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Shrinking cities in Poland: identification of the phenomenon and its socioeconomic implications

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Abstract

Motivation: A steady decline in the urban population is a pressing problem for many countries in the world. Urban depopulation is also observed in Poland. This phenomenon not only leads to demographic changes, but it also has economic, financial, social, and environmental implications. Numerous studies have shown that urban shrinkage has different causes and implications, which reflects the complex and multifaceted character of the problem

Aim: The aim of this article was to identify and classify shrinking cities in Poland based on the criterion of a steady decline in the urban population, to classify shrinking cities based the rate of urban depopulation, and to examine the relationship between urban depopulation and the indicators of local socioeconomic development.

Results: Urban shrinkage was explored not only in the theoretical, but also in the practical context because this process can be expected to intensify in the future. The study demonstrated that the rate of urban shrinkage in Poland increased between 2012 and 2021 and affected a growing number of cities. Urban shrinkage was identified in 174 urban municipalities with the use of the proposed approach. These cities can be divided into three groups based on the rate of urban shrinkage. The identified groups of cities were characterized by different levels of economic growth and different relationships with the analyzed indicators of urban shrinkage.

Keywords: urban depopulation; demographic crisis; population aging; urban economy
JEL: H72; J11; R51

1. Introduction

Urban shrinkage is a phenomenon that has been analyzed in the international literature since the late 20th century. Urban depopulation is observed in a growing number of cities in both developed and developing regions of the world, including Europe, Asia, North America, and Australia. In Poland alone, urban depopulation is expected to affect 98% of the cities by 2050. According to numerous authors, in addition to demographic changes, urban shrinkage also has economic, financial, social, infrastructural, and environmental implications. Therefore, urban shrinkage is a multifaceted and complex phenomenon that is difficult to define, and it should be addressed not only for theoretical and practical reasons, but also because it has important implications for everyday life of individual inhabitants.

It should be noted that a single, unifying definition of urban shrinkage has not been proposed to date in the literature. Therefore, an attempt was made in this article to determine the characteristic attributes of a shrinking city and to identify shrinking cities based on steady population decline as the main criterion. Shrinking cities in Poland were quantified by analyzing changes in the urban population, and they were classified based on the rate of urban depopulation with the use of k-means clustering. The second research objective was to evaluate the relationship between urban depopulation in the identified groups of shrinking cities in Poland and the indicators of local socioeconomic development. Multiple linear regression analysis was used for this purpose.

The research hypothesis states that urban depopulation in each group of shrinking cities in Poland is related with the indicators of local socioeconomic development. The analyzed period was 2017–2021, and all urban municipalities in Poland were included in the study. Data for previous years were used for comparative purposes.

The article comprises five sections. The first section contains a review of the literature on various definitions and criteria for identifying shrinking cities. The second section describes the applied methodology, stages of research, quantitative methods, and data used in the empirical analysis. The results of the study are described in the third section and discussed in the fourth section. Conclusions are formulated and recommendations for future research are made in the last section of the article.

2. Literature review

According to the literature, steady urban depopulation is a complex and multifaceted phenomenon that is ambiguous and difficult to measure (Martinez-Fernandez et al., 2012, p. 214). A single, unifying definition of urban shrinkage has not been proposed to date (Hartt, 2019, p. 1652). An analysis of the literature (a Google Scholar search of the term "shrinking city" produced around 12,800 results) revealed that the definition of a shrinking city contains three main el-

ements: urban depopulation, the accompanying phenomena, and the implications of urban shrinkage. Various approaches to interpreting these phenomena have been proposed, which testifies to the complexity of the analyzed problem.

Urban depopulation is the first, undisputed criterion for identifying shrinking cities. In the literature, various approaches to quantifying the loss of the urban population, determining the rate of urban depopulation, its duration, the minimum baseline population, or the demographic status of a region have been proposed to identify shrinking cities. Such analyses have been conducted by Wolff & Wiechmann (2018) and Hoekveld (2014) among others. In some studies, urban shrinkage was identified based on an arbitrarily defined period of time during which the urban population decreased, including two years (Hollander, 2011; Wiechmann & Bontje, 2015), five years (Shrinking Cities International Research Network, SCRIN) (Stryjakiewicz & Jaroszewska, 2016, p. 28), or more than 10 years (Oswalt et al., 2006). Relative changes in the urban population were determined by proposing percentage thresholds of population decline, such as 0.15% per year — SCRIN (Jaroszewska, 2019, p. 77), 1% (Oswalt et al., 2006) or more than 10% or 25% over a period of more than 40 years (Hartt, 2021, p. 231; Schilling & Logan, 2008). In some studies, shrinking cities were identified based on quantitative thresholds, such as a minimum population loss of 1000 (see Berglund, 2020, p. 424) or 10,000 (Wiechmann & Bontje, 2015; Hartt, 2021, p. 232). Urban shrinkage was also diagnosed by comparing population loss in a given city with the rate of population changes in a given region or a group of countries (i.e. Cunningham-Sabot et al., 2013; Haase et al., 2016).

