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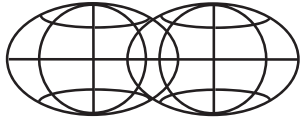MUZEUM HISTORII POLSKI

Regional differences in the age structure of Poland's population in the years 1999–2010: a multivariate approach

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Abstract. One of the characteristic features of the modern world is the dynamics of demographic changes. Depending on their nature and intensity, they can be a driving force behind socio-economic development or doom it to stagnation or regression. There is no doubt, however, that a declining demographic potential, especially unfavourable changes in the age structure of the population (an ageing society), may contribute to economic difficulties in the given area, often leading to social problems. The aim of the research the results of which are presented in this article was to analyse regional differences in the age structure of Poland's population in two time intervals, viz. the years 1999 and 2010, using multivariate techniques, and more specifically, principal components analysis and cluster analysis. They both make it possible to accommodate many features of the population age structure simultaneously, thus better illustrating the two situations (the years 1999 and 2010) and changes that took place in between, than univariate approaches.

Contents:

1. Introduction

One of the characteristic features of the modern world is the dynamics of demographic changes. Depending on their nature and intensity, they can be a driving force behind socio-economic development or doom it to stagnation or regression. Some countries and regions make an efficient use of their growing potential and favourable demographic structures as a development-boosting factor (e.g. China, India, Brazil, South Korea), while in others (e.g. some African states) this is hardly the case. There is no doubt, however, that a declining demographic potential, especially unfavourable changes in the age structure of the population (a population ageing society), may contribute to economic difficulties in the given area, often leading to social problems.

Demographic variations can in fact be observed at every spatial scale. The aim of the research the results of which are presented in this article was to analyse regional differences in the age structure population of Poland in two time cuts, viz. the years 1999 and 2010, using multivariate techniques, and more specifically, principal components analysis and cluster analysis. They both make it possible to accommodate many features of the population age structure simultaneously, thus better illustrating the two situations (the years 1999 and 2010) and changes that took place in between, than univariate approaches.

2. Research assumptions

The study of the regional heterogeneity of the age structure of Poland's population was carried out for two moments in time, viz. the years 1999 and 2010. This allowed us to make a comparison of the two situations, and thus to identify changes that took place in the period between them. This was done using comparative statics. In the research, the demographic structures of Poland's 16 voivodships were compared as described by a set of 15 variables. The variables were the proportions of the population in the following age groups: 0–4 years, 5–9, 10–14, 15–19, 20–24, 25–29, 30–34, 35–39, 40–44,

45–49, 50–54, 55–59, 60–64, 65–69, and 70 and over, in the total population of an individual voivodship.

Use was made of a three-level model of analysis (Parysek, Mierzejewska, 2009a, 2009b, 2010a, 2010b) which embraced: (a) determining differences among the voivodships in terms of each of the 15 input variables, and changes in this field; (b) determining differences in the age structures of the voivodships in terms of principal components of those structures and their changes; (c) determining differences in the age structure of the voivodship populations in a synthetic approach.

At the first analytical level, for each study period a simple statistical description of the variables was prepared, with special emphasis on their variance (the standard deviation and the coefficient of variation). At the second level, the principal components method was employed to distinguish the chief planes (levels) of difference, and at the third, a classification was made using cluster analysis.

The spatial structure and its heterogeneity was determined in a spatial classification procedure (a typology) involving a spatial interpretation of the classifications derived earlier (Parysek, 1982).

3. Factors shaping the age structure of Poland's population in the post-war years

One of the most basic characteristics of a population is its distribution by age. This follows from the fact that various spheres of people's economic and social activity, and especially their reproductive ability, are connected with a specified age (Gawryszewski, 2005). The proportion of the working-age population determines economic development, the number of children and teenagers is important in terms of the future labour force, while the share of the population of post-working age greatly affects the dependency rate (Gontarek, Kamińska, 2006). The population can be grouped by age in a variety of ways, depending on the goal of the analysis. The most popular is perhaps the division in economic terms into the pre-working, working and post-working age groups in several variants. In the literature on the subject one can also find a division into socio-economic age groups, where

the following are distinguished (cf. Gawryszewski, 2005): (a) crèche age (0‑2 years); (b) kindergarten age (3‑6 years); (c) primary-school age (7‑14 years); (d) secondary-school age (15‑19 years); (e) university age (20‑24 years); (f) working age (18-64/59 years – 64 for males, 59 for females); and (g) post-working age (60/65 and over – 65 for males, 60 for females).

This way of population grouping seems very interesting, but there is a slight mismatch between the present system of school education and the boundary values adopted above. Besides, this division does not accommodate age differences among the working population, and it is those differences that may be crucial in deciding the future demographic potential and possibilities of socio-economic development of the given area. Therefore, for the purposes of the present study, the following additional groups were distinguished in the population of working and post-working age: (a) start of economic activity (25‑29 years); (b) occupational maturity (45‑49 years); (c) occupational advancement (50‑54 years); (d) decline in economic activity (55‑59 years); (e) cessation of work (60‑64 years); and (f) retirement (65‑69 years).

The population's age structure is a derivative of demographic change as shaped by vital statistics (births and deaths) and partly by migration flows (Jurek, 2004). In the Polish conditions, however, the present age structure of the country's population is still the result of Second World War losses. There have also appeared some new factors that gained in significance during the systemic transformation and that crucially modify the effect of the traditional ones (vital statistics and migration). The most important ones include a new model of the family, the population's more intensive economic activity and in effect a postponement of parenthood, or giving up parenthood altogether in favour of a career at work (Giddens, 2006; Næss, 2000; Inglot-Brzęk, 2010).

4. The age structure of voivodship populations and its changes between 1999 and 2010: a univariate approach

In 1999, the groups contributing the largest mean proportions to the age structure of the population of the 16 voivodships were those of 15‑19, 20‑24 and 40‑44 years, and the smallest proportions, the pre-retirement and retirement age groups (55‑59, 60‑64 and 65‑69 years; cf. Table 1). The variable

Table 1. Statistical characteristics of variables describing the age structure of inhabitants of Polish voivodships in the years 1999 and 2010

A	1999			2010		
	B	C	D	B	C	D
0-4	5.43	0.41	7.54	5.19	0.40	7.81
5-9	6.75	0.50	7.41	4.65	0.30	6.55
10-14	7.96	0.50	6.30	5.23	0.33	6.35
15-19	**8.79**	0.33	3.75	6.44	0.42	6.47
20-24	8.01	0.32	4.05	7.58	0.42	5.51
25-29	7.00	**0.18**	**2.60**	8.66	**0.22**	**2.59**
30-34	6.25	0.29	4.59	7.95	0.38	4.83
35-39	6.90	0.30	4.39	7.05	0.26	3.71
40-44	8.27	0.43	5.19	6.14	0.25	4.00
45-49	7.89	0.60	7.61	6.45	0.29	4.45
50-54	6.13	0.49	7.98	7.67	0.35	4.58
55-59	**4.15**	0.36	8.73	7.46	0.53	7.08
60-64	4.46	0.31	7.00	6.06	0.50	8.32
65-69	4.25	0.32	7.45	**3.49**	0.32	9.12
70 and more	7.77	**1.03**	**13.29**	**9.97**	**0.93**	**9.35**

Explanation: A – variable (age interval); B – mean; C – standard deviation; D – coefficient of variation

Source: Own compilation on the basis of Central Statistical Office data

that turned out to differentiate the age structures of the voivodships most sharply was the proportion of people aged 70 and over; for this age interval both the standard deviation and the coefficient of variation assumed the highest values (1.03 and 13.29, respectively). Thus, there were voivodships where the proportion of people in this age group was relatively small (for example, in Warmińsko-Mazurskie, 6.47%; Pomorskie, 6.71%; Lubuskie, 6.77%; or Zachodniopomorskie, 6.78%) and those where this proportion was the largest of all the age intervals analysed (for example, in Łódzkie, 9.53%; Świętokrzyskie, 9.21%; Mazowieckie and Lubelskie, 9.02% each). The voivodships differed least in the proportion of people aged 25–29, which was 7% on average (with the lowest standard deviation at 0.18 and the lowest coefficient of variation at 2.6), and the proportion of people of secondary-school age (15–19 years), which was also the largest (8.79%) while having a low coefficient of variation (3.75).

The situation was somewhat different in 2010, when both the largest average (16-voivodship) proportion (9.97%) and the greatest heterogeneity of voivodships as measured by the standard deviation (0.93) and the coefficient of variation (9.35%) were recorded for the 70+ age interval (cf. Table 1). Thus, the mean proportion of this population group was up from the year 1999, while the differences among the voivodships in this respect narrowed, which can be seen as a clear manifestation of society's ageing. The largest proportion of people aged 70 and over was noted in Świętokrzyskie (11.3%), Podlaskie (11.11%) and Łódzkie (11.1%), while the smallest, in Wielkopolskie (8.76%) and Warmińsko-mazurskie and Lubuskie (8.75% each).

The lowest mean proportion of the population in 2010, 3.49%, was that of people aged 65–69, which may be the consequence of the lowest mean proportion of people in the 55–59 group in 1999. This is also a variable clearly differentiating the voivodships (a coefficient of variation of 9.12%). Generally, the widest differences among the voivodships in terms of the variables adopted were in the mean proportion of older people (60 and over) as well as children and teenagers (19 and under), and the smallest, as in 1999, in the mean proportion of people aged 25–29.

