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THE ENTROPY AS A PARAMETER OF DEMOGRAPHIC DYNAMICS: CASE STUDY OF THE POPULATION OF SERBIA

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Knjaževac – a shrinking town in the depopulation region of eastern Serbia.

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The entropy as a parameter of demographic dynamics: Case study of the population of Serbia

ABSTRACT: The aim of this article is to apply Shannon's entropy model in the study of demographic reproduction dynamics of the population in the Republic of Serbia from the regional aspect (NUTS 3 level) in the period from 1961 to 2021. Based on the values of absolute and relative entropy, the tendencies of demographic dynamics are determined, which is one of the most important parameters for building an optimal scheme of territorial organization and population distribution. In this context, explanations and conclusions were given about the homogeneity (or heterogeneity) of demographic dynamics and regional differentiation of demographic space in Serbia.

KEYWORDS: geography, population, demography, system, region, organization

Entropija kot kazalnik demografske dinamike: študija primera prebivalstva Srbije

POVZETEK: Avtorji v članku na podlagi Shannonovega modela entropije preučujejo dinamiko demografske reprodukcije prebivalstva Republike Srbije na ravni regij NUTS 3 med letoma 1961 in 2021. Na podlagi vrednosti absolutne in relativne entropije so določili težnje demografske dinamike, ki je eden najpomembnejših parametrov za oblikovanje optimalnega načrta prostorske ureditve in razporeditve prebivalstva. Avtorji so podali razlage in predstavili sklepne ugotovitve o homogenosti (ali heterogenosti) demografske dinamike in regionalne razčlenjenosti srbskega demografskega prostora.

KLJUČNE BESEDE: geografija, prebivalstvo, demografija, sistem, regija, prostorska ureditev

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1 Introduction

Mathematical and statistical methods are increasingly used in geography in connection with the development of the model paradigm and the systemic approach, especially in the study of population dynamics, which deals with the changes in the number and distribution of inhabitants in the demographic system and the factors that cause these changes. The process of regional differentiation of demographic development represents one of the most complex problems of science in general and of demography and population geography in particular. The objects of study of these two scientific disciplines are the tendencies and laws of population reproduction under the conditions of the social and natural environment in which the factors determining them are formed. The development of population statistics and technology GIS leads to the emergence of a huge amount of data that require mathematical analysis and the development of appropriate models. In this field, population geography and demography have a repertoire of various statistical and mathematical models for describing population dynamics (Breznik 1980).

Demographic dynamics as a result of the process of population reproduction has been studied by many demographers in the world and in the Republic of Serbia (Macura 1997; Spasovski and Šantić 2013; Marinković and Radivojević 2016; Penev and Predojević-Despić 2019). Models of population dynamics are treated not only by demographers, but also by biologists (Rudnicki and Łoskot 1991; Rudnicki 2023). However, models of dynamics cannot be transferred from biological to sociobiological populations. In general, models of population growth can be divided into deterministic and stochastic models. An example of the first is the Malthusian model of exponential population growth, where the whole complex of influences is included in the exponent, and an example of the second is the Shannon model of entropy as a parameter of the internal state of the system.

The novelty of the entropy model is that it can explain the driving forces and the course of the demographic process in a new way. Our goal is to provide a statistical description of population dynamics in Serbia using Shannon's entropy model. Entropy can be interpreted as a parameter for the internal state of a system. The aim of this work is to determine entropy as a parameter for regional demographic dynamics in the population system of Serbia.

2 Review of the concept of entropy

The concept of entropy (from Greek *εν τροπη* – internal change) entered the geographic and demographic sciences in the 1960s in connection with the conception of the geosystem as a self-organizing territorial system. The term »information« is defined as a signal or influence of one element (or system) on another so that the latter changes in a certain direction. Information expresses the ability of organized matter to determine its state in time (Kapica 2008). The amount of information determines the ability to predict the behaviour of the system in time – the higher the level of organization (more information), the lower the influence of the environment, the lower the dose of randomness. The measure of the expected amount of information is called entropy, which can be understood as a measure of the uncertainty or heterogeneity of the system. The more complex the system is, i.e., the more elements and connections it has, the more stable it is. The degree of entropy change of the system depends on the information resource. Perhaps this is one of the basic laws of progressive organization of matter in general. In geography, it can also be interpreted as a measure of the complexity of the territorial structure. Moreover, negentropy (a measure of organization) can be understood as a potential measure of predictability, a quantitative measure of the possibility of extrapolating the state of the system (Grčić 1990). The potential error of extrapolation is determined by entropy – mathematically, entropy is a measure of uncertainty. The mathematical model for information entropy was developed by Claude Shannon (1948) as a quantitative measure of the »vagueness« or uncertainty in the probability distribution of randomly varying characteristics of a quantity.

Wilson (1970) modified Shannon's concept and entropy formula and introduced the so-called »entropy maximizing model« into the study of spatial interactions, the task of which is to determine the most probable distribution (configuration) of observed phenomena in geographic space (Wilson 2010). Based on the application of the principle of maximum entropy in the social sciences, an attempt is being made to formulate a theory of social thermodynamics that could be useful for developing predictive models for the dynamics of certain sociogeographic systems such as cities, migration flows, mass consumption, or even election outcomes (Hernando et al. 2012; Cardona-Almeida, Obregón and Canales 2019).

The Shannon model of entropy has been used in the study of various processes and interactions in geographic and demographic systems (Bailey 1990; Lesne 2014; Damos 2015). Today, the following research directions can be distinguished in geographic and demographic work on entropy: 1) entropy as expected information used to test the hypothesis about the spatial distribution of phenomena; 2) entropy as a measure of the dispersion of random phenomena; 3) entropy maximization models to determine the most likely spatial distribution and allocation of phenomena in the system (Czyż and Hauke 2015). Entropy as a measure of spatial order or homogeneity (uniformity) of the empirical system under study is widely used in research on urban and demographic systems (Medvedkov 1967; Sonis 1968; Zborowski 1985; Deka, Tripathi and Khan 2010; Cabral et al. 2013; Batty et al. 2014; Purvis, Mao and Darren 2019).

3 Research area and data

3.1 Research area

The Republic of Serbia (excluding data for Kosovo and Metohija) has an area of 77,474 km^2 and a population of about 6,690,887 (according to the 2021 census). From the point of view of the demographic transition theory, the trend of birth and death rates in the period 1961–2021 in Serbia has not stabilized within expectations (13.6 per thousand).

The trajectory of birth and death rates from 1961 to 1991 approached the steady-state model of demographic transition in proportions that ensure positive natural growth (Figure 1). As early as 1992, the paths of birth and mortality trends crossed – mortality continued to increase, reaching 20.1‰ in 2021, while birth rates declined, reaching 9.1‰. Natural growth continued to decline, reaching –10.9‰ in 2021. In this

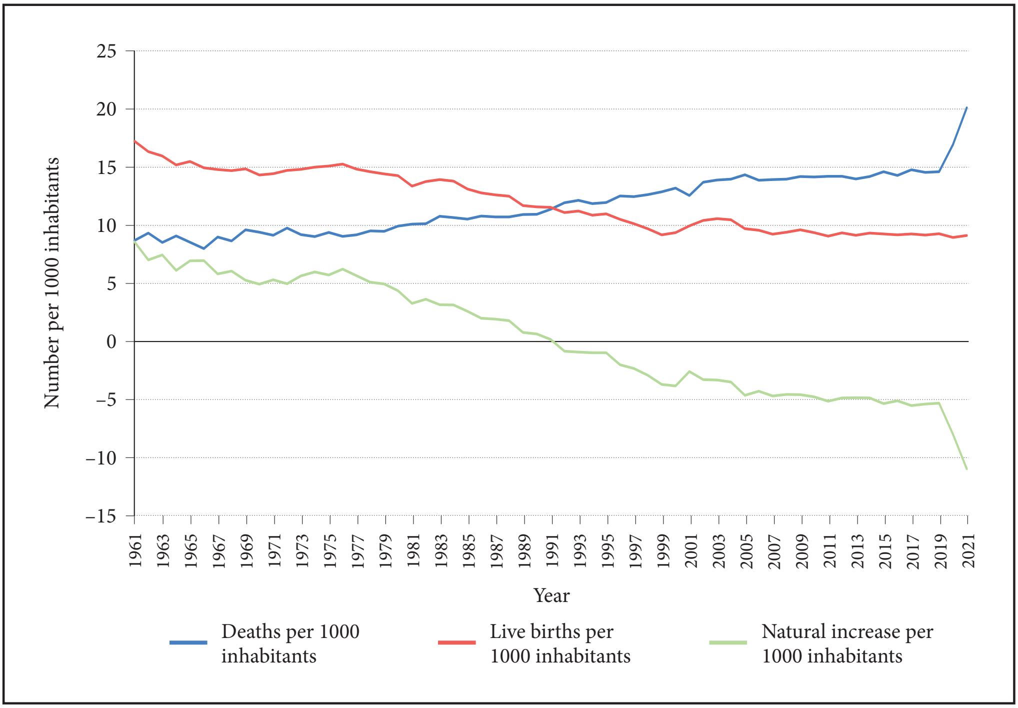

Figure 1: Evolution of mortality, birth rate and natural population growth in Serbia in the period 1961–2021 (Statistical office of the Republic of Serbia 2022).

way, the population entered a phase of demographic crisis, which does not ensure the sustainability and homeostasis of the functioning of the demographic system (Javor 2014; Penev and Predojević-Despić 2019).

3.2 Data

The focus is on research of dynamics of natural population movement in Serbia based on data series of vital statistics in spatial and temporal terms. The data source is Natural population trends in the Republic of Serbia, 1961–2010 (2012) and Municipalities and regions of the Republic of Serbia for the years 2011–2021 (2022), both from Statistical Office of the Republic of Serbia. These publications enable comparability of data on population size and changes in natural population in territorial statistical areas at the level NUTS 3. The information base for determining entropy in this research consists of matrices in which temporal and spatial data series on demographic determinants of natural population movement in Serbia are crossed (61 years in the period 1961–2021 and 25 NUTS 3 territories).

4 Methods

4.1 The Shannon's model of entropy

According to the Shannon equation for entropy, the quantities p_i express the degree of independence of the following system states from the previous ones. The next system state is related to the previous one by the probabilities p_i. The probability p_i represents the probability that the system will take the *i*-th new state independently of the previous one.
If we calculate the probability:

$$p_i = \frac{n_i}{\sum n_i} \tag{1}$$

where n_i is an indicator of certain demographic determinants (number of inhabitants, number of live births, number of deaths, etc.) in a given area *i*. To obtain information about the statistically most probable distribution of events (system states), the monotonic event probability function *p* is preferably used:

$$hp = \log_2 \frac{1}{p} = -\log_2 p \tag{2}$$

This function decreases from ∞ (infinite number of information, probability equal to 0) to 0 (zero information, probability equal to 1). It should be noted that the unit of measurement of the information depends on the base of the logarithm. In computer science, base 2 logarithms (i.e. $\log_2$) are most commonly used, and information is measured in bits (binary digits – binary numbers; natural logarithms can also be taken, but then the unit of information is nit – natural digits). An important feature of the entropy measure is the common unit (bit), with which we can compare the study of phenomena and processes (Zborowski 1985). The expected value of the information about the occurrence of each event in the set S (which is equal to the entropy of the distribution with probabilities $p_i \ldots, p_n$) is equal to:

$$\mathrm{H(S)} = \sum_{i=1}^{N} p_i (h_{p_i}) = \sum_{i=1}^{N} p_i \log_2 \frac{1}{p_i} = -\sum_{i=1}^{N} p_i \log_2 p_i \tag{3}$$

The minus sign is added because the logarithm of a number less than one and greater than zero is a negative number, and entropy cannot be a negative number. The values of p_i are constantly between 0 and 1. Entropy is a measure of order or disorder of the system and is denoted by the letter »S«. If all events in the system are equally likely, then uncertainty (chaos) is at maximum. The probability p_i for the *i*-th state is a measure of uncertainty. The lower bound of entropy is 0, i.e., there is only one alternative for the realization of the event, and the probability is $p_i = 1$. The upper bound of entropy (maximum entropy) means that all events (or states) have the same probability, i.e., where:

$$p_1 = \frac{1}{n}, \; p_2 = \frac{1}{n}, \ldots p_n = \frac{1}{n} \tag{4}$$

so then it is the upper or maximum limit of entropy:

$$H_{max}(S) = -\sum_{i=1}^{N} \frac{1}{n} \log_2 \frac{1}{n} = \log_2 n \tag{5}$$

Therefore, if all $p_1 = \frac{1}{n}$ then the maximum entropy is $H_{max}(S) = \log_2 N$.

From all this follows that the entropy values of the system H(S) constantly move within the limits: $0 \leq H \leq H_{max}$. With increasing number *n*, the number of possible states increases, and the entropy of the system S increases monotonically.

4.2 Methodological steps in the study

Using the described mathematical procedure, we obtain the actual entropy (H) and the relative entropy (H_0) of territorial homogeneity of the given determinant in year *i*. By comparing the evolution of the entropy measure by years in a given time interval for a set of territorial units (areas), we can draw a conclusion about the changes in territorial homogeneity (or heterogeneity) of the demographic system. By comparing this measure in the time sequence, we can determine the isotropy (uniformity) or anisotropy of the spatial process, which can be used to predict the number of inhabitants, the number of live births, and the number of deaths, as well as natural growth. The relative entropy H_0 shows the percentage ratio to the maximum entropy H_{max}. The relative entropy is calculated using the following formula:

$$H_0 = H/H_{max} \tag{6}$$

or in expanded form:

$$H_0 = -\frac{1}{\log_2 N} \sum_{i=1}^{N} pi \log_2 pi \tag{7}$$

Actual entropy can take values between zero and infinity. The use of relative entropy facilitates the comparison of data, and its values are constant within the limits $0 \leq H_0 \leq 1$. Relative entropy is maximum (1) when the probability of an event occurring is equal, and minimum (0) when one of the events is absolutely probable while the others are impossible. The relative measure (H_0) allows to compare the growth differentiation with the maximum differentiation ($H_{max} = \log_2 n$). At the same time, the given measure H_0 can be easily converted into percentage values (provided $0 \leq H \leq 1$). The analysis performed using the entropy measure allows us to compare the degree of homogeneity of the observed determinants of natural population movement in each studied area. Relative entropy values of demographic dynamics of administrative areas, comparison and grouping can be used in the process of demographic regionalization.

A measure of entropy provides information about the dynamics of the determinants of the demographic process, but not about the causes of changes in demographic dynamics in space and time. The intensity of the synergetic influence of external factors can be calculated as the homogeneity limit (L) (Sonis 1968; Zborowski 1985).

If the maximum value of entropy is $H_{max} = \log_2 n$ and $H = \log_2 \lambda n$, where *n* is the number of parts of a whole (e.g., the number of years of observation of a process, the number of territorial units of the distribution, etc.) and λ is the multiplier of homogeneity:

$$\lambda = \frac{1}{n} 2^H \tag{8}$$

also, we can calculate the *Limiter*:

$$L = 1 - \lambda, \text{ where: } 0 \leq L \leq 1 - \frac{1}{n}. \quad (9)$$

The homogeneity limiter expresses the summary effect of the totality of factors of the process under study. The characteristics of homogeneity are inversely proportional to the homogeneity limiter, such as negentropy inversely proportional to entropy (Figure 3).

Theoretical ideas pointing to the possibilities of a systemic approach in defining the problem of the dynamics of demographic processes are not new (Radovanović 1987; 1988), but concrete application is complicated by the limitations of statistical databases. More recently, GIS technologies and statistical databases enable the application of complex system methods, models, and parameters in the study of specific demographic processes (Aburto et al. 2019; Li et al. 2015; Marius, Lenart and Canudas-Romo 2019; Costa-Cabanas, Chalub and Souza 2022). A systemic approach to the complex process of demographic evolution requires parameterization of the spatiotemporal determinants of the demographic system with a broad application of geographic information databases and statistical, mathematical, and cartographic methods and models.

Shannon's entropy model is based on probability theory and statistical data as carriers of information about the state of the system. In demographic systems, we use as information the movement of the absolute number of inhabitants, the number of births, the number of deaths, and the ratio between the number of births and the number of deaths. Each of these determinants has a matrix of 25 ranges of 61 years filled with absolute natural positive numbers. Relative numbers have the problem that negative values appear as zero in the probability calculation. Absolute entropy is converted to relative entropy (H_0) to allow comparability of results by territorial units. The territorial division into districts, which territorially corresponds to the statistical regions of NUTS 3, was not changed in the considered period, so there are no problems with the comparability of the data in time and space. The absolute values for the calculation of entropy represent the number of inhabitants in each region of NUTS 3. Differences between regions in population numbers lead to a MAUP (modifiable real unit problem), but the entropy is based on the probability of the state, so this problem is put into perspective.

5 Results

In the following text, we explore the possibility of using the concept of entropy as a measure of the diversity or homogeneity of demographic dynamics. The starting point for the calculation is a matrix in which the statistical evolution of a given demographic determinant (e.g. the number of inhabitants, the number of live births, or the number of deaths) is crossed in a series of years and in a series of areas. In this way, we can calculate the probability distribution of some determinants (p_i) horizontally (matrix rows) and vertically (matrix columns), in our case by years in the period 1961–2021 and by 25 regions in Serbia (NUTS 3).

5.1. Entropy as a measure of demographic dynamics over time

The entropy curves of demographic dynamics in the territorial division as a function of time in the period 1961–2021 show a downward trend (Figure 2). The entropy values range from 0.97 to 0.88 for the total population, from 0.98 to 0.92 for the number of deaths, and from 0.96 to 0.85 for the number of live births. From a thermodynamic point of view, this means that the system is gradually »cooling down« but is still far from absolute zero, which would mean the end of the dynamics of the system. Decreasing paths of relative entropy indicate the transition from territorial heterogeneity to territorial homogeneity of these determinants. In other words, decreasing entropy values signify the process of simplification of territorial structure, which can be understood as an indicator of territorial concentration and polarization. The relative entropy of the number of inhabitants and deaths in Serbia decreases monotonically, while the entropy of the number of live births shows greater instability and even a sharp decrease in the last two decades of the observation period.

A decrease in entropy means that the spatial concentration of demographic dynamics increases and the territorial core of the system decreases. In other words, the decrease of entropy value involves the process of simplification of territorial structure, which can be understood as an indicator of territorial polarization.

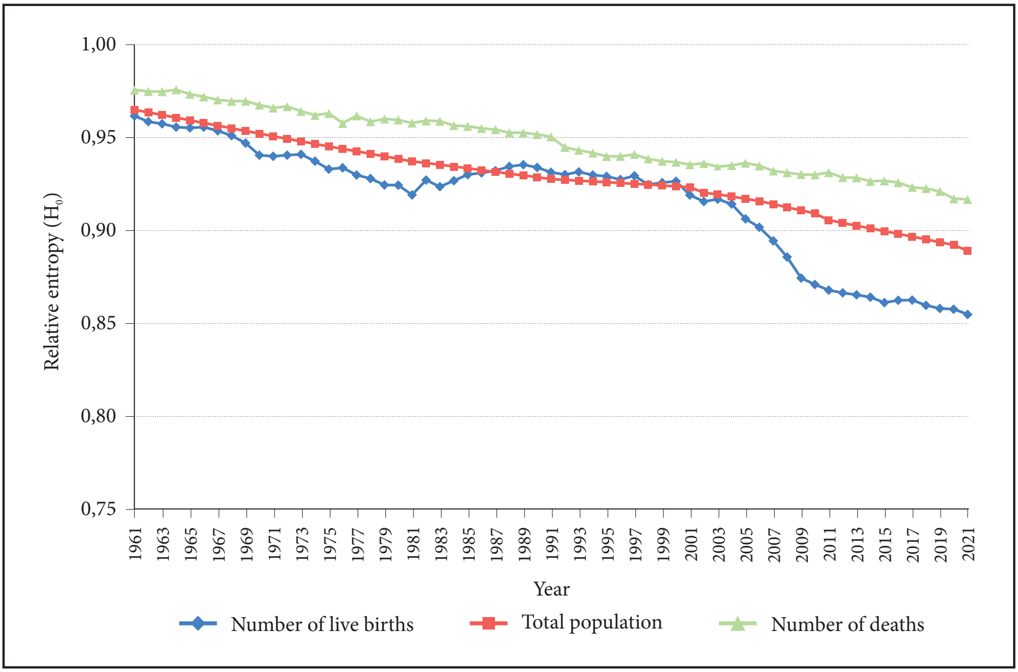

Figure 2: Distribution of relative entropy (H_0) of some demographic determinants in Serbia, as a function of time in the period from 1961 to 2021.

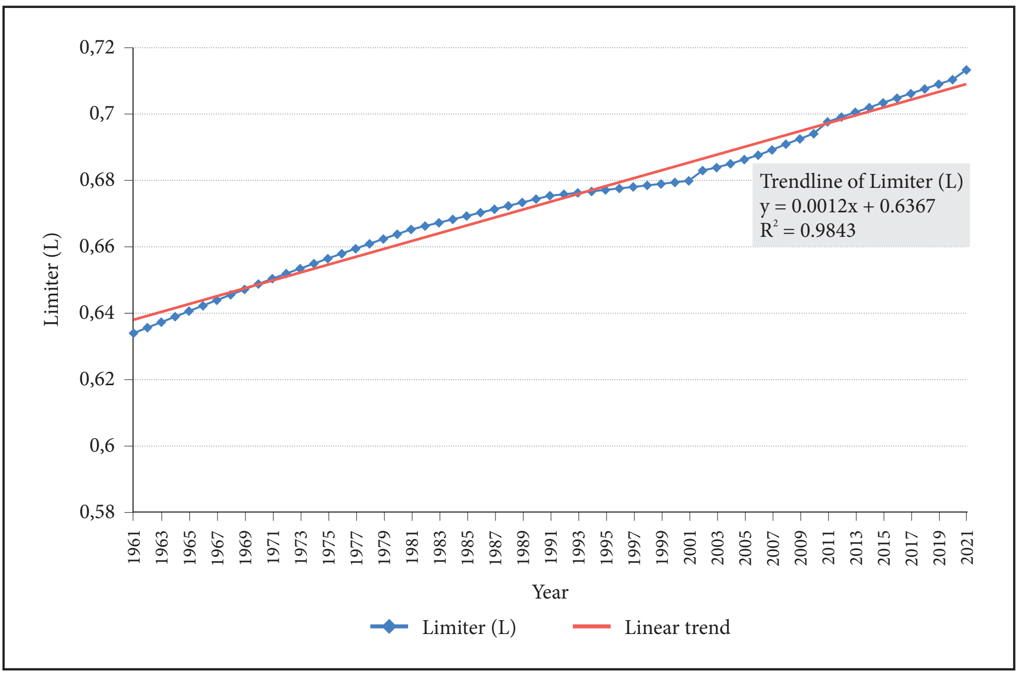

Figure 3: Entropy Limiter (L) of the changes in the spatial distribution of the total population of Serbia by areas. The characteristics of homogeneity are inversely proportional to the homogeneity limiter.

The relative entropy of the number of inhabitants and deaths in Serbia decreases monotonically, while the entropy of the number of live births shows greater instability and even a sharp decrease in the last two decades of the observation period. The trajectories show that the demographic dynamics during the observation period ranges from more uniform to less uniform spatial distribution. The trajectory of the entropy of live births decreases faster than the trajectory of the number of deaths and the total population.

5.2 Entropy as a measure of demographic dynamics in space

If we consider the areas (NUTS 3) as subsystems of the demographic system and calculate for each subsystem the value of entropy of demographic dynamics in a given period, we can hierarchize and classify the areas for each of the observed demographic determinants (Table 1; Figures 4–7). According to the results presented in Table 1, the differences in entropy values by region are relatively small, but still sufficient to distinguish two models of dynamic natural reproduction of a population – the first model is below the level of the entropy average, the second above the average. This indicates a process of territorial polarization of demographic dynamics on the territory of Serbia.

In the further procedure, the standard deviation from the average entropy value was calculated to obtain four area categories that serve as criteria for regional classification. According to the »two-sigma rule«, about 95% of the values are within the interval of –2 to +2 standard deviations from the mean. The classification of the areas according to the intervals of relative entropy values is presented cartographically (Figures 4–7).

The trends of relative entropy in each of the 25 areas show territorial differentiation of demographic population dynamics during the observation period. These maps show areas where the dynamics of the observed determinants were more homogeneous or heterogeneous during the indicated period. In this way, the process of polarization of the territorial structure of demographic dynamics in Serbia becomes

Table 1: Entropy of demographic dynamics from 1961 to 2021, by regions in Serbia.

Region	Number of inhabitants		Number of live births		Number of deaths		Births per 100 deaths	
	H	H_0	H	H_0	H	H_0	H	H_0
Belgrade	5.91375	0.99714	5.91956	0.99812	5.83050	0.98310	0.48354	0.08153
West Bačka	5.92611	0.99922	5.85863	0.98784	5.90803	0.99617	0.34752	0.05860
South Banat	5.92308	0.99871	5.88517	0.99232	5.91974	0.99815	0.24479	0.04127
South Bačka	5.92163	0.99846	5.92522	0.99907	5.89259	0.99357	0.25941	0.04374
North Banat	5.92753	0.99946	5.86094	0.98823	5.86143	0.98831	0.90492	0.15258
North Bačka	5.92446	0.99894	5.89435	0.99386	5.92160	0.99846	0.27749	0.04679
Central Banat	5.92800	0.99954	5.87421	0.99047	5.91459	0.99728	0.30557	0.05152
Srem	5.92722	0.99941	5.90343	0.99540	5.89104	0.99331	0.39574	0.06673
Zlatibor	5.92689	0.99935	5.84061	0.98480	5.90219	0.99519	0.51779	0.08731
Kolubara	5.92677	0.99933	5.87150	0.99001	5.90837	0.99623	0.35972	0.06065
Mačva	5.92783	0.99951	5.87090	0.98991	5.89993	0.99481	0.42865	0.07228
Moravica	5.92916	0.99973	5.89009	0.99315	5.89532	0.99403	0.39769	0.06706
Pomoravlje	5.92295	0.99869	5.87737	0.99100	5.90670	0.99595	0.34029	0.05738
Rasina	5.92670	0.99932	5.87266	0.99021	5.89560	0.99408	0.38497	0.06491
Raška	5.92497	0.99903	5.91664	0.99762	5.87645	0.99085	0.61588	0.10385
Šumadija	5.92704	0.99938	5.90072	0.99494	5.89827	0.99453	0.38279	0.06454
Bor	5.91299	0.99701	5.82711	0.98253	5.92200	0.99853	0.34321	0.05787
Braničevo	5.91192	0.99683	5.85293	0.98688	5.92683	0.99934	0.29882	0.05039
Zaječar	5.91197	0.99684	5.85419	0.98709	5.92502	0.99904	0.22501	0.03794
Jablanica	5.92533	0.99909	5.84467	0.98549	5.89782	0.99445	0.44365	0.07480
Nišava	5.92892	0.99969	5.90694	0.99599	5.88304	0.99196	0.39070	0.06588
Pirot	5.91110	0.99669	5.80817	0.97933	5.92048	0.99827	0.30427	0.05130
Podunavlje	5.92676	0.99933	5.88677	0.99259	5.90630	0.99588	0.39419	0.06647
Pčinja	5.92709	0.99939	5.85530	0.98728	5.92319	0.99873	0.58608	0.09882
Toplica	5.91386	0.99715	5.84429	0.98542	5.91485	0.99732	0.36556	0.06164
Average	*5.92899*	*0.999705*	*5.901659*	*0.995097*	*5.90028*	*0.994864*	*0.404197*	*0.068153*

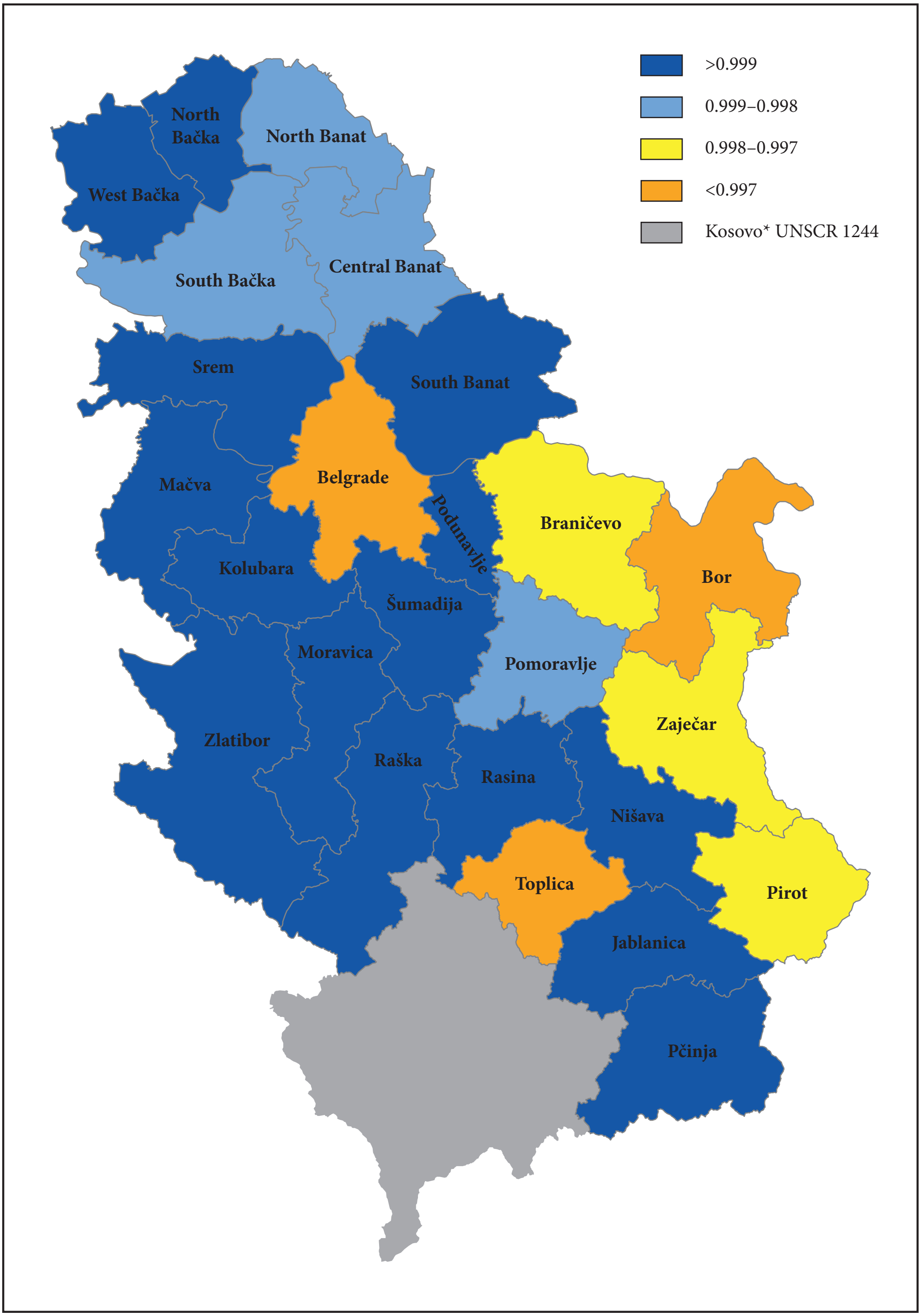

Figure 4: The relative entropy (H_0) of population movements by region.

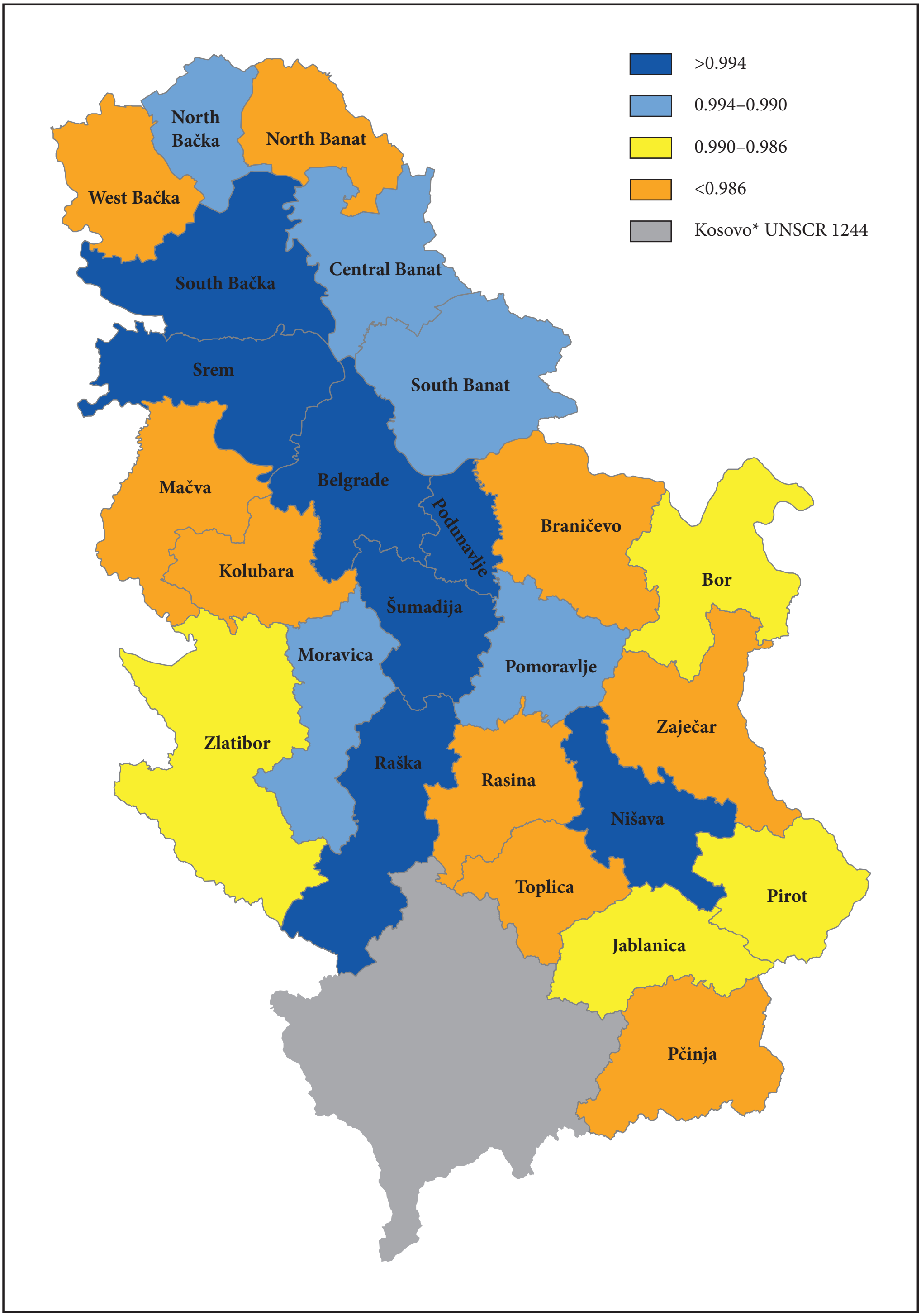

Figure 5: The relative entropy (H_0) of the number of live births movements by region.

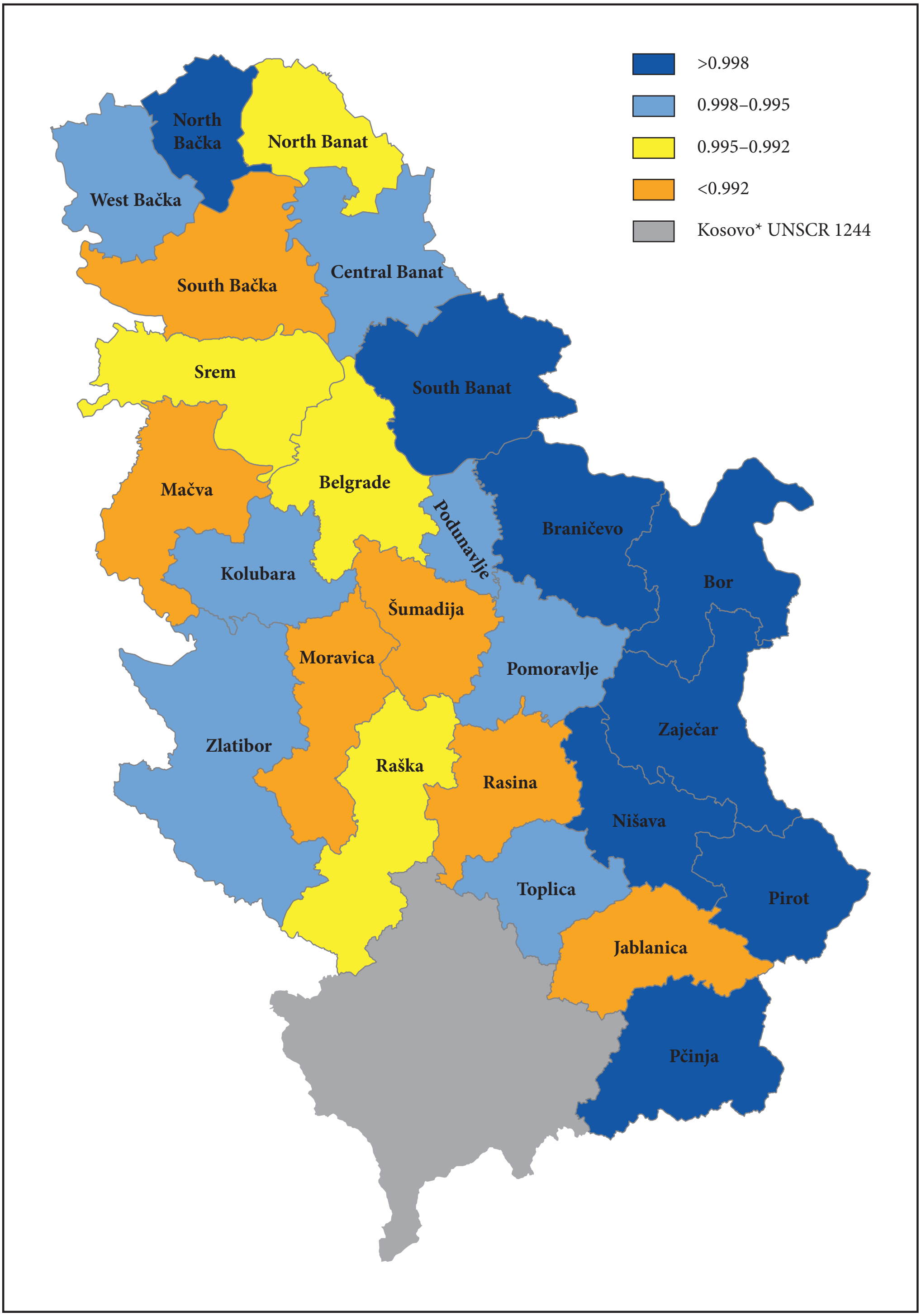

Figure 6: The relative entropy (H_0) of the movement of the number of deaths by region.

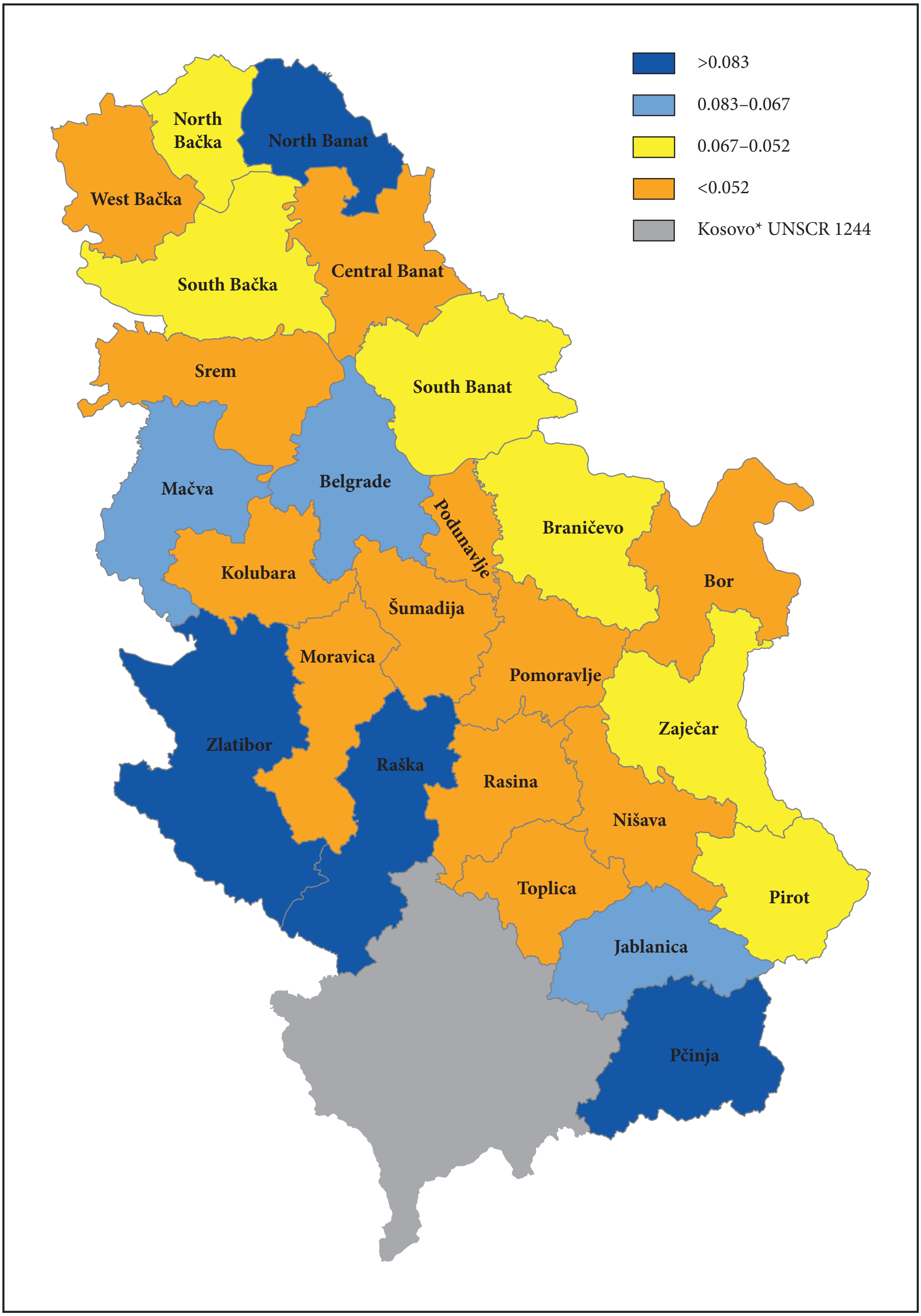

Figure 7: The relative entropy (H_0) of the number of live births per 100 deaths by region.

visible. Interregional differences in the values of relative entropy of the same demographic determinants are relatively small, but they are sufficient as an indicator of the different pace of depopulation and spatial concentration of the demographic system of Serbia in the last 61 years (see Table 1 and Figures 4–7).

Considering the homogenization of Central Serbia and Vojvodina in terms of negative population growth (and demographic aging), we can discuss regional differences in natural population renewal only at the level of this »negativity«. Small interregional differences in the relative values of entropy within the same demographic determinants confirm the statement that almost the entire territory of Central Serbia and Vojvodina has become a relatively homogeneous area characterized by depopulation from the point of view of natural population movement (Vojković 2007).

The number of live births by region (Figure 5) is above average in the middle belt regions with larger cities and nodes that act as centers of attraction for young people and families with children (Subotica, Novi Sad, Belgrade, Niš, Užice Kraljevo, Čačak, Pažarevac, etc.). Below-average values are characteristic of depopulation areas in border and hilly or mountainous regions, for which emigration and population aging are typical (Kerbler 2015). In Serbia, during the period under consideration, there was an intensive process of population aging in rural settlements and migration of young population to cities. As a result of this process, there was a polarization of the dynamics of natural reproduction of the population between rural and urban settlements and regions (Nikitović 2019). As early as the 1980s, depopulation became evident in cities as well (Živanović 2013; Djurkin, Antić and Budović 2021).

The relative entropy of the movement of the number of deaths (Figure 6) in the eastern and western peripheral areas and in the hilly and mountainous regions of Serbia shows clearly above-average values. As for the evolution of the number of live births per 100 deaths, a below-average relative entropy is characteristic for the Pannonian districts (except for the northern Bačka district) and some districts in central Serbia, where the probability of a repetition of the system state due to depopulation decreases (Figure 7).

6 Discussion

The entropy approach to the study of demographic dynamics as a stochastic process, in contrast to the Malthusian and neo-Malthusian deterministic theories of population reproduction, leads to the design of the »internal environment« of the demographic system that ensures its self-organization and the relative independence of its functioning from external conditions and resources. The higher the entropy, the greater the stability of the system. Maximum entropy means the most probable state of the system. The opposite of entropy is the concept of negative entropy, i.e. negentropy. The effect of entropy and negentropy is a prerequisite for the sustainability of the system. The term stability usually refers to the behavior of a system near the equilibrium state. We say that the state of the system is stable when the system returns to equilibrium after small perturbations. When this is not the case, instability increases. Considering the fact that population is a biosocial system, it is a very complex question where is the »X« factor that triggers the demographic process (Višnjevski 2005). Population policy tries to direct the natural movement of the population in the desired direction through (economic, social) fertility measures (Josipovič 2003; Vasić 2019; Graovac 2021). Some countries try to compensate for negative natural population growth by positive net migration (Nikitović 2017). Small changes on an annual basis indicate high sustainability of the system state, but over a longer period of 60 years, an entropy indicator suggests that decreasing demographic dynamics increasingly disrupts the demographic equilibrium and threatens the sustainability of the homeostasis of the country's demographic system. In this context, the question of how to respond to the demographic challenges inevitably arises (Vojković, Kokotović-Kanazir and Bakić 2022).

Shannon's model of entropy as a parameter of population dynamics, while important, is not the only basis for demographic regionalization of Serbia. Besides dynamic stability, it is necessary to study the parameters of territorial structure (i.e. its viable and measurable characteristics), such as: territorial concentration, territorial differentiation, territorial integration (homogeneity) and composition, as well as sub-parameters and aspects (Vasilevski and Polan 1978). Only such a set of variables is essentially a complete coordinate system in a multidimensional demographic space, where each of the parameters serves as the coordinate axis of the next. Such a set is not only a tool for analysing the dynamics of the territorial structures of the population, but also an important constructive lever for the territorial organization and management of the demographic system. The theoretical and methodological importance of parameterization should be emphasized. On the theoretical side, by combining a qualitative and quantitative component of demographic analysis, parameterization aims to provide an objective comparison and typology of different territorial structures and a deeper study of regional demographic characteristics. As for the methodology, it is topical because it offers the possibility of combining different approaches and methods in a single and coherent indicator method necessary for regionalization.

7 Conclusion

The problem of stability and harmony of the demographic process in time and space is increasingly raised in scientific debates and is the subject of spatial planning and population policies of European countries in the face of worsening demographic crisis and territorial polarization. In this context, the concept of demographic region also becomes an important element for understanding the meaning of demographic transition and transformation at different spatial scales. In this article, a modest attempt has been made to apply the concept of entropy to the study of demographic imbalance in Serbia over the last six decades. We have tried to determine the parameters of demographic dynamics using Shannon's concept of entropy, in the context of the change in the statistical state of the system in time and space. The conceptual and methodological postulates presented are hypothetical in nature and undoubtedly require further logical-methodological elaboration and empirical confirmation. Of course, emphasizing the process aspect of this preliminary theory does not mean that we abandon its structural-territorial aspect, especially since the territorial structure can be considered as the current state of the demographic process. The study of the process of changes in the territorial structure should be studied together with the changes in other structures of the demographic system. The spatial dynamics of change should be studied from the point of view of special territorial processes such as territorial division, concentration, integration and territorial composition, using complex mathematical models and appropriate statistical bases.

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