

Current Spatial Aspects of Demographic Differentiation and Urbanization Process in Poland (Pilot Study)

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Abstract. The paper aims to analyze the balance between selected spatial demographic factors, i.e., elements of local demographic structure of population and intensity of urbanization process in Poland. Urbanization is currently perceived as an ambiguous process: people move to the metropolises (cities), but in turn, there is an observed decrease in fertility rates in urban areas. The hypothesis that rapidly urbanizing areas attract a cohort of young households at a fertile age is being investigated. It was assumed that there are specific regions that deviate from the general trend of an aging urban population. This would be reflected in the age distribution and higher fertility rate, especially in the settlement of selected growing urban, peri-urban, and rural areas of some cities. The sources of the data were the statistics of Poland (Polish CSO) at a certain given level of spatial (administrative) units (NUTS). As far as expected results are concerned, in the context of population characteristics and differentiation according to specific locations and geographical areas of Poland, our pilot study may have policy implications, such as the need for city planners to consider spatial variables in order to achieve the desired trade-off between meeting social needs and developing urban ecosystems in a sustainable manner. The starting point of the research methodology is a spatial matrix of correlations between selected demographic and urban process' characteristics.

Keywords: Urbanization · Demographic Differentiation · Poland

1 Introduction

In 2022, the global human population achieved a milestone of 8 billion [1]. Since 1975, the world has been adding another billion people every 12 years and is projected to surpass 9 billion around 2037 and 10 billion around 2058 (Fig. 1). Over the last decades, a persistent rise in population worldwide has significantly altered the landscape of urban fabric. Between 1975 and 2014, humanity has taken up more land for settlements than in all previous centuries [2].

Today, at least 56% of the population lives in cities, and urbanization is proceeding steadily worldwide. By 2050, approximately 7 out of 10 people will live in cities [4], with the urban population predicted to more than double from its current level [5].

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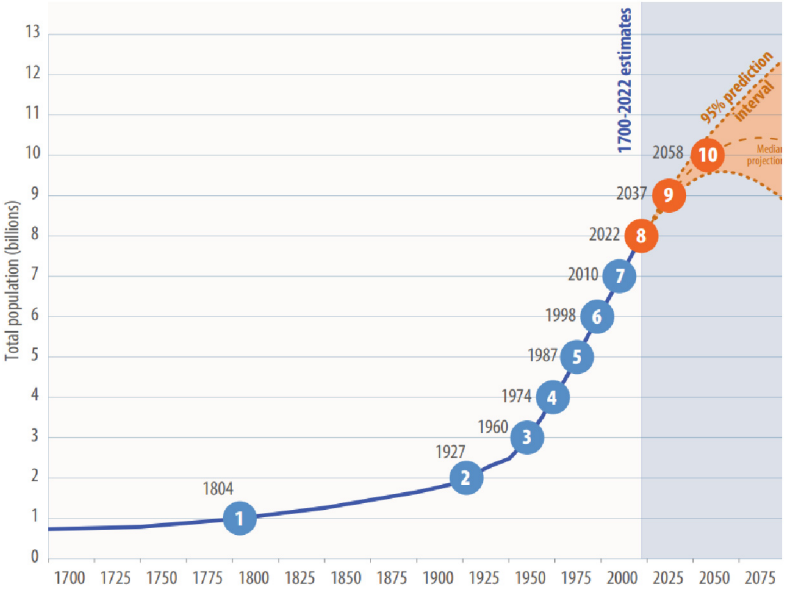

Fig. 1. Global population: estimates for 1700–2022 and projections for 2022–2100 [3].

In 2020, there were 1934 metropolises with more than 300,000 inhabitants, accounting for nearly 60% of the world's urban population, and it is expected that almost 1 more billion people will become metropolitan inhabitants in the next fifteen years [6].

In general, more economically developed regions have higher rates of urbanization than less developed regions [5, 7]. Total fertility rates have been lower than replacement rates in most economically developed regions for decades, though rates in less-developed economies remain higher [8]. The total population of the least developed countries is growing at a rate that is 2.5 times faster than the growth rate of the total population of the rest of the world [9]. In this context, population sizes in more economically developed, highly urbanized regions have recently declined, while those in the least-developed, least-urbanized regions have increased during the same period, reflecting fertility differences.

Cities expanded in size by 1.5% per year between 2000 and 2015. The land uptake by cities was higher in low-income countries (2.6%) than in middle-income countries (1.9% in lower middle and 1.5% in upper middle) or high-income countries (1%) [10]. Due to that expansion, many cities have grown beyond the boundaries of their central municipality. Simultaneously with global urban growth, there is an intensive urban sprawl process that forms low-density, often dispersed developments around the cities. Urban sprawl increased by 95% in 24 years worldwide, almost 4% annually, with built-up areas expanding by almost 28 km^2 per day. Europe has been the most sprawled and also the most rapidly sprawling continent, by 51% since 1990 [11].

In 2021, the population of Poland was declining. The population decline was for the first time during decades in both urban and rural areas; in previous years, the number

of urban residents continued to decline, while the number of people living in rural areas increased (Fig. 2).

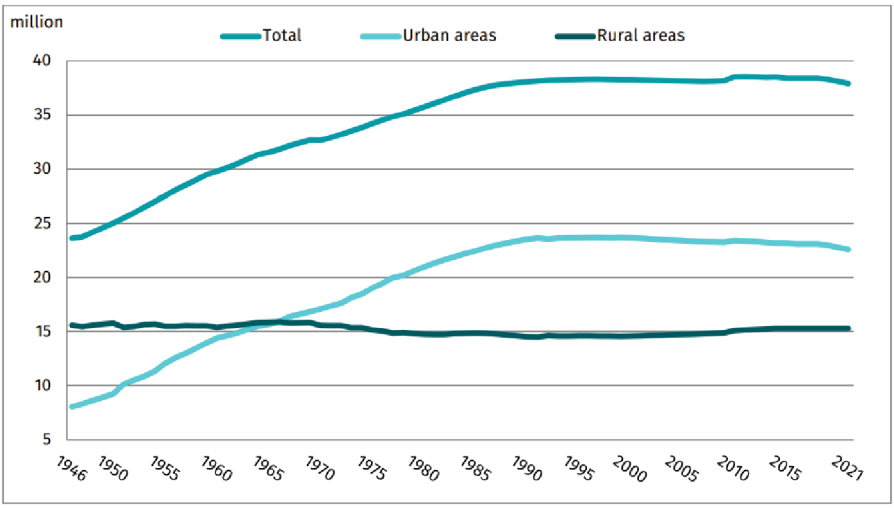

Fig. 2. Urban and rural population in Poland (1946–2021). Source: [12].

At the same time, in 2021, Poland's construction industry attained peak efficiency following impressive growth during the last decade [13]. In fact, 2020 was the first year that residential construction in Poland reached levels that were last seen during the communist era, with a high demand for additional housing as the post-war (WWII) baby-boomer generation entered the labour market. Earlier study portraits that the current construction boom is related to progressive suburbanization around Poland's mayor cities rather than inner urban growth of the central areas of metropolises [14].

The main aim of this paper was to reveal current latent factors specific to observed demographic and urbanization processes in Poland as well utilize some new portions of data collected within the completed in 2021 Polish National Population and Housing Census.

Accordingly, this study addresses the following questions: How demographic profile of inhabitants (families) interrelates to urban characteristics of settlement they reside? What are the differences in the combination of degree of urbanization and demographic structure of the population between spatial units? Are there any particular housing preferences associated with various cohorts of the population?

The main hypothesis is as follows: Rapidly urbanizing areas attract a cohort of young families at a fertile age.

The focus is on the year 2021 because this is the year of the most recent dataset available from the Central Statistics Office (annual editions) and the year of the last census, which is conducted in Poland once per decade.

2 Data and Methods

2.1 Methods

The applied procedure aimed to collect relative vast volume of data (variables) within the set of NUTS 4 administrative spatial units (380 counties in Poland). The next step of study involved dimension reduction using factor analysis (FA). Initial input variables were transformed into compound factors (components). Results of FA i.e. selected components were, in turn described, reinterpreted and visualized on cartographical maps to reveal their spatial differentiation, as the latent factors which determined the general trends of demographic and urbanization processes in Poland in 2021.

The objective of data reduction is to remove redundant (highly correlated) variables from the data file, replacing the entire input data variables with a smaller number of uncorrelated variables. Structure detection is used to examine the underlying (or latent) relationships between variables. The aim is to reveal the complex components with a very clearly defined influence of the observed phenomena.

The starting steps of FA were estimation of Covariance Matrix and Correlation Matrix of input variables. Then, the communalities of loading factors were extracted using principal component analysis (PCA) procedure. The PCA method produced a solution using principal component extraction (not rotated). For each of new component of PCA initial eigenvalues, individual percentage and cumulative percentage of variance were estimated. The components with eigenvalues were saved. The extraction communalities are estimates of the variance in each variable accounted for by the components. The high values of communalities indicate that the extracted components represent the variables well. These results was the starting point to FA aimed to reveal new insight into rotated components (Rotation Method: Varimax with Kaiser Normalization) and cut off the components with the diminished variance based on extraction rotation sums of squared loadings. The next steps of FA concerned only the chosen subset of initial components of PCA with a satisfactory level of representation and variance of the initial variables. Elimination of components was based on scree plot.

All procedures were completed using IBM SPSS software (ver.28).

2.2 Input Variables

The list of selected input variables involves characteristics concerning demographic, urbanization as well infrastructure data which (in opinion of authors) let reveal some specific spatial trends and heterogeneity of observed phenomena (Table 1). The acquired variables concern the data within the set of 380 spatial administrative units at NUTS 4 level (counties).

Table 1. Input statistical variables (by counties 2021).

Input Variable name	Description (per county in 2021)
RE2021Tot	Dwellings completed (per 10 000 inhabitants)
LQ2021	Location quotient of dwellings completed (relative measure; [15])
RoadsPow2021	Density of roads per 100 sq.km
Cars2021	Passenger cars (absolute number)
Stops2021	Active stops of public transport (absolute number)
RevPerPerson2021	Average gross monthly salaries
UEB2021	Share of urbanization %
PNPow2021	Natural increase
WSM0_17_2021	Migration balance index (0–17 years)
WSM0_64_2021	Migration balance index (17–64 years)
WSM64+2021	Migration balance index (over 64 years)
RodzinyTotal2021	Total number of households (families)
TotalRoDzieci	Total number of child families
RoDzieci0_2021	Total number of childless families
RoDzieci1_21	Total number of families with 1 child
RoDzieci2_21	Total number of families with 2 children
RoDzieci3_21	Total number of families with 3 children
RoDzieci4+21	Total number of families with 4 or greater children
TotalDzieci21	Total number of children
AvgDzieci	Average number of children per family
NieprodPer100Prod2021	Non-working age population per 100 people of working age
Wom15-34	Total number of women aged 15–34
Wom35-49	Total number of women aged 35–49

2.3 FA Results

There were four components extracted as compound measures of observed phenomena (Table 2). They explained 86.03% of total variance (from initial variables). The Varimax rotation method with Kaiser normalization was applied during FA.

Table 2. Total variance explained by selected FA components.

Component	Initial Eigenvalues Variance			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	%	Cumulative %	Total	%	Cumulative %	Total	%	Cumulative %
1	11.88	51.67	51.67	11.88	51.67	51.67	10.81	47.00	47.00
2	4.31	18.74	70.41	4.31	18.74	70.41	3.95	17.16	64.16
3	2.55	11.07	81.48	2.55	11.07	81.48	2.87	12.46	76.62
4	1.04	4.54	86.03	1.04	4.54	86.03	2.16	9.40	86.03

Table 3. Rotated component matrix. Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 7 iterations (IBM SPSS software v.28).

Initial variables	Component				Initial variables description
	1	2	3	4	
RE2021Tot	0.25	0.83	0.29	0.14	Dwellings completed (per 10 000 inhabitants)
LQ2021	0.29	0.77	0.36	0.15	Location quotient of dwellings completed (relative measure; [15])
RoadsPow2021	0.26	-0.09	0.76	-0.04	Density of roads per 100 sq.km.
Cars2021	0.96	0.08	0.19	-0.02	Passenger cars (absolute number)
Stops2021	0.87	0.17	-0.15	-0.01	Active stops of public transport (absolute number)
RevPerPerson2021	0.29	0.22	0.50	-0.30	Average gross monthly salaries
UEB2021	0.11	-0.16	0.85	-0.32	Share of urbanization %
PNPow2021	0.14	0.54	0.09	0.74	Natural increase
WSM0_17_2021	-0.03	0.80	-0.44	0.05	Migration balance index (0-17 years)
WSM0_64_2021	0.25	0.92	-0.05	0.04	Migration balance index (17-64 years)
WSM64+2021	0.00	0.79	-0.31	0.10	Migration balance index (over 64 years)
RodzinyTotal2021	0.97	0.11	0.21	0.00	Total number of households (families)
TotalRoDzieci	0.98	0.13	0.17	0.03	Total number of child families
RoDzieci0_2021	0.94	0.08	0.28	-0.06	Total number of childless families
RoDzieci1_21	0.96	0.09	0.22	-0.05	Total number of families with 1 child
RoDzieci2_21	0.97	0.18	0.13	0.07	Total number of families with 2 children
RoDzieci3_21	0.89	0.15	-0.05	0.34	Total number of families with 3 children
RoDzieci4+21	0.70	0.05	-0.19	0.52	Total number of families with 4 or greater children
TotalDzieci21	0.98	0.14	0.13	0.09	Total number of children
AvgDzieci	-0.12	-0.04	-0.55	0.72	Average number of children per family
NieprodPer100Prod2021	-0.11	-0.16	0.23	-0.68	Non-working age population per 100 people of working age
Wom15-34	0.96	0.09	0.21	0.05	Total number of women aged 15-34
Wom35-49	0.96	0.11	0.21	-0.01	Total number of women aged 35-49

The interpretation of FA components were based on comparison to initial variables using rotated component matrix, which is in fact the matrix of Pearson's correlation coefficients (Table 3).

1. **Mobile vital families**. The first factor was interpreted as the demographic component of mobile families (of childbearing age) with stable incomes in areas connected (communicated), with possible expansion of development.
2. **Migration families.** The second factor was interpreted as migration component of families with relatively stable incomes in areas of development expansion (including outside cities).
3. **Small rich families.** The third factor describes the demographic component of small, high-income families (including childless and multi-generational families) in cities and areas of urbanization and development expansion.

4. **Large immobile families**. The fourth factor describes the demographic component of immobile families with large numbers of children and low incomes outside cities.

2.4 Spatial Differentiation of FA Components

All values on maps represent adequate volume of variance of certain components.

Mobile Vital Families. This component is associated with stable-income families at fertile age inhabiting connected areas (reflected in high amounts of personal cars and bus stops) with possible expansion of urbanization. The area of representation of this component is heterogeneous (Fig. 3).

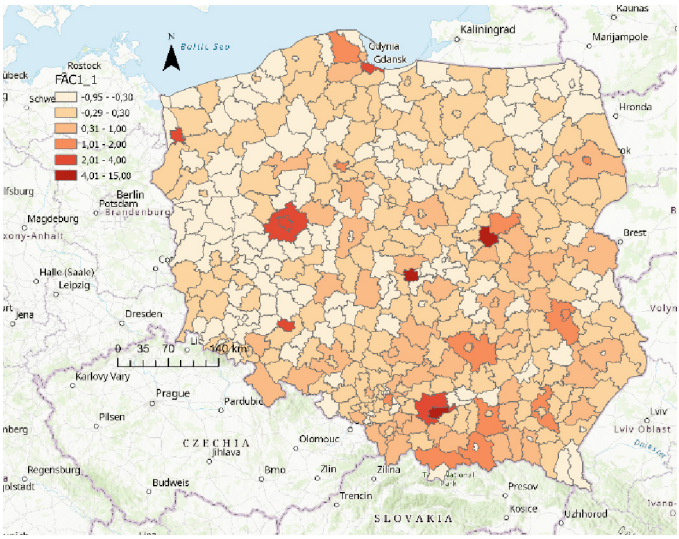

Fig. 3. Mobile vital families.

In some cases these are major Poland's cities, in others these are *"bagels"* surrounding the central municipality (mostly in a South East Poland).

Migration Families. This component is particularly interesting in the context of urban growth research because it's associated with the areas of intensive urbanization. This factor is defined by the high values of migration (positive balance), relatively high natural increase and stable income of inhabitants. The cartogram of the distribution of this component portrays overrepresentation of this cohort on the areas surrounding central cities of metropolitan areas (Fig. 4).

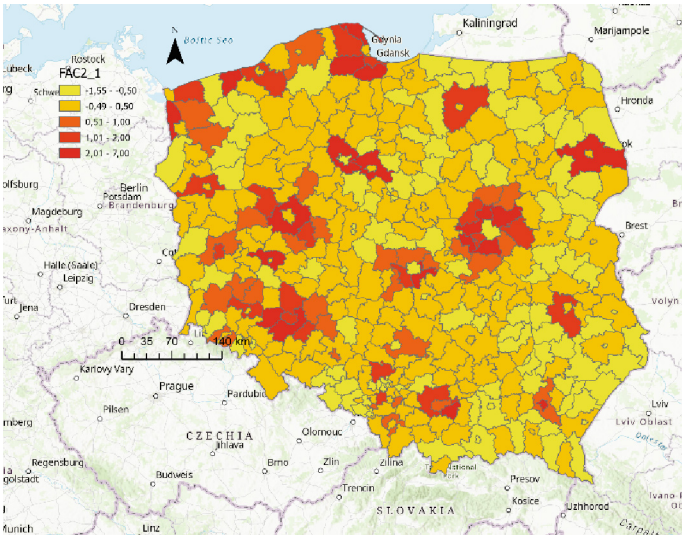

Fig. 4. Migration families

Small Rich Families. In contrast, this component is intensively distributed in central municipalities and highly urbanized areas (Fig. 5). It describes small (often childless or one kid) high-income families. This segment seems to be more pronounced in a North West Poland.

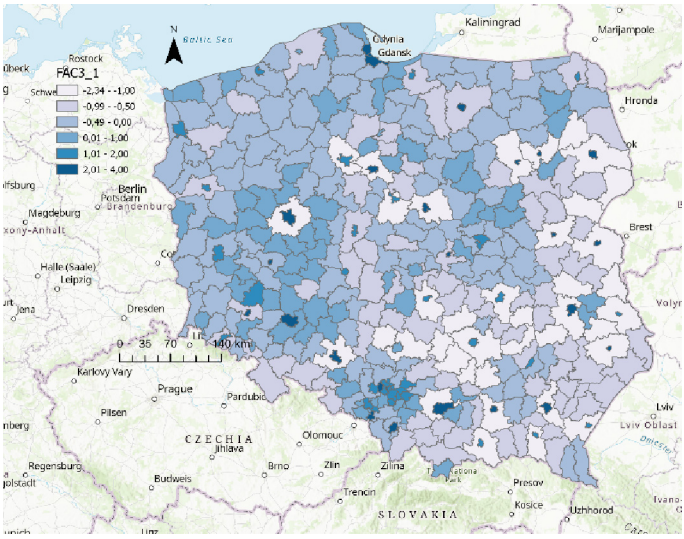

Fig. 5. Small rich families

Large Immobile Families. The fourth factor describes the cohort of large low income immobile families residing low urbanized areas. Geovisualizations of this factor provides unspecific picture (Fig. 6). This component seems to be widely distributed across country with, prevailing in outskirts of the cities.

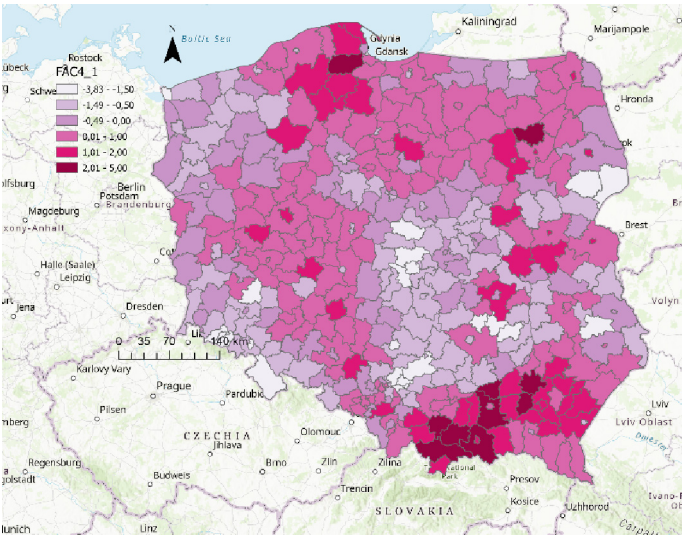

Fig. 6. Large immobile families

3 Discussion

Understanding population trends and anticipating demographic change are essential for national development planning and achieving continued progress towards the Sustainable Development Goals [3, 16–18] while drivers of human settlement distribution stays barely explored [19].

This pilot study identified compound factors specific to current sociodemographic and urbanization processes in Poland. Four extracted components (Mobile vital families (1), Migration families (2), Small rich families (3), Large immobile families (4) provided a range of latent determinants of the observed phenomena. The analysis suggests that the housing preferences of the settlers may be associated with their sociodemographic profile.

Thus, in all four cohorts the level of income of households plays a significant role. High income families are associated with residing highly urbanized areas. While stable income families are associated with the areas of intensive urbanization (the area of urban expansion) and wider unspecific areas. A further research is needed to assign the areas of overrepresentation of ‘Mobile vital families’ (1) component to better characterize the areas they inhabit.

In this study the low income families are associated with outskirt areas mainly. Another important characteristic of this cluster is immobility and high fertility rate. In contrast, high income families relate to having less (or no) kids.

The main hypothesis that the intensively urbanizing areas attract a cohort of young families at a fertile age was partially approved. The study reveal the interrelation of the areas of expansion and specific profile of settlers. They are 'Migration families' (2) characterized with stable income and relatively high level of natural increase on the area. On the other hand, no relevant age characteristic have been assigned to this group. The relation with the higher number of children haven't been confirmed either.

In the context of fertility research, mainly components three and four are on the focus of the interest. While 'Small reach families' (3) component resides cities and possess high incomes, the 'Large immobile families' (4) occupy lowly urbanized areas and tent to be poorly paid.

The fertility age was a significant parameter for components one and three, while there was no difference observed within the age category (defined for segment of 15–34 years and 35–49 years old).

Consideration of more variables describing infrastructure and urban/rural environment is recommended for future research.

4 Conclusions

The results of this study strengthen the evidence of interrelation between social profile of inhabitants and urban characteristics of settlement they reside. Complex causes likely underlie the detected spatial aspects of demographic differentiation and urbanization processes in Poland. There is a need to further examine the granularity of these disparities and the underlying causes for the observed discrepancies between different spatial units. Identifying housing needs and preferences associated with various cohorts of the population will remain a challenge for research and policymaking in the years to come.

5 Post Scriptum

The above study was prepared with consciousness that the observed phenomena dated for 2021 may change dramatically due to enormous flux of fugitives from Ukraine since February 2022. There were mainly women and children within estimated 1.6 million people. Some of them will settle in Poland, while others decide to transit or return to Ukraine. This change should be considered while multiplying this study for the following years data.

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