According to many authors, in addition to the central criterion of population loss, urban shrinkage should also be defined based on other phenomena (Beauregard, 2009). Five groups of such factors have been identified (Wolff & Wiechmann, 2014):

- demographic factors, including population ageing (Wang & Fukuda, 2019); negative net migration rate and natural population change (Guimarães et al., 2016; Wolff et al., 2013);
- economic factors which are an essential component of urban shrinkage, including the loss of competitive advantage (Rieniets, 2009, pp. 233–235); economic transformations and structural crises (Hollander et al., 2009, pp. 225–226; Wiechmann, 2008, p. 431); low budget revenues and low quality of public services (Glaeser & Gyourko, 2006, p. 34; Hall & Jonas, 2014, pp. 5–6; Wichowska, 2019); unemployment and other economic phenomena (Wichowska, 2021a; 2021b);
- sociological factors such as crime rate, drug addiction, and prostitution (Cui & Walsh, 2015; Frazier et al., 2013);
- factors associated with the real estate market, including a decrease in the supply of housing, decrease in property prices (Rieniets, 2009, pp. 233–235; Schilling & Logan, 2008), lower demand for real estate, decrease in property value (Glaeser & Gyourko, 2006; Hollander et al., 2018, p. 592); and the number of vacant homes (Silverman et al., 2013);

– environmental factors (i.e. Haase, 2008).

These categories of variables are associated with the socioeconomic development of cities (Wichowska, 2021a), and they can constitute a separate group of criteria for defining and identifying shrinking cities. Therefore, urban shrinkage should be examined in a broader context that extends beyond purely demographic criteria. In some studies, the identified criteria were also used to evaluate the analyzed cities. Most researchers agree that urban shrinkage has negative consequences (Hollander et al., 2009; Rieniets, 2009, pp. 238–239). This conclusion stems from the observation that rapidly growing cities tend to increase their population (Wiechmann & Pallagst, 2012, pp. 266). However, in recent years, some authors have posited that urban shrinkage also has positive consequences (Sousa & Pinho, 2015; Hart, 2019). Several conditions have to be met for urban depopulation to deliver positive effects, and most of them are associated with local policies in the area of urban revival, finance, housing, and infrastructure (i.e. Faust et al., 2016; Hartt & Warkentin, 2017; Manville & Kuhlmann, 2018; Rieniets, 2009, pp. 233–235). Therefore, when defining urban shrinkage, this phenomenon should be evaluated as positive or negative.

For the needs of this study, urban shrinkage was defined as a steady decrease in the urban population over a period of minimum five years at an annual rate of 0.15%, accompanied by adverse socioeconomic phenomena that can differ across countries and regions and can be remedied through adequate policy-making at the local level.

3. Methods

The present study consisted of several stages. In the first stage, shrinking cities were identified by analyzing the rate of population loss in Polish cities (according to the adopted definition of urban shrinkage). In the next step, the number of potential classes of the identified shrinking cities was determined with the use of Ward's hierarchical clustering method. Shrinking cities in Poland were then divided into classes by k-means clustering (Murtagh & Legendre, 2014; Tibshirani et al., 2001). This approach was used to identify shrinking cities in Poland, determine the rate of urban shrinkage, and describe the scale of the problem.

The socioeconomic implications of urban shrinkage are most often used in the literature to identify shrinking cities. Therefore, the following research hypothesis was formulated: the loss of population in each group of shrinking cities in Poland is related with changes in variables describing local socioeconomic development. The research hypothesis was validated with the use of linear regression analysis. This method is widely used in economics to identify significant relationships between variables (Brooks, 2008, pp. 27–28). The linear regression analysis was previously used by Wichowska (2021b) in a study of urban shrinkage. The group of variables proposed by Marks-Bielska et al. (2017) and previously applied by Wichowska (2021a) was used in the present study to select potential objective explanatory variables associated with soci-

oeconomic development and to ensure repeatability. In the author's previous research, these variables were selected as factors that characterize the socioeconomic development of Polish urban municipalities as well as economic phenomena that accompany urban shrinkage, indicated in the review of literature. Mean values of the following parameters were selected as potential explanatory variables: X_1 — own-source revenues per capita generated from the personal income tax; X_2 — percentage of own-source revenues in total municipal revenues; X_3 — own-source revenues per capita; X_4 — percentage of residents with access to the sewerage network; X_5 — percentage of residents with access to the water supply network; X_6 — number of self-employed residents per 100 working-age population; X_7 — number of companies per 1000 population; X_8 — unemployment rate in the working-age population; X_9 — employment rate in the working-age population; X_{10} — proportion of the elderly population per 100 working-age population; X_{11} — investment expenditures per capita; X_{12} — proportion of investment expenditures in total expenditures; X_{13} — ratio of newly registered companies to companies removed from the business register (REGON) per 10,000 population; X_{14} — internal migration per 1000 population; and X_{15} — foreign migration per 1000 population. The average population loss in Polish cities was represented by the dependent variable Y.

Data for the study were obtained from the Statistics Poland (2022). The analyzed period was 2017–2022, but data for previous years were also used for comparative purposes. The study covered all urban municipalities in Poland.

It should be noted that accurate population figures in the analyzed cities were difficult to estimate for the needs of this study. Statistics Poland data are only estimates, and they account only for persons who have registered their residence address. As of 2016, Polish citizens are no longer required to register their residence, which could undermine the accuracy of estimations of urban depopulation. However, there are no other objective, comparable and reliable methods of determining the population of Polish municipalities.

4. Results

There were 302 urban municipalities in Poland between 2012–2021, and their number did not change in the analyzed period. On average, a steady population decline was noted in 163 (54%) of urban municipalities during that period. In most of these municipalities (123), the annual population decline exceeded 0.15%. In the past decade, the population of shrinking cities decreased by more than 1% on average per year. A steady decrease in the population of 200 Polish cities was observed in the last five years. In 174 of these cities, the annual population decline exceeded 0.15%, and their populations decreased by 1.38% on average. An analysis of changes in the population of Polish cities in successive five-year periods revealed a higher rate of urban shrinkage. Between 2012 and 2016, urban shrinkage was observed in 143 Polish cities.

The highest rates of urban shrinkage were noted in the voivodeships of Lower Silesia and Silesia. In the last five years, 29 shrinking cities were identified in Lower Silesia, and 27 — in Silesia. These regions were followed by Łódź and Lublin voivodships with 15 shrinking cities each. Nearly 50% of the total number of shrinking cities in Poland were localized in the above voivodeships.

The rate of urban depopulation remained fairly stable in all analyzed cities between 2017 and 2021. In 23 cities, the rate of population decline remained high in the first four years of the analyzed period, and was somewhat lower in 2021.

Ward's hierarchical clustering method was used to divide shrinking cities into three groups based on the rate of population decline. In the next step, shrinking cities were classified by k-means clustering. The results of the classification are presented in Table 1. The first group consisted of 89 cities with a moderate rate of population decline in the studied period. In these cities, the annual population loss was determined at 1.46% on average, and the average population exceeded 47,800. The second group comprised 55 shrinking cities whose population decreased at an annual rate of 1.02% on average. In these cities, the average population exceeded 55,200. The third group consisted of 30 shrinking cities with the highest annual rate of population decline (2.11%) and average population of 36,200. The average population decline in the identified groups of shrinking cities between 2017 and 2021 is presented in Chart 1.

The relationship between population decline and the indicators of local socioeconomic development in the analyzed groups of cities were examined in the last stage of the study. The multiple linear regression analysis revealed that average population decline in shrinking cities in Poland was significantly related to their socioeconomic development. In all 174 shrinking cities, significant relationships were noted between average population loss vs. variables X_3, X_5, X_9, X_{10}, X_{13}, and X_{14}. Based on the calculated values of the coefficient of determination (R^2), the above variables explained 60% of variance in depopulation. In the second group of urban municipalities, with the lowest rate of population decline, significant relationships were found between average population loss vs. variables X_5, X_6, X_7, X_9, X_{10}, and X_{14}. In this group, R^2 was determined at 68%. In the third group of cities with the highest rate of population decline, significant relationships were observed between average population loss vs. variables X_1, X_3, X_7, X_8, X_{10}, and X_{12}. In this group, socioeconomic phenomena explained the highest percentage of variance in the dependent variable (Y), and R^2 was determined at 77%. Despite the fact that all methodological assumptions were met, the linear regression analysis did not produce satisfactory results in the first group of cities, and only one variable (X_1) was significantly related to average population decline. The above model explained only 9% of variance in the dependent variable.

The results of the linear regression analysis and the results of statistical analyses, which were conducted to validate the basic assumptions of the linear regression model, are presented in Table 2.

An analysis of the first criterion for identifying a shrinking city, namely population decline, revealed that urban shrinkage is an escalating problem in Poland (Szalanska et al., 2023, p. 259). This phenomenon was observed in numerous cities in all time intervals proposed in the literature, including 2-year, 5-year, and 10-year periods (Hollander, 2011; Oswalt et al., 2006; Stryjakiewicz & Jaroszewska, 2016, p. 28; Wiechmann & Bontje, 2015). In this study, the minimum depopulation threshold for identifying a shrinking city was adopted at 0.15%. This parameter exceeded 1% on average in all identified groups of Polish cities (a threshold that is adopted by some authors), and its values differed considerably across the examined urban municipalities. Three groups of Polish cities were identified based on the rate of population decline. In addition, the population of all shrinking cities was considerably higher than the threshold of 1000 residents, adopted in some studies (Berglund, 2020, p. 424). In 2017–2021, the average population of shrinking cities in Poland exceeded 47,800.

An analysis based on the geographical location of the studied cities revealed that shrinking cities are geographically clustered, which is yet another attribute proposed by some authors (Cunningham-Sabot et al., 2013; Haase et al., