

## **КІЛЬКІСНІ МЕТОДИ В ЕКОНОМІЦІ. ЦИФРОВА ЕКОНОМІКА**

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### **THE ROLE OF INFOSTAT UKRAINE-POLAND CLUSTER IN CREATING INFORMATION INFRASTRUCTURE OF CROSS-BORDER AREAS**

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**Abstract.** *Due to integration and disintegration processes of the contemporary world as well as a large scale of population movements, cross-border areas have recently become the subject of in-depth studies and analyses. Against this background, the Polish-Ukrainian border region stands out due to the clear asymmetry of economic, institutional and social potentials, intensified by political and military conflicts and the fact that it is the external border of the European Union. The aim of the article is to present the specificity of the Polish-Ukrainian cross-border area, as well as the characteristics of the information cluster as an institutional support for boosting development processes in peripheral areas. The paper presents an analysis of objective and subjective aspects of quality of life using taxonomic measures of development. The level and spatial structure of inequalities in economic development and subjective well-being was presented using the Theil index. The use of geographic coordinates and Moran's I statistics allowed us to examine the spatial interdependence of the distribution of objective and subjective measures.*

**Keywords:** *cross-border areas, integration, disintegration, information cluster, taxonomic methods, Poland, Ukraine*

#### **1. Introduction**

The dynamics and interdependence of socio-economic phenomena in the modern world are becoming particularly evident in the case of cross-border areas. This is facilitated by integration and disintegration processes taking place in many countries and regions, political crises and a huge scale of migration. Cross-border regions, classified at NUTS 3 level, cover about 40 per cent of European territory. They are inhabited by than 150 million people and account for almost 30 per cent of European GDP. It is worth stressing here that cross-border processes are not only of regional significance, but in geographically smaller countries they are also of strategic political and macroeconomic importance. In these areas there are various types of asymmetry of potential between countries and regions - in particular technological, economic, institutional and infrastructural potential (not only in terms of transport or energy, but especially in terms of legal solutions facilitating the transparent development of entrepreneurship or local government, including the information infrastructure of the state).

Z. Paszkowski emphasises that the strengths of borderland are openness to new ideas, mobility, susceptibility and adaptability to changing conditions and trends, innovativeness. These features of borderland philosophy transform a marginal region into a region of expansion, a region of innovation, a region of cultural mixture with a creative and growth development vector (Z. Paszkowski, 2008, p. 87). It is worth noting that A. Połomska-Jasieniowska made a comprehensive description taking into account both positive and negative features of the borderland (A. Połomska-Jasieniowska, 178).

A necessary condition for the functioning of any cluster is a perfectly functioning information infrastructure. The information environment of cross-border areas is a combination of information systems of several countries. Information deficiencies mean higher risks in terms of economic and social activities. On the other hand, in cross-border areas there is a huge demand for information, due to the increased flow of goods and services, joint business ventures and investments, activities in special economic zones and technology parks or the use of various forms of support in projects carried out by entities on both sides of the border. Therefore, there is a need to create a uniform information infrastructure for cross-border areas to provide a transparent information environment for potential partners.

The aim of the paper is to present the specificity of the Polish-Ukrainian cross-border area with particular emphasis on the emerging paradoxes and the necessity of creating an information cluster as an institutional support for boosting development processes in peripheral areas.

The paper presents an analysis of objective and subjective aspects of quality of life using taxonomic measures of development - Hellwig's method, model-free method, Weber's medians. The level and spatial structure of inequalities in economic development and subjective well-being was presented using the Theil index. The use of geographical coordinates and Moran's I statistics allowed for spatial interdependence of the distribution of objective and subjective measures and identification of spatial clusters.

## **2. Specificity of socio-economic development of cross-border areas - synthetic evaluation**

### *a) Analysis of the demographic situation according to Webb's classification of population movements*

The development of a region and its prosperity depend to a decisive degree on the potential of human resources. The factors of great importance for the study of demographic processes include the net migration (SM) and natural increase (PN). The relationship between these two indicators (converted per 1000 population) has been determined by Webb's classification. This is one of the best known methods of measuring the relationship between natural increase or decrease and positive or negative net migration, which in turn determines the occurrence of a certain type of real population growth or decrease.

