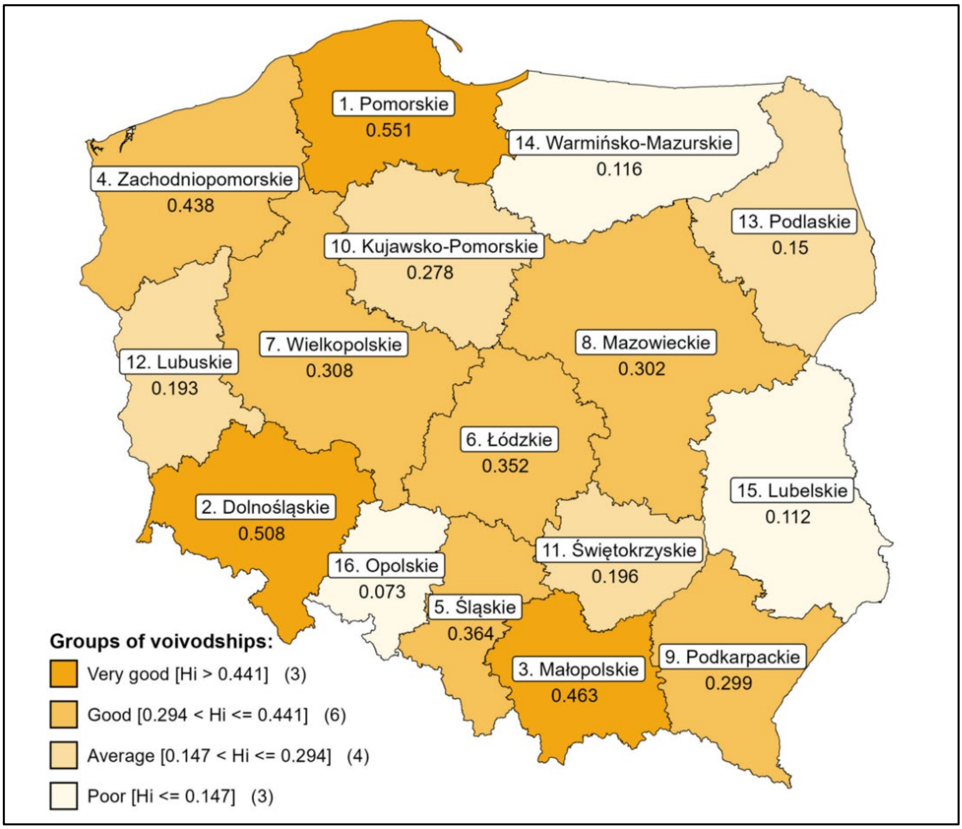
Table 6. Values of Hellwig's measure for individual voivodships

Voivodship	Social order	Economic order	Environmental order	Institutional-political order
Dolnośląskie	0.508	0.475	0.144	0.303
Kujawsko-Pomorskie	0.278	0.341	0.319	0.555
Lubelskie	0.112	0.226	0.331	0.235
Lubuskie	0.193	0.408	0.420	0.407
Łódzkie	0.352	0.330	0.135	0.279
Małopolskie	0.463	0.380	0.377	0.309
Mazowieckie	0.302	0.890	0.114	0.094
Opolskie	0.073	0.348	0.184	0.348
Podkarpackie	0.299	0.154	0.633	0.091
Podlaskie	0.150	0.227	0.514	0.049
Pomorskie	0.551	0.369	0.433	0.341
Śląskie	0.364	0.290	0.217	0.120
Świętokrzyskie	0.196	0.172	0.308	0.220
Warmińsko-Mazurskie	0.116	0.169	0.577	0.403
Wielkopolskie	0.308	0.459	0.220	0.415
Zachodniopomorskie	0.438	0.374	0.211	0.274

Source: authors' work.

In the case of the social order (Cartogram 1), the three top-performing voivodships are Pomorskie, Dolnośląskie and Małopolskie, while Warmińsko-Mazurskie, Lubelskie and Opolskie voivodships performed the most poorly. The group described as 'good' consists of six voivodships and forms the largest one. Based on the geographical location of the objects, it can be observed that voivodships with relatively higher values of Hellwig's measure are situated in north-western, central and southern Poland (excluding Opolskie Voivodship, which was mentioned before). In contrast, in the eastern part of the country, voivodships represent the social order of sustainable development less favourably. The range of this index is 0.478.

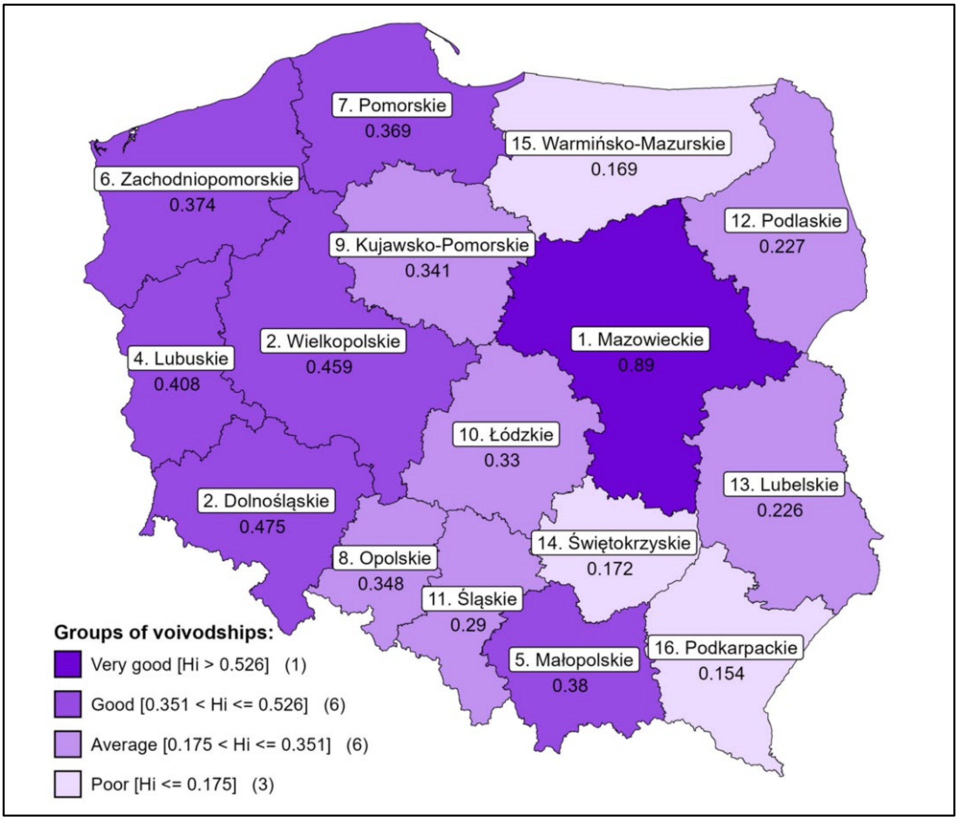
Cartogram 1. Social order across voivodships



Source: authors' work.

Analysing the values of Hellwig's measure in the context of economic order, as shown on Cartogram 2, a significant dominance of Mazowieckie Voivodship over other regions is evident. This voivodship is the only one classified in the 'very good' group, achieving an aggregate variable of 0.89, which is close to the pattern. Additionally, it borders only with voivodships classified as 'average' and 'poor'. Moreover, the 'good' group, excluding Małopolskie Voivodship, is predominantly located in the western part of the country. The range of Hellwig's measure for this order equals 0.735, which is more than twice the average value, due to the outlier value of Mazowieckie Voivodship.

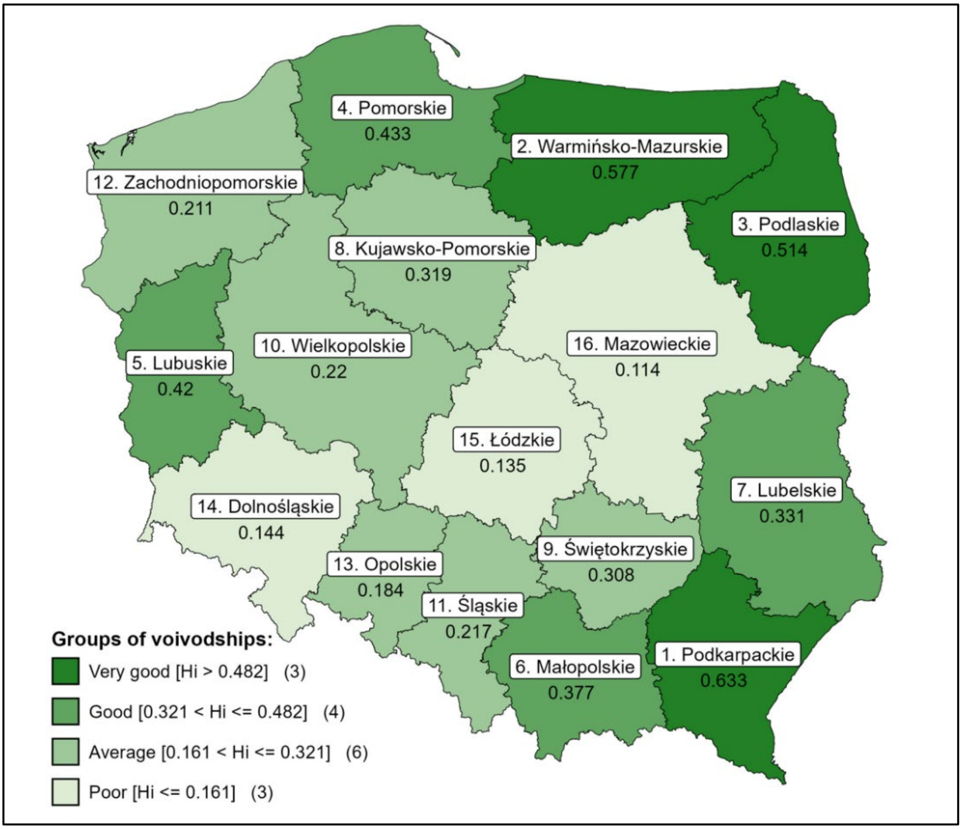
Cartogram 2. Economic order across voivodships



Source: authors' work.

Cartogram 3 reveals a clear regional differentiation of voivodships in terms of the environmental order of sustainable development. In the northern and south-eastern parts of the country, voivodships occupy the top half positions of the constructed ranking. This is likely due to the lower degree of industrialisation in these regions, which helps to maintain high ecological value. In contrast, there is a predominance of 'average' and 'poor' voivodships in central and south-western Poland. The 'very good' and 'poor' groups each consist of three voivodships. The 'very good' group includes Podkarpackie, Warmińsko-Mazurskie and Podlaskie voivodships. Meanwhile, Dolnośląskie, Łódzkie and Mazowieckie voivodships form the 'poor' group. The difference between the maximum and minimum values of the aggregate variable is 0.519.

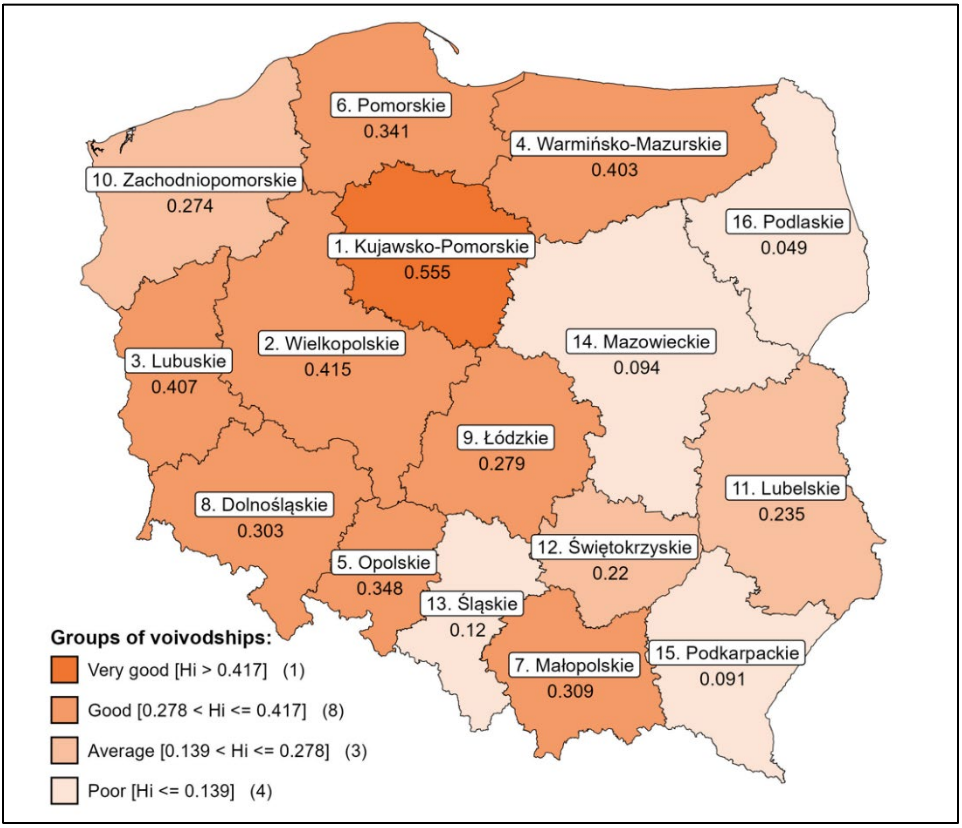
Cartogram 3. Environmental order across voivodships



Source: authors' work.

As regards the institutional-political order of sustainable development (Cartogram 4), voivodships located in the south-western and northern parts of Poland exhibit higher values of the index. Conversely, lower values are observed in the eastern part of the country. Similarly to the economic order, the 'very good' group consists of only one voivodship; however, this time, it is Kujawsko-Pomorskie Voivodship. The largest group is the one described as 'good', created by eight voivodships, representing half of all the objects. The range of the index values for this order is 0.506.

Cartogram 4. Institutional-political order across voivodships



Source: authors' work.

In the next step, we attempt to achieve the highest level of aggregation by creating an index that characterises the level of sustainable development in each voivodship with a single value. Assuming that each order has an equal impact on sustainable development and using the previously calculated Hellwig's measure values, the SDI is determined. From a mathematical perspective, this means that each order is assigned an equal weight, reducing the weighted average to an arithmetic mean. The SDI values are presented in Table 7. The voivodships are again divided into groups and a ranking is established.

Table 7. SDI values for individual voivodships

Voivodship	Sustainable Development Index
Dolnośląskie	0.358
Kujawsko-Pomorskie	0.373
Lubelskie	0.226
Lubuskie	0.357
Łódzkie	0.274
Małopolskie	0.382
Mazowieckie	0.350
Opolskie	0.238
Podkarpackie	0.295
Podlaskie	0.235
Pomorskie	0.423
Śląskie	0.248
Świętokrzyskie	0.224
Warmińsko-Mazurskie	0.316
Wielkopolskie	0.351
Zachodniopomorskie	0.325

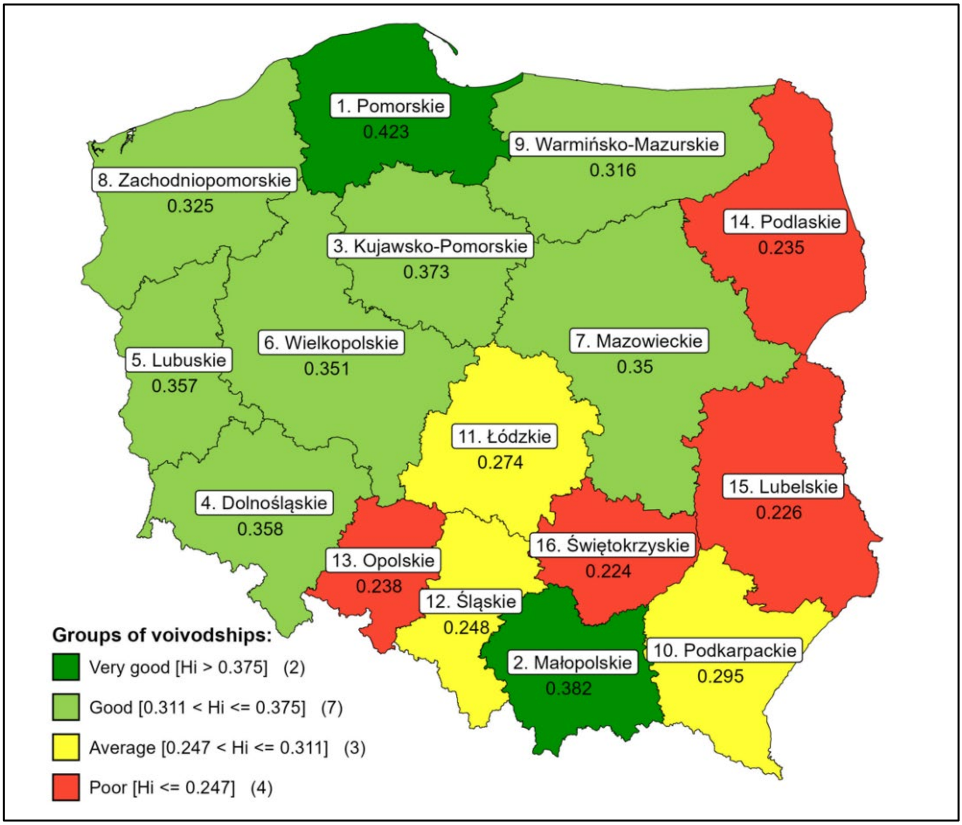
Source: authors' work.

Cartogram 5 illustrates that the four classes of voivodships, founded on SDI values, exhibit a certain degree of spatial coherence, forming distinct clusters. Below is a description of each class in detail:

a) Very good – this class is an exception, consisting of only two voivodships located on opposite sides of Poland: Pomorskie and Małopolskie. Notably, Pomorskie Voivodship borders only with voivodships from the 'good' group, whereas Małopolskie Voivodship is surrounded exclusively by 'average' and 'poor' voivodships. This is also the smallest class in this classification;
b) Good – the largest group among the analysed classes, comprising seven voivodships: Kujawsko-Pomorskie, Dolnośląskie, Lubuskie, Wielkopolskie, Mazowieckie, Zachodniopomorskie and Warmińsko-Mazurskie. This group covers nearly half of Poland's territory, predominantly extending across the northern and western regions;
c) Average – this class includes voivodships located in central and southern Poland: Podkarpackie, Łódzkie and Śląskie;
d) Poor – consisting of four voivodships: Opolskie, Podlaskie, Lubelskie and Świętokrzyskie. These objects are mostly situated in the eastern part of the country (Opolskie Voivodship is an exception), demonstrating the lowest level of sustainable development in the analysis.

It is also worth noting that the SDI has the smallest range among all the discussed indicators, which is around 0.2. This is due to the fact that the SDI, as an attempt at the highest level of aggregation, is based on averaged values.

Cartogram 5. The level of sustainable development across voivodships



Source: authors' work.

The analysis of the differentiation of voivodships for individual orders of sustainable development, which involves constructing a distance matrix, requires transforming all variables into stimulants and normalising their values. After that, using formula (9), Euclidean distances d_{ij} are calculated for each pair of voivodships. The results of the calculations are presented in Table 8 below.

Table 8. Euclidean distances between voivodships – summary across four orders of sustainable development

Order	Most similar voivodships	Value of d_{ij}	Most different voivodships	Value of d_{ij}
Social	Lubelskie, Podlaskie	0.218	Mazowieckie, Warmińsko-Mazurskie	1.599
Economic	Lubuskie, Małopolskie	0.230	Mazowieckie, Podkaprackie	1.699
Environmental	Dolnośląskie, Opolskie	0.272	Lubuskie, Świętokrzyskie	1.513
Institutional-political	Lubelskie, Świętokrzyskie	0.165	Kujawsko-Pomorskie, Mazowieckie	1.439

Source: authors' work.

Mazowieckie Voivodship appears among the most different pairs in three out of the four analysed categories. In contrast, Lubelskie Voivodship is part of the most similar pairs in the social and institutional-political orders. Lubuskie and Świętokrzyskie Voivodships are also noteworthy, as they belong to both the most similar and the most dissimilar pairs. This highlights the multidimensional nature of sustainable development: a region may be similar to others in one area while significantly differing in another. Overall, the differences in Euclidean distances between voivodships may reflect their regional specificities, which provides a valuable source of information for further research or more targeted, thematically differentiated regional policy interventions.

4. Conclusions

Below is a summary of our findings and the main conclusions formulated on the basis of our research results:

- Due to the economic and institutional-political orders, the voivodships located in the western part of the country exhibit relatively higher values of Hellwig's measure. It is important to emphasise that the economic order, in addition to the economic sphere, also includes such aspects as transport and labour productivity;
- Voivodships considered better in terms of the environmental order predominate in the northern and eastern regions of Poland;
- Mazowieckie and Podkarpackie voivodships serve as examples of regions that rank both at the top and bottom of the created rankings, depending on the analysed order of sustainable development. This may indicate problems in implementing a coherent policy in these areas;
- In the case of the SDI, some classes of voivodships form geographically homogeneous groups. This points to a certain disparity in the level of sustainable

development, suggesting the need to determine the exact causes of these differences and take relevant action to reduce their effects. This applies primarily to the region covering parts of central, southern and eastern Poland;

- Individual distance matrices correspond to the created rankings, as, on average, the most similar pairs of voivodships occupy similar, often adjacent ranking positions. Conversely, the most dissimilar pairs of voivodships tend to have relatively more distant or even extreme ranking positions, as exemplified by Mazowieckie and Podkarpackie voivodships in the context of economic order. It should be noted that this is not always the case, as 'different' does not necessarily mean 'worse';
- An advantage of the conducted research is the addition of a fourth order (institutional-political), which allows for a broader perspective on sustainable development;
- The study is characterised by objectivity due to equal weights assigned to individual orders of sustainable development, an identical number of variables for each order and equivalent weights for all criteria within each dimension;
- In similar research, differentiated weights may be applied based on the coefficients of variation or determined through expert surveys to identify the most influential indicators of sustainable development;
- It is important to consider that in a similar study, all ranking positions and, consequently, the conclusions drawn in the above points may change. Factors influencing these changes may include the selection of a different set of variables (which could be beneficial or detrimental for certain voivodships), assigning different weights to each order of sustainable development (if such an approach is considered), analysing different time periods and choosing a different calculation method, e.g. TOPSIS;
- The conducted analysis or similar studies can be expanded by incorporating the aspect of spatial autocorrelation or using the Extended Hellwig Method (Roszkowska & Filipowicz-Chomko, 2021), or applying a wider set of variables if data availability permits or if new challenges in regional sustainable development emerge;
- A further direction of research could involve monitoring the situation related to sustainable development in Poland during the implementation of the goals outlined in the 2030 Agenda, as well as after their achievement, and comparing the results from different study periods.

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Report from the 42nd National Scientific Conference named after him. Professor Władysław Bukietyński Methods and Applications of Operations Research MZBO

Grzegorz Tarczyński[a]

The 42nd National Scientific Conference named after him. Professor Władysław Bukietyński Methods and Applications of Operations Research MZBO (Pol. Metody i Zastosowania Badań Operacyjnych) was held on 13th–15th October 2024, in Zieleniec, Poland. The conference was organised by the Department of Economics and Operational Research of Wroclaw University of Economics and Business. Basic information about the conference is available at: https://badania.uew.pl/events/xlii-ogolnopolska-konferencja-naukowa-im-profesora-wladyslawa-bukietynskiego-metody-i-zastosowania-badan-operacyjnych-mzbo-2024/.

The organising committee included Grzegorz Tarczyński, PhD, DSc, Assoc. Prof. at the Wroclaw University of Economics and Business, and Piotr Peternek, PhD. The scientific committee was chaired by Marek Kośny, PhD, DSc, ProfTit.

The conference was held under the patronage of:
– His Magnificence the Rector of the Wroclaw University of Economics and Business;
– the Operations Research Section of the Polish Academy of Sciences;
– the Polish Section of INFORMS.

The conference topics focused on the methodological and application aspects of the mathematical modeling of decision problems, including:

- classical methods of operational research;
- soft and behavioural operational research;
- decision support systems and expert systems;
- optimisation models;
- multi-criteria decision support;
- decision-making under risk and uncertainty;
- group decision-making and negotiations;
- data science and data mining;

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- artificial intelligence and neural networks;
- evolutionary algorithms, fuzzy systems;
- applications of operational research;
- other related topics.

For over 40 years, the MZBO conference has been an important forum for the exchange of ideas and discussions on issues related to the theory and application of operational research. The main goal of the conference was to present the latest scientific achievements in the field of mathematical modelling of decision problems and to exchange experiences on the possibilities of applying methods and tools of the broadly-understood optimisation in economics, finance, management and other scientific disciplines.

The conference gathered 38 participants. This group consisted of faculty members or doctoral students of several universities and institutions, namely the AGH University of Krakow, Bialystok University of Technology, Krakow University of Economics, Maria Curie-Skłodowska University in Lublin, Nicolaus Copernicus University in Toruń, Poznań University of Economics and Business, Poznań University of Life Sciences, SGH Warsaw School of Economics, University of Economics in Katowice, University of Lodz, University of Szczecin, Wroclaw University of Economics and Business, and WSB Merito University Poznan.

During the conference, participants presented 29 papers on various topics, the main theme of which was optimisation and operational research. Additionally, two special sessions were held, organised by: the Operational Research Section of the Committee on Statistics and Econometrics of the Polish Academy of Sciences, chaired by Tadeusz Trzaskalik, PhD, DSc, ProfTit from the University of Economics in Katowice, who presented the current problems related to teaching operational research, and the Polish Section of INFORMS, where issues concerning the sharing economy were presented by Przemysław Szufel, PhD from the SGH Warsaw School of Economics. The sessions were chaired by Bogumił Kamiński, Józef Stawicki, Marcin Anholcer, Ewa Roszkowska, Marek Nowiński, Helena Gaspars-Wieloch, Artur Prędki, and Ewa Konarzewska-Gubała.

The following papers were presented during the thematic sessions of the conference:

- Tadeusz Trzaskalik, *Discussion panel on the teaching of operational research* (special session);
- Przemysław Szufel, *Optimizing task allocation and service technician routes in the sharing economy service model* (special session);
- Ewa Roszkowska, Dorota Górecka, *The use of multi-criteria methods based on reference points to assess the degree of implementation of sustainable development goals by the European Union countries*;

- Helena Gaspars-Wieloch, *AHP, scenario approach and optimism coefficient as support for new and risky projects in the case of independent criteria*;
- Marzena Filipowicz-Chomko, Ewa Roszkowska, *The use of the linguistic multi-criteria method based on the GDM2 measure to assess negotiation offers*;
- Dariusz Kacprzak, *A hybrid method for determining objective weights of decision-makers based on the entropy method and TOPSIS*;
- Witold Orzeszko, Grzegorz Dudek, Piotr Fiszeder, Radosław Pietrzyk, *Identification of determinants of bitcoin volatility using statistical models and machine learning*;
- Małgorzata Just, Krzysztof Echaust, Agata Kliber, *Relationships between energy commodity markets and energy sector stock markets in Europe*;
- Maciej Bartkowiak, *Selected criteria of the quality of a fair division of a set goods*;
- Marcin Anholcer, *On different perspectives on the problem of fair distribution*;
- Michał Jakubczyk, Dominik Golicki, *Study of preferences towards health states described by the EQ-5D-Y-3L system in children – preliminary results of a nationwide study using the discrete choice method*;
- Anna Łyczkowska-Hanćkowiak, Aleksandra Wójcicka-Wójtowicz, *Application of oriented fuzzy numbers in modeling student retention*;
- Aleksandra Łuczak, Sławomir Kalinowski, *Multidimensional analysis of energy poverty of residents of territorial units*;
- Michał Bernardelli, *Optimization of airport management by minimizing risky air connections*;
- Anna Gorczyca-Goraj, Marek Szopa, Piotr Frąckiewicz, *Admissible quantum extensions, on four strategies, for classical games*;
- Marek Szopa, Anna Gorczyca-Goraj, Piotr Frąckiewicz, *Application of quantum games to optimize strategic decisions*;
- Milena Bieniek, *Optimal decisions in supply chain contracts*;
- Konrad Kułakowski, Michał Strada, Sebastian Ernst, Jacek Szybowski, *Detection of manipulations in the pairwise comparison method*;
- Daniel Kaszyński, *Algorithmic bias in creditworthiness assessment*;
- Michał Stasiak, *Application of state models of binary-time representation to build algorithmic trading systems for the cryptocurrency market*;
- Piotr Miszczyński, *Decision support in the banking sector in the context of ESG*;
- Paweł Hanczar, Dariusz Wawrzyniak, *Optimization of the municipal waste collection schedule*;
- Krzysztof Dmytrów, *Modification of the multi-criteria location selection method ensuring full implementation of the selected strategy*;
- Grzegorz Tarczyński, *Proposal of a model optimizing the locations of correlated goods in a warehouse taking into account distributed storage*;

- Jerzy Michnik, Peyman Zandi, *Proposal of a model for the assessment of operational risk based on sustainable development and the domino effect using fuzzy entropy and the fuzzy WINGS method*;
- Kacper Zielak, *Sustainable development in Poland in quantitative terms – state as of 2022*;
- Piotr Peternek, Izabela Dziaduch, *Evaluation of the importance of criteria assessing the quality of public transport services using the fuzzy AHP method*;
- Dorota Górecka, Ewa Chojnacka-Pelowska, *Group multi-criteria decision-making in the field of transferring public funds: open tenders for non-governmental organizations in Poland*;
- Adam Kucharski, *The impact of macro factors on achieving the position of a leader in the efficiency of implementing electromobility*.

In keeping with the long-standing tradition of the MZBO conference, its organisers held a competition for the best presentations delivered during the thematic sessions. The aim of the competition was to select the best papers discussing operational research methods and applications. The competition jury, consisting of Ewa Konarzewska-Gubała, Józef Stawicki, Artur Prędki and Grzegorz Tarczyński selected the winners:

- Michał Bernardelli, *Optimization of airport management by minimizing risky air connections*;
- Dorota Górecka, Ewa Chojnacka-Pelowska, *Group multi-criteria decision-making in the field of transferring public funds: open tenders for non-governmental organizations in Poland*;
- Małgorzata Just, Krzysztof Echaust, Agata Kliber, *Relationships between energy commodity markets and energy sector stock markets in Europe*;
- Konrad Kułakowski, Michał Strada, Sebastian Ernst, Jacek Szybowski, *Detection of manipulations in the pairwise comparison method*.

During the conference, the participants also discussed the current problems related to the promotion of operational research methods and tools in the scientific, business and academic environment.

The next MZBO conference will be organised by the Department of Decision Support and Analysis at the Institute of Econometrics, College of Economic Analysis at the SGH Warsaw School of Economics. The event will be held on 12th–14th October 2025. Information about the conference is available at: mzbo2025.sgh.waw.pl.