When comparing the age structure of voivodship populations in the years 1999 and 2010, one

can find that this was a period of a decline in the proportion of the following age groups: 0–24, 40–49 and 65–69, and of an increase in the proportion of people aged 25–39 and 50–64 years as well as those aged 70 and over. Those tendencies of change do not augur well for the country's demographic future and call for a suitable population-boosting policy and its consistent implementation.

5. Principal components of the age structure of voivodship populations (a complex level of analysis)

The transformation of the 15 original variables adopted for analysis into principal components gave the following results for the year 1999: the first component (V_1) accounted for 31.13% of the total variance, the second (V_2), for 21.05%, and the third (V_3), for 11.72%. Thus, the remaining components accounted jointly for 36.1% of the original variance. In 2010 the transformation of the variables into principal components looked somewhat different. The first component (V_1) accounted for 25.87% of the variance of the entire set of variables, the second component (V_2), for 23.3%, the third (V_3), for 14.07%, and the remaining ones, for a total of 36.76% (cf. Table 2).

The character of a principal component is determined by the original variables correlated with it. Thus, in 1999 the first component was described primarily by per cent of the population aged 50–54 and 55–59, and the second component, by that of the population aged 45–49. The third and fourth

Table 2. Variance of the variables of the age structure of voivodships populations transformed into principal components

A	1999		2010	
	a	b	a	b
V1	31.13	31.13	V1	31.13
V2	21.05	52.18	V2	21.05
V3	11.72	63.90	V3	11.72
V4	9.67	73.57	V4	9.67
the rest	26.43	100.00	the rest	26.43

Explanation: A – Component; a –%; b – cumulative%;

Source: Own compilation

principal components showed a much weaker connection with the original variables: the third with the percentage of people aged 65-69, and the fourth, with those aged 5-9 and 25-29. The first component can thus be called one of a decline in economic activity; the second, of occupational maturity; the third, of the population of retiring age; and the fourth, of the start of economic activity. Therefore it was those age groups that were primarily responsible for regional differences in the age structure of Poland's population in 1999 (Table 3).

The variables defining the nature of principal components in 2010 were different. A very strong relation with the original variables was shown by the first three components, the first of which was correlated with per cent of the population aged 20-24 and 55-59 years; the second, with the proportion of people aged 50-55 as well as 70 and over, and the third, with the percentage of people aged

60-64 and 65-69. The first principal component can thus be called one of the university period and of a decline in economic activity; the second, of occupational advancement and retiring age; and the third, of cessation of work and of retirement (Table 4).

The individual principal components can be treated as successive levels differentiating the voivodships in terms of the properties of those components.

The character of the principal components, both in 1999 and 2010, shows that the factor differentiating the voivodships in terms of the age structure of their residents is primarily the proportion of mature people (aged 45 and over), and only to a little extent that of children and teenagers. Inter-regional differences in Poland's oldest population are undoubtedly connected with the country's demographic transformation after the Second World

Table 3. Variables determining the properties of the principal components of the age structure of voivodships in 1999

A	B
V_1 (of decline in economic activity)	– per cent of people aged 50-54 ($r^2 = 0.714$, $\alpha < 0.001$) – per cent of people aged 55-59 ($r^2 = 0.630$, $\alpha < 0.001$)
V_2 (of occupational maturity)	– per cent of people aged 45-49 ($r^2 = 0.598$, $\alpha < 0.001$)
V_3 (of population of retiring age)	– per cent of people aged 65-69 ($r^2 = 0.254$, $\alpha = 0.05$)
V_4 (of start of economic activity)	– per cent of people aged 5-9 ($r^2 = 0.317$, $\alpha < 0.05$) – per cent of people aged 25-29 ($r^2 = 0.247$, $\alpha < 0.05$)

Explanation: A – Component, B – Variable

Source: Own compilation

Table 4. Variables determining the properties of the principal components of the age structure of voivodships in 2010

A	B
V_1 (of university period and decline in economic activity)	– per cent of people aged 20-24 ($r^2 = 0.715$, $\alpha < 0.001$) – per cent of people aged 55-59 ($r^2 = 0.564$, $\alpha < 0.001$)
V_2 (of occupational advancement and retiring age)	– per cent of people aged 50-55 ($r^2 = 0.651$, $\alpha < 0.001$) – per cent of people aged 70 and over ($r^2 = 0.551$, $\alpha < 0.001$)
V_3 (of cessation of work and retirement)	– per cent of people aged 60-64 ($r^2 = 0.554$, $\alpha < 0.001$) – per cent of people aged 65-69 ($r^2 = 0.728$, $\alpha < 0.001$)

Explanation: A – Component, B – Variable

Source: Own compilation

War, especially its demographic dynamics, change of the state borders, and rural-to-urban migration.

The calculated values of the components allow a classification at each of the distinguished levels of difference. The most interesting, however, seems to be the classification of voivodships in terms of those principal components which accounted for most of the variance of the original variables, i.e. the first and second components, in each of the years analysed.

For 1999, on the basis of a linear ordering of the first principal component (decline in economic activity), the following five classes of voivodships were distinguished that differ in the proportion of people reaching the end of their working life:
- Class I: Łódzkie,
- Class II: Śląskie, Dolnośląskie, Podlaskie, Małopolskie, Lubelskie, Świętokrzyskie, and Warmińsko-Mazurskie,
- Class III: Zachodniopomorskie,
- Class IV: Opolskie, Podkarpackie, Pomorskie, Wielkopolskie, Mazowieckie, and Kujawsko-Pomorskie, and
- Class V: Lubuskie.

This component is bipolar in nature, which means that gathered at one end of the scale in the linear ordering are voivodships with a relatively high proportion of people aged 50‒54 (class I embracing the voivodship of Łódzkie), and on the opposite one, those with a relatively low proportion of people aged 55‒59 (class V embracing Lubuskie). When this classification is depicted on a map, one can distinguish seven regions, the largest one being composed of six voivodships of north-eastern, eastern and southern Poland, with the exception of Podkarpackie. This shows the coefficient of mosaicity for this classification to be fairly low, at 1.4 (cf. Fig. 1).

The classes distinguished on the basis of the second principal component (occupational maturity) for 1999 look as follows:
- Class I: Kujawsko-Pomorskie,
- Class II: Świętokrzyskie, Dolnośląskie, Lubuskie, Zachodniopomorskie, Mazowieckie, Małopolskie, and Pomorskie,
- Class III: Podlaskie and Wielkopolskie,
- Class IV: Łódzkie, Podkarpackie, Opolskie and Lubelskie, and
- Class V: Śląskie and Warmińsko-Mazurskie.

Classes

I   II   III   IV   V
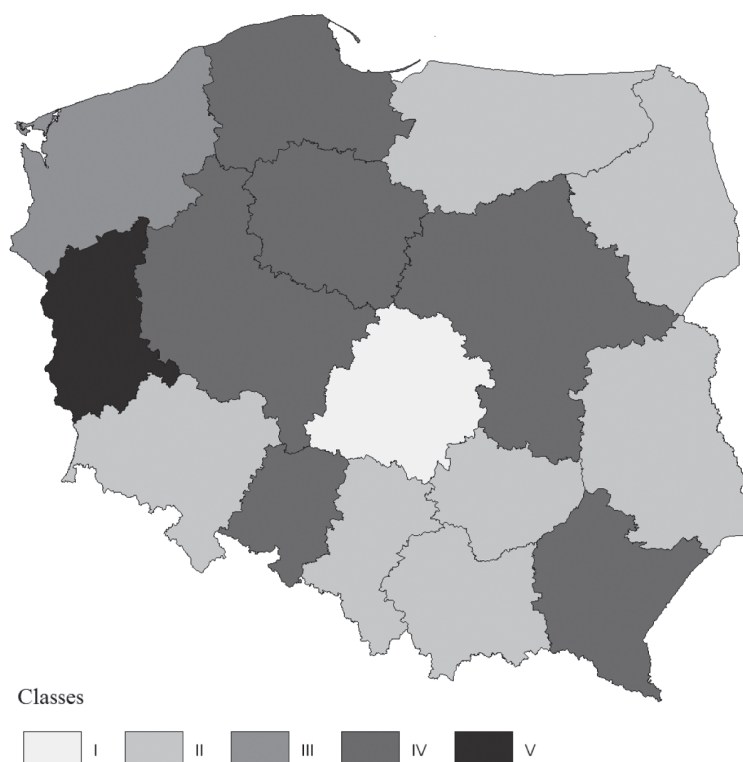
Fig. 1. Classification of voivodships in terms of V_1 (decline in economic activity) in 1999
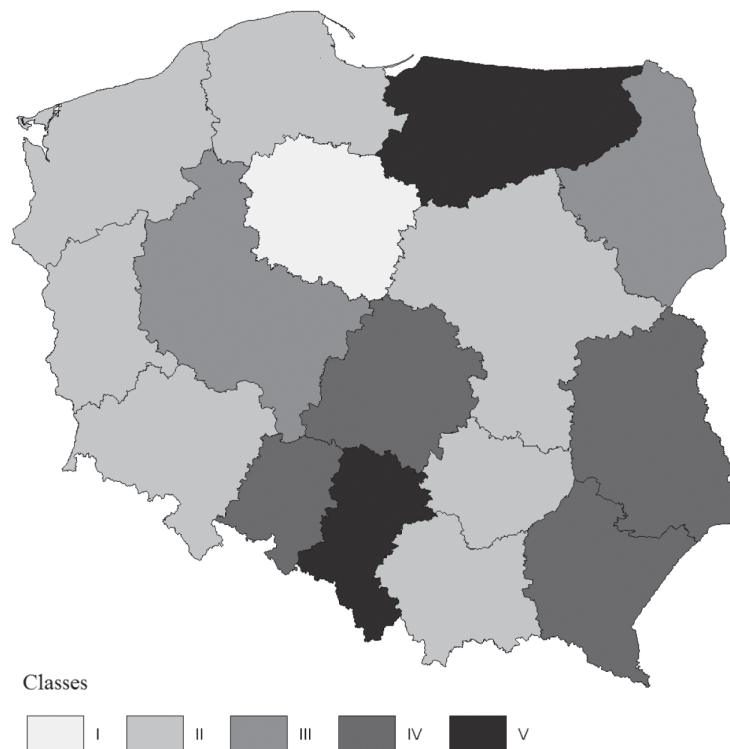
Source: Own compilation

The interpretation of this classification is fairly difficult because this component is determined not only by one basic variable (per cent of people aged 45‒49), but also by other variables, although to a lesser extent. It seems, however, that class I can be taken to be represented by a voivodship with a large proportion of the occupationally mature population, which then declines in the successive classes distinguished, to reach a minimum in class V. When its results are presented on a map, this classification allows distinguishing as many as nine regions, the two largest embracing (a) four voivodships of Pomorskie and western Poland (Pomorskie, Zachodniopomorskie, Lubuskie, Dolnośląskie), and (b) three in central Poland (Mazowieckie, Łódzkie, Małopolskie; cf. Fig. 2). Both regions include voivodships of class II. In the case of this regionalisation, the coefficient of mosaicity equals 1.8.

For the year 2010, the classification of voivodships by principal components looks different. The first principal component (of the university period and economic activity) also has a clearly bipolar character, one end occupied by voivodships with a large proportion of the population in the period of economic decline (class I), and the opposite one by those with a large proportion of people of university age (class V). This classification looks as follows:

- Class I: Łódzkie,
- Class II: Warmińsko-Mazurskie,
- Class III: Mazowieckie, Śląskie and Opolskie,
- Class IV: Pomorskie, Podlaskie, Dolnośląskie, Świętokrzyskie, Kujawsko-Pomorskie, Lubelskie, Małopolskie, Wielkopolskie, and Podkarpackie, and
- Class V: Lubuskie and Zachodniopomorskie.

Depicted on a map, this classification shows there to be seven regions, the largest embracing five voivodships of eastern and south-eastern Poland (cf. Fig. 3). Clearly visible in the figure is a relatively high proportion of the population of university age in western and eastern Poland, and of the population in the period of economic decline in central Poland. The coefficient of mosaicity in the case of this classification is relatively low again, at 1.4.

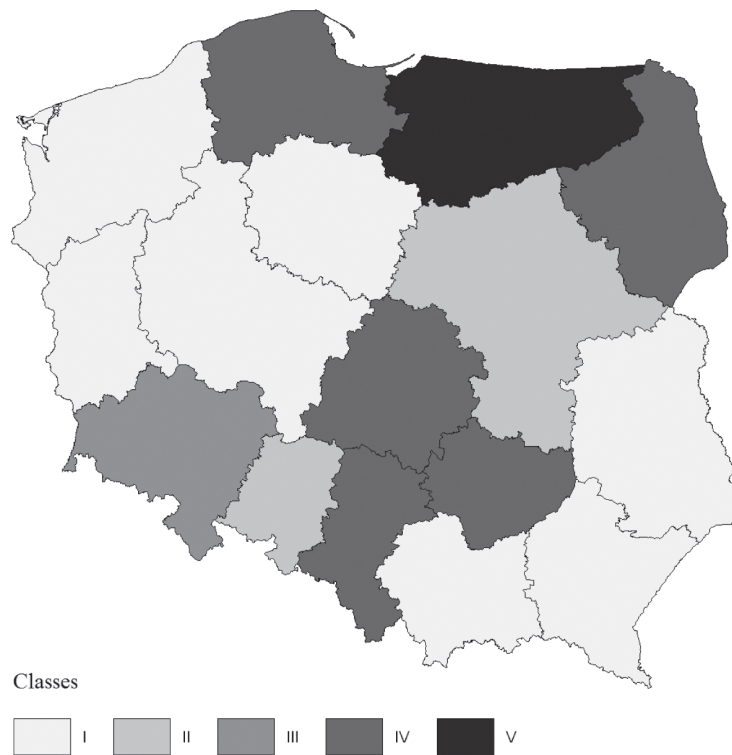**Fig. 2.** Classification of voivodships in terms of V_2 (occupational maturity) in 1999

Source: Own compilation
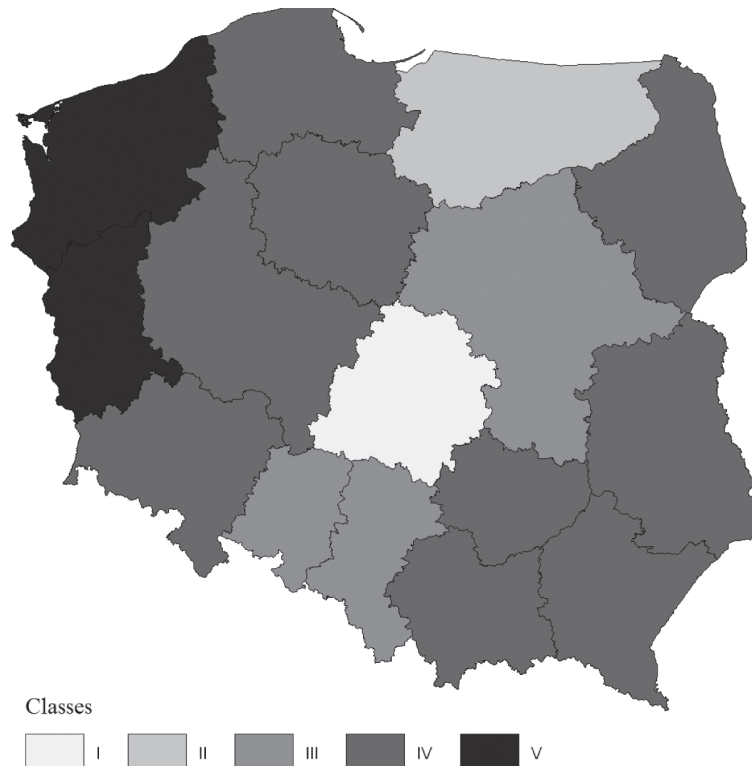
Fig. 3. Classification of voivodships in terms of V_1 (university period and decline in in economic activity) in 2010
Source: Own compilation

Fig. 4. Classification of voivodships in terms of V_2 (occupational advancement and retiring age) in 2010
Source: Own compilation

The second principal component for the year 2010 (occupational advancement and retiring age) is also bipolar in nature. Simplifying, located at one pole are voivodships with a high proportion of people of retiring age (class I), and at the other, with a low proportion (class V). The classification made on the basis of this component looks as follows:

- Class I: Lubelskie, Małopolskie, Lubuskie, Wielkopolskie, Podkarpackie, Zachodniopomorskie, and Kujawsko-Pomorskie,
- Class II: Mazowieckie and Opolskie,
- Class III: Dolnośląskie,
- Class IV: Pomorskie, Świętokrzyskie, Łódzkie, Podlaskie, and Śląskie, and
- Class V: Warmińsko-Mazurskie.

Presented on a map, the classes form nine regions, the largest embracing four voivodships in the north-western part of the country with a relatively high percentage of the population of retiring age, and the coefficient of mosaicity equals 1.8 (cf. Fig. 4). The lowest proportion of the population in this age group can be found in the voivodships of northern Poland, especially Warmińsko-Mazurskie.

6. The age structure of voivodship residents: a synthetic approach

Taking into consideration all the variables describing the age structure of the population, and using cluster analysis, a synthetic classification of the voivodships was made (assuming the 5-class variant).

For the year 1999, those were the following classes (cf. Fig. 5):

- Class I: Opolskie, a voivodship with the highest percentages of people aged 30‑34, 35‑39 and 60‑64 among all voivodships;
- Class II: Podkarpackie, with the highest percentages of children and teenagers (0‑4, 5‑9 and 10‑14 years) and the smallest one of people aged 40‑45;
- Class III: Kujawsko-Pomorskie, whose age structure is close to the means calculated for all the voivodships;
- Class IV: Lubuskie, Wielkopolskie, Pomorskie and Mazowieckie, or regions with a high percentage of young people and a low percentage of older people; and
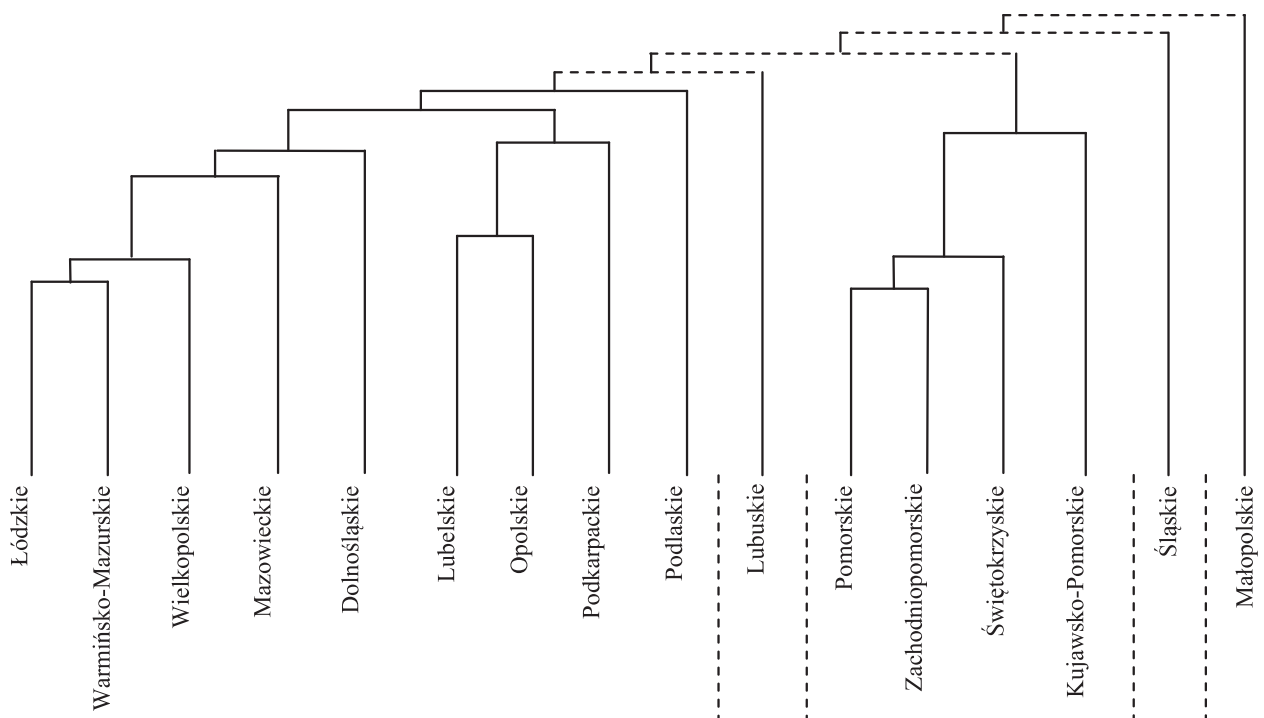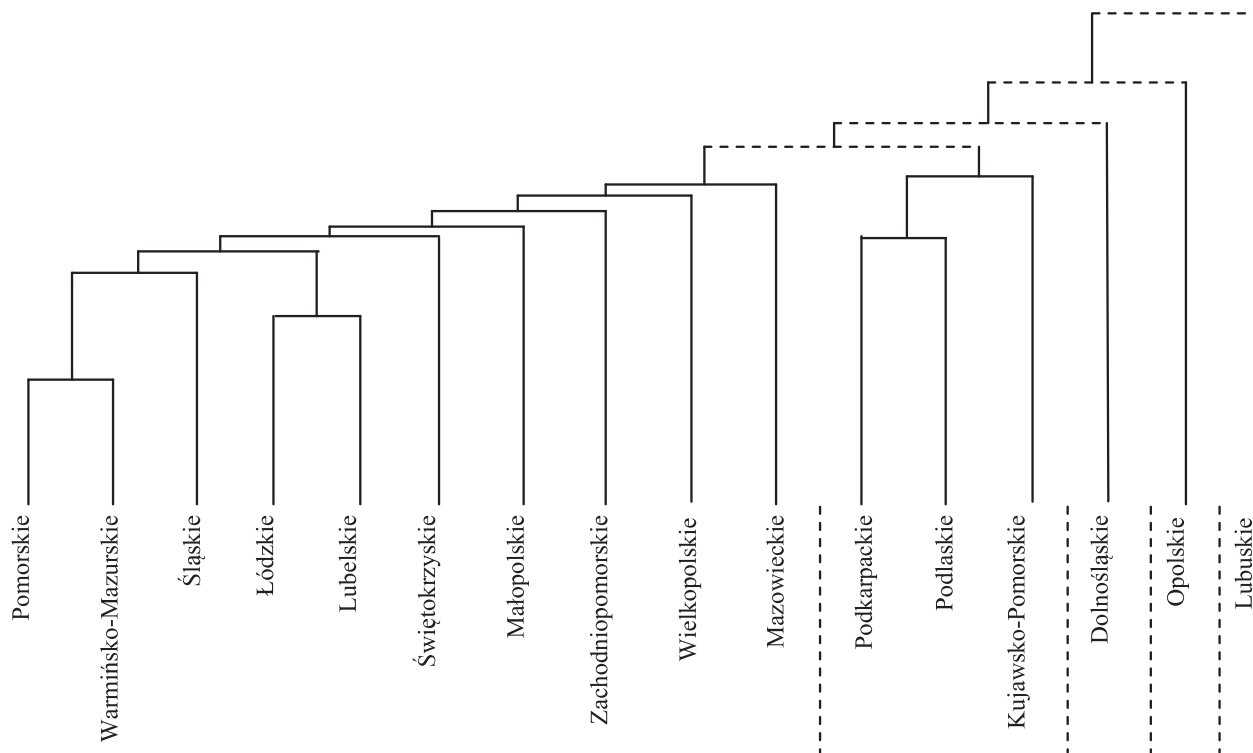

Fig. 5. Structure of similarity of voivodships in terms of population age in 1999

Source: Own compilation

Fig. 6. Structure of similarity of voivodships in terms of population age in 2010

Source: Own compilation

- Class V: Dolnośląskie, Podlaskie, Lubelskie, Śląskie, Świętokrzyskie, Warmińsko-Mazurskie, Zachodniopomorskie, Łódzkie and Małopolskie, all with a similar age structure of the population.

In 2010, in turn, the following classes were distinguished (cf. Fig. 6):
- Class I: Opolskie again, with the lowest percentage of children up to 9 years old and the highest percentage of people aged 40–49;
- Class II: Podkarpackie again, with a high proportion of children and young people, especially those aged 10–24, and a low proportion of older people;
- Class III: Dolnośląskie, in which one can observe the lowest proportion of the population aged 40–44, and the highest one of that in the 55–59 age interval;
- Class IV: Warmińsko-Mazurskie, whose characteristic feature is a low proportion of older people and a high proportion of young ones, especially those at the start of their working career (25–29 years); and

- Class V: Podlaskie, Lubelskie, Śląskie, Świętokrzyskie, Zachodniopomorskie, Łódzkie, Małopolskie, Kujawsko-Pomorskie, Lubuskie, Wielkopolskie, Pomorskie, and Mazowieckie, all with a similar age structure of the population.

Thus, standing out in both 1999 and 2010 were the specific demographic structures of Opolskie and Podkarpackie voivodships, with the tendency of change occurring in Opolskie indicative of demographic ageing of its population, while in Podkarpackie the proportion of children declining in favour of teenagers, and the proportion of older people getting close to the mean. Standing out in 2010 were also Warmińsko-Mazurskie with its relatively young population, and Lower Silesia with a growing proportion of people at the end of their working career and pensioners, while the age structure of the Kujawsko-Pomorskie population, so characteristic in 1999, in 2010 became similar to those of most Polish voivodships. In 1999, visible in the graphic depiction of the classes were eight regions differing in the age structure of their

populations (the coefficient of mosaicity = 1.6), while in 2010 there were only five such regions (the coefficient of mosaicity = 1). Thus, the differences among voivodships in the age structure of their populations narrowed, especially in north-western, western and central Poland. The greatest heterogeneity in 2010 was displayed by the voivodships of southern Poland, with Podkarpackie characterised by a relatively young population, Opolskie and Dolnośląskie by an older one, and Warmińsko-Mazurskie by a relatively big proportion of young people.

7. Conclusion

The age structure of the population of a region is especially important when planning its socio-economic development. It is shaped primarily by vital statistics and migrations, but in the case of Poland one can still observe a demographic echo of the Second World War and the early post-war period, as well as of the systemic transformation of the early 1990s and the cultural changes that accompanied it.

Polish voivodships show considerable heterogeneity in the age structure of their populations, but the differences were wider in 1999 than in 2010. This is indicative of a unification of their age structures.

The contrasts in the age structures are primarily due to the older groups, which means that the voivodships tend to grow increasingly similar in the proportion of children and teenagers (this figure declining in most of them). An interpretation of the population age structures in the years 1999 and 2010 depicted on maps in terms of principal components is not easy because of their diversified, complex, and sometimes bipolar nature. But they, too, seem to indicate that the age structures tend to unify. Unlike in regions distinguished on the basis of the first two principal components in 1999, in 2010 one can hardly see any fundamental differences in the population structure in eastern and western Poland, where the percentages of both, people of university age and those of retiring age are relatively high. There is a greater heterogeneity in this respect in a central belt running across the

country, from Warmińsko-Mazurskie in the north, through Mazowieckie and Łódzkie, to Śląskie and Opolskie in the south.

In 2010, there were only four voivodships with a distinctive population age structure, which means that in as many as the 12 remaining ones those structures were highly similar. Some differences could only be found among a few voivodships of southern Poland and in Warmińsko-Mazurskie in the north. This fact, too, shows a unification in the age structure of the population.

The analysis conducted corroborates the thesis of the demographic ageing of Poland's population in no uncertain terms, this fact being true not only of the country as a whole, but also of practically each and every of its voivodships. This puts them in a difficult situation when required to boost their economic competitiveness, while the increasingly unfavourable age structures of the population cannot but be treated as a potential threat to the stability of socio-economic development.

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