We can distinguish the following developmental and regression types:

Developmental types (population growth):

--type A:  $PN+ > |SM-|$  - prevalence of natural increase over migration loss,

--type B:  $PN+ > SM+$  - population growth results more from positive natural increase than from positive net migration,

--type C:  $PN+ < SM+$  - population growth results more from positive net migration than from positive natural increase,

--type D:  $|PN-| < SM+$  - prevalence of migration growth over natural loss.

Regressive types (population decline):

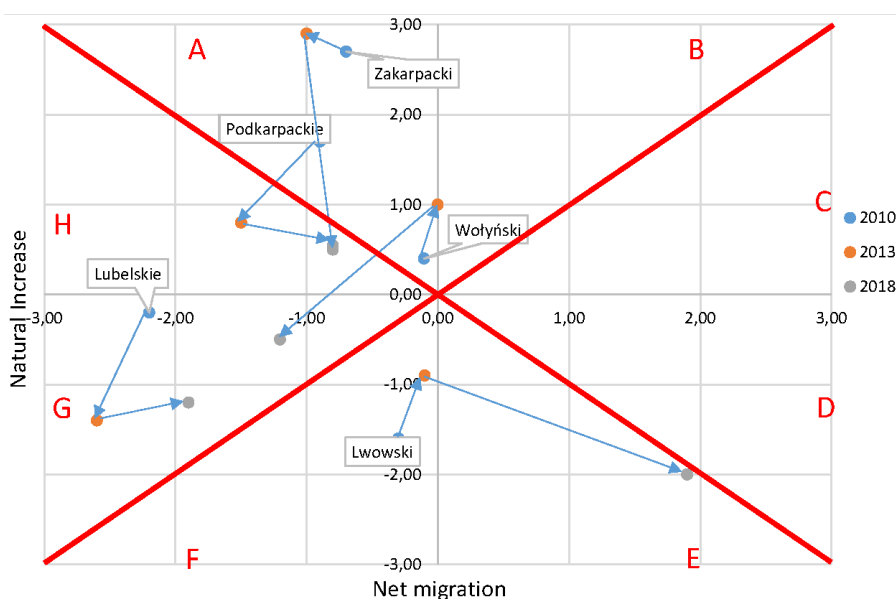
--type E:  $|PN-| > SM+$  - prevalence of natural loss over migration growth,

--type F:  $|PN^-| > |SM^-|$  - population loss is caused more by negative natural increase than by negative net migration,

--type G:  $|PN^-| < |SM^-|$  - population loss is caused more by negative net migration than by negative natural increase,

-type H:  $PN^+ < |SM^-|$  - prevalence of migration loss over natural increase.

If the values of the coefficient of natural increase and the coefficient of net permanent migration are equal, additional transition types are introduced. The transitional type may occur both between units being depopulated and populated, as well as within one of these categories. If the size of the migration loss is equal to the natural loss, the area belongs to the depopulation areas, but it is impossible to determine which factor prevails. The type of the examined unit is determined by reading the relation of both variables using a coordinate system (and additionally introduced diagonals) in which the ordinate axis corresponds to the values of the natural population growth rate and the abscissa axis to the values of the net permanent migration in the examined period.



**Figure 1. Population development types of border areas according to Webb's method**

Webb's method allowed to determine the development types of population of the studied border areas in 2010, 2013 and 2018. The analysis shows that in 2010, out of 5 studied areas - in 3 areas there was a population growth (Podkarpackie Voivodship, Volyn Oblast and Zakarpatska Oblast), in 2 areas there was a population loss (Lubelskie Voivodship and Lviv Oblast). The actual population growth caused by the prevalence of natural increase over migration loss (type A) occurred in Podkarpackie Voivodship, Zakarpatska and Volyn Oblasts. Population loss caused more by negative natural increase than negative net migration (type F) was observed in Lviv Oblast. In 2018, compared to 2010, only Lubelskie Voivodship maintained its demographic type (type G) - population loss was caused more by negative net migration than negative natural increase. In Podkarpackie Voivodship and Zakarpatska

Oblast there was an increase in the negative net migration, which, despite the positive natural increase, caused a decrease in population. As a result, Podkarpackie Voivodship and Zakarpatska Oblast were classified as regressive type H. Volyn and Lviv Oblasts changed their development types. In the case of Lviv Oblast, there was a transition to type E (despite a positive net migration, there is a decrease in population due to a large negative natural increase). The Lviv agglomeration, due to its location, becomes an attractive place for the population from the eastern part of Ukraine, under conditions of armed conflict with Russia. In the case of Volyn Oblast, on the other hand, a transition from type A to G was observed, in which a negative net migration dominates over a negative natural increase.

The observed demographic changes in the border voivodships and oblasts in 2010 and 2018 were largely unfavourable.

However, it is worth noting that in recent years we can observe, in some cases, favourable trends - in the case of Podkarpackie (reduction of negative net migration), Lubelskie (reduction of negative net migration and negative natural growth) and Lviv Oblast (change from negative to positive net migration).

#### *b. Taxonomic measures of development.*

Taxonomic analysis is used to assess the level of differentiation of objects characterized by a set of statistical features. The selection of these characteristics is often controversial (especially when their number is large), and the fact that we have a choice of several methods for creating synthetic indicators.

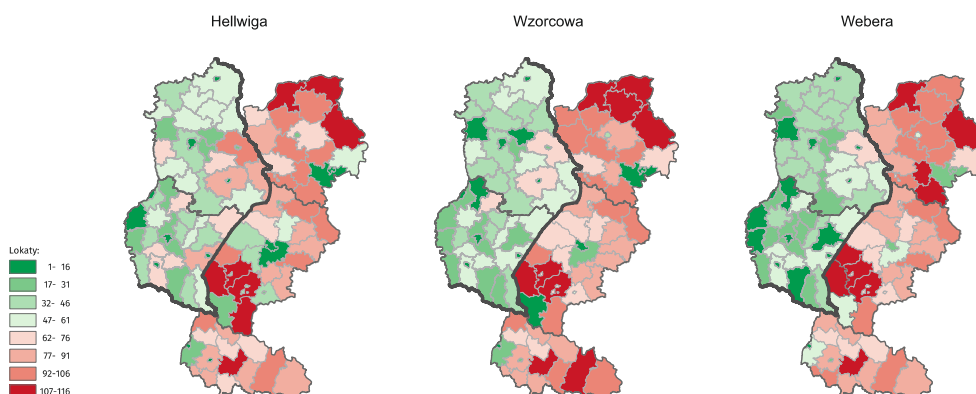
Therefore, in this paper we limited ourselves to only five sub-indicators (dwellings completed, sold production of industry, number of enterprises, employed persons - all features converted per 1000 inhabitants and average monthly wage in euros) and used three methods (simple aggregate indicators, Hellwig's method, Weber's median) (Błachut, Cierpiał-Wolan, Czudec, Ślusarz, 2017).

Table 1

**Synthetic indicators for selected economic factors**

Year	Taxonomic methods	Volyn Oblast		Zakarpatska Oblast		Lviv Oblast		Lubelskie Voivodship		Podkarpackie Voivodship	
		value	position	value	position	value	position	value	position	value	position
2010	Hellwig	0.10003	4	0.00000	5	0.66225	3	1.00000	1	0.90414	2
	Model-free	0.21149	5	0.24692	4	0.33441	3	0.47690	2	0.51356	1
	Weber	0.00002	4	0.00000	5	0.01976	3	0.77912	2	0.79565	1
2013	Hellwig	0.21921	4	0.00000	5	0.65970	3	1.00000	1	0.92665	2
	Model-free	0.21507	5	0.24783	4	0.29836	3	0.50444	2	0.53626	1
	Weber	0.00340	4	0.00000	5	0.01359	3	0.82160	2	0.83190	1
2018	Hellwig	0.37053	4	0.00000	5	0.73830	3	0.92255	2	1.00000	1
	Model-free	0.26348	4	0.19061	5	0.31314	3	0.51074	2	0.54617	1
	Weber	0.00464	4	0.00000	5	0.01689	3	0.73763	2	0.74613	1

The analysis of synthetic indicators on the basis of three methods placed Podkarpackie Voivodship in terms of selected economic factors in 2010, 2013, 2018 on the first place (except for Hellwig's method in 2010). Practically, the second and third place (Lubelskie Voivodship and Lviv Oblast) also remained unchanged throughout the analysis period. In 2018, all methods indicated the last position of Zakarpatska Oblast.



**Map 1. Synthetic evaluation of powiats and regions by selected methods in 2018**

In terms of powiats and regions, one can see the difference between the Polish and Ukrainian sides. However, the closer we get to the border, the smaller the differences become. In Ukraine, the cities - regional capitals and single regions directly neighbouring with them - are definitely distinguished. Thus, both in Poland and in the Ukraine, we see the influence of large urban agglomerations.

*c. Characteristics of spatial inequalities in the level of economic development;*

The level and spatial structure of inequality in economic development can be characterized using the Theil index (Theil 1979). The level of total inequality can be separated into "between" and "within" values of groups in a combined and exhaustive manner. These groups are subsets of a set of spatial units.

The total inequality of the studied characteristic is given by an expression (Rey, 2004, p. 194):

$$T = \sum_{i=1}^n s_i \log(ns_i) \quad (1)$$

where:

$n$  is the number of spatial units,

$s_i$  is a fraction

$$s_i = \frac{y_i}{\sum y_i} \quad (2)$$

where

$y_i$  denotes the examined trait characteristic in the  $i$ -th spatial unit.

The Theil index takes values in the range  $[0; \ln n]$ .

The normalization of the Theil index is obtained by dividing it by its maximum value. This makes it possible to compare differential spatial objects.

The structural analysis of spatial inequality is based on its additivity.

If we extract  $m$  groups of spatial units indexed by  $j$ , the Theil index can be decomposed into the part of inequality coming from intra-group differences (expressed by Theil indexes for groups) and from inter-group differences, i.e.

$T = T_B + T_W$ , where  $T_B$  denotes inequalities "between", and  $T_W$  inequalities "within" groups (e.g. powiats grouping gminas within a voivodship)

Decomposition  $T$  can be presented as follows:

$$T = \sum_j^m s_j T_j + \sum_j^m s_j \ln \left( \frac{n}{n_j s_j} \right)$$

where:

- $m$  - number of groups,
- $j$  - group number,
- $s_j$  – fraction of the  $j$ -th group,
- $T_j$  – Theil index in the  $j$ -th group,
- $n$  - number of spatial units,
- $n_j$  – number of spatial units in the  $j$ -th group.

Table 2

**Average value of the objective well-being index**

Specification	Inner zone	Border zone	Total	p-value
Podkarpackie Voivodship	0.3219	0.2034	0.2839	0.024
Lubelskie Voivodship	0.2628	0.1585	0.2410	0.005
Lviv Oblast	0.2229	0.1031	0.1981	0.019
Zakarpatska Oblast	0.2750	0.1440	0.2168	0.034
Volyn Oblast	0.1829	0.1026	0.1588	0.050
Total	0.2518	0.1456	0.2216	<0.001
p-value	0.269	0.040	0.123	

Objective measures of well-being are greater in the inner zone than in the border zone in each voivodship. Using a right-sided test of two means, the differences are statistically significant in each of the voivodships as well as when comparing the entire border and inner zones. In terms of objective well-being, the area of each voivodship is not a homogeneous territory. For inter-voivodship comparisons, ANOVA analysis and F-test were used. Voivodships in the inner zone do not differ significantly, although spatially they are not adjacent to each other. However, the border zones of each of the voivodships, despite their spatial proximity, do not form a homogeneous territory.

The Theil index was used to examine the intensity of inequality of the distribution of the objective well-being index.

Table 3

**Theil index after normalization**

Specification	Inner zone	Border zone	Total
Podkarpackie Voivodship	0.0607	0.0151	0.0497
Lubelskie Voivodship	0.0394	0.0156	0.0379
Lviv Oblast	0.0943	0.1935	0.0990
Zakarpatska Oblast	0.0894	0.0564	0.0784
Volyn Oblast	0.1119	0.0313	0.0929
Total	0.0510	0.0368	0.0486

Polish voivodships are less differentiated in terms of objective well-being than Ukrainian oblasts both in the border zone and the inner zone. The border zone of Lviv oblast has the most uneven distribution of the examined index reaching almost 20% of the maximum value. The inner zone of Volyn oblast is also strongly differentiated with the result of 11% of the maximum value. In general, the inner zone is more differentiated than the border zone. Combining this fact with the results for the averages, we can conclude that the border zones differ significantly from each other, but inside their area they are quite homogeneous. The

opposite situation is in the inner zones - in general they are better developed and similar to each other, but more heterogeneous inside their area. This picture is confirmed by the decomposition of the Theil index.

Table 4

**Theil index decomposition**

Specification	Within groups	Between groups
Podkarpackie Voivodship	24.1%	75.9%
Lubelskie Voivodship	19.3%	80.7%
Lviv Oblast	20.2%	79.8%
Zakarpatska Oblast	12.0%	88.0%
Volyn Oblast	11.1%	88.9%
Inner zone	52.4%	47.6%
Border zone	8.6%	91.4%

In each voivodship and oblast the main source (about 80%) of the difference in the level of objective well-being is the difference between its average level between the border zone and the inner zone. The border zones of the voivodships are enclaves despite their spatial proximity. Only less than 9% of inequality is due to their internal differentiation.

**3. Quality of life in cross-border areas - selected aspects**

The analysis of subjective individual well-being was conducted on the basis of a pilot household survey of over 800 respondents in similar proportions in Podkarpackie Voivodship (410) and Lviv Oblast (380). Respondents completed a questionnaire on material aspects of life, social and intellectual aspects, satisfaction with key areas of life, and belonging and identification with a social group. The questions were formulated according to a Likert format, giving the possibility to answer expressing the degree of agreement/disagreement (from "strongly agree" to "strongly disagree"), with a middle mark expressing a neutral opinion. The scales constructed were based on the survey modules of the Oxford Quality of Life Index and Dashboard (OXQOL) (see Anand et al., 2010), whose version modified for Polish conditions was tested in a pilot survey (see Okrasa, 2013).

In general, this operationalisation of the concept of subjective well-being agrees with the recommendations of the OECD (2013) to include three key aspects, which are considered to be the overall assessment of one's life, well-being and a sense of meaning and purpose related to achieving satisfaction with one's life.

The qualitative nature of the data, which have not only a subjective dimension but can be expressed on an ordinal scale (without the possibility of calculating the moments of the distributions), indicates that one should resort to non-standard measures of inequality, from the class of positional measures.

*a) Synthetic index of subjective well-being*

The synthetic index of subjective well-being was created based on selected questions from the survey. The selection of variables was based on the results of principal components analysis and their content evaluation. The questions were grouped into four categories: daily lifestyle, material life dimension, social and intellectual life dimension, belonging and identification with the community.

The following table presents the average value of the subjective well-being index by voivodship and border area.

Table 5

**Index of subjective well-being**

Specification	Inner zone	Border zone	Total
Podkarpackie Voivodship	3.059	3.155	3.129
Lviv Oblast	3.412	3.573	3.464
Total	3.304	3.279	3.291

It turns out that the subjective feeling of well-being is significantly higher in Lviv Oblast than in Podkarpackie Voivodship (p-value < 0.001), and in each region this feeling is significantly higher in the border zone than in the inner zone (p-value < 0.001 for Podkarpackie Voivodship and p-value=0.018 for Lviv Oblast).

*a) Characteristics of spatial inequalities in subjective well-being*

To investigate the spatial inequality of the subjective well-being index, we can use the Theil index and the Allison and Foster measure.

Table 6

**Theil index after normalization**

Specification	Inner zone	Border zone	Total
Podkarpackie Voivodship	0.00133	0.00087	0.00092
Lviv Oblast	0.00101	0.00120	0.00100
Total	0.00117	0.00111	0.00104

Analysis of the Theil index shows little variation in both the inner and border zones. The cross-border zone is more homogeneous compared to the rest of the surveyed area.

To assess this phenomenon we can use the median-based measure of Allison and Foster (2004).

Denoting by  $i = 1, \dots, n$  the number of consecutive category (answers), and by  $c_i$  the evaluation chosen by the respondent in a given question, and by  $k$  the median category (i.e. the one to which the "median person" belongs), the mean of the evaluation distribution can be presented as

$$\mu_X(c) = \sum_{i=1}^n c_i f_X^i \quad (4)$$

where  $f_X^i$  is the percentage of the population in the  $i$ -th category.

The mean of the distribution of ratings in categories below and above the median can be expressed as follows:

*below the median*

$$\mu_X^L(c) = 2 \left( \sum_{i=1}^{k-1} c_i (F_X^i - F_X^{i-1}) + c_k (0,5 - F_X^{k-1}) \right), \quad (4a)$$

*above the median*

$$\mu_X^U(c) = 2 \left( \sum_{i=k+1}^n c_i (F_X^i - F_X^{i-1}) + c_k (F_X^k - 0,5) \right), \quad (4b)$$

where  $c = (c_1, \dots, c_n)$  is the vector of ratings, and  $F_X^i$  denotes the distribution of the random variable  $X$  representing the responses (ratings) selected by the respondents.

The inequality measure (AF) proposed by Allison and Foster has the form

$$IXAFc = \mu_X^U(c) - \mu_X^L(c). \quad (5a)$$

The normalized measure of inequality of the distribution of well-being

$$I_X^{U(AF)}(c) = \frac{IXAFc}{c_n - c_1} \in [0,1]. \quad (5b)$$

The measure  $I_X^{U(AF)}$  does not change when translating and scaling the evaluation vector  $c$ . Comparability is restricted to scales with the same structure (for the same categories, the same ratings must be assigned).



The analysis indicates that the more uneven distribution, i.e. the scatter of answers given by inhabitants of Lviv Oblast was always greater than the scatter of answers in Podkarpackie Voivodship. Taking into account the general sense of well-being, a greater scatter of given answers concerning satisfaction with one's life occurred in Lviv Oblast.

*c) Spatial clusters - the use of Moran's I statistics*

The use of Moran's I statistics based on the concept of spatial autocorrelation allows the identification of global and local spatial clusters.

In the first case (global) Moran's I statistic is given by the expression:

$$I = \frac{n}{W} \frac{\sum_{i=1}^n \sum_{j=1}^n w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^n (x_i - \bar{x})^2}, \quad (6a)$$

where:

$w_{ij}$  - weight of the connections between units  $i$  and  $j$ , in an  $n \times n$  matrix, where  $n$  - number of units;

$W$  - sum of all weights  $w_{ij}$ ,

$x_i$  - observation in unit  $i$ ,

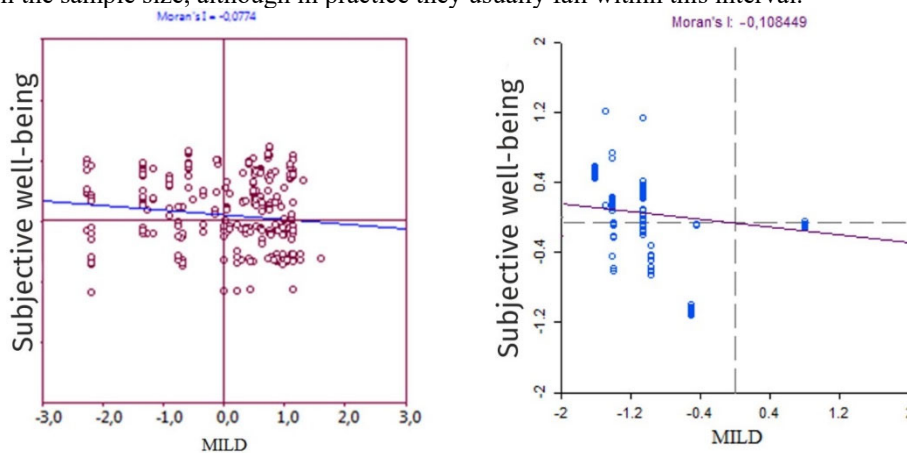
$\bar{x}$  - the arithmetic mean of all the units studied.

If Moran's global statistic has a value close to one, then units with the same level of the attribute are spatially grouped; a value close to minus one means that closely located units have different levels of the attribute; and at zero, the values of the attribute are randomly distributed in space.

In the second case, the local Moran's I statistic, which can be interpreted as a decomposition of the global Moran's I statistic, is given by the formula:

$$I_i = \frac{n(x_i - \bar{x}) \sum_{j=1}^n w_{ij} (x_j - \bar{x})}{\sum_{j=1}^n (x_j - \bar{x})^2}. \quad (6b)$$

Unlike its prototype, i.e. Pearson's linear correlation coefficient, the values taken by Moran's I statistic are not formally restricted to an interval with extremes -1 and 1, depending on the sample size, although in practice they usually fall within this interval.



**Figure 2. The relationship of the multidimensional index of local deprivation (MILD) with the subjective well-being of gminas in Podkarpackie Voivodship and Lviv Oblast**

Moran's global statistic close to zero indicates that objective measures of well-being do not translate into their subjective counterpart. It is clear that the powiats of Lviv Oblast form clusters with similar levels of quality of life in the subjective and objective dimensions. On the basis of the analysis, in Podkarpacie we can observe a rather strong positive influence of

the size of the gmina's population on the subjective aspects of the quality of life of neighbouring gminas (Moran's I global statistic was over 0.6). Gminas with low population and low subjective well-being tend to cluster spatially. Even stronger relationships were obtained for the relationship between objective aspects of quality of life and gmina size, in this case for both Lviv Oblast and Podkarpackie Voivodship.

#### 4. Conclusion

The specificity of socio-economic development of the Polish-Ukrainian cross-border area was confirmed by the presented analysis of both objective and subjective aspects of quality of life, taking into account spatial inequalities in local development. In-depth studies of households, especially in the aspect of subjective well-being, reveal many paradoxes (cf. Cierpiał-Wolan, 2017, Okrasa, Cierpiał-Wolan, Wójcik, 2015).

Hence, there is a need to create a unified information infrastructure for this area within the framework of the cluster initiative, as no single country alone can meet the growing demand for information. Only joint research, uniform methodology, metadata and parainformation system, use of all possible data sources (statistical, administrative, Bigdata, etc.) and close cooperation of scientific and research units and various types of institutions can create a friendly environment for business development. What is inherently the essence of a cluster, i.e. cooperation of the economic, scientific and public sectors, on the border between Poland and Ukraine may require separate cluster initiatives. In the context of many definitions and types of clusters.

Infostat can be treated as a cluster of institutional nature serving the development of an information infrastructure system in a cross-border area. In terms of the cluster life cycle and its effects the Science-Information-Statistics Cluster "INFOSTAT UKRAINE-POLAND" is in the initial (embryonic) phase of development.

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## РОЛЬ УКРАЇНСЬКО-ПОЛЬСЬКОГО КЛАСТЕРА "ІНФОСТАТ" У СТВОРЕННІ ІНФОРМАЦІЙНОЇ ІНФРАСТРУКТУРИ ПРИКОРДОННИХ РЕГІОНІВ

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**Анотація.** Внаслідок процесів інтеграції та дезінтеграції сучасного світу, а також великих масштабів мобільності населення, прикордонні регіони останнім часом стали предметом поглиблених досліджень та аналізу. На цьому тлі польсько-українські прикордонні регіони виділюється чіткою асиметрією економічних, інституційних та соціальних потенціалів, що посилюється політичними та військовими конфліктами та тим, що це зовнішній кордон Європейського Союзу. Метою статті є представити специфіку польсько-українського прикордонного простору, а також характеристики інформаційного кластеру як інституційної підтримки для активізації процесів розвитку в периферійних регіонах. У статті представлений аналіз об'єктивних та суб'єктивних аспектів якості життя за допомогою таксономічних вимірів розвитку. Рівень та просторову структуру нерівності в економічному розвитку та суб'єктивному добробуті було представлено за допомогою індексу Тейла. Використання географічних координат та статистики І-Морана дозволило дослідити просторову взаємозалежність розподілу об'єктивних та суб'єктивних показників.

**Ключові слова:** прикордонні регіони, інтеграція, дезінтеграція, інформаційний кластер, таксономічні методи, Україна, Польща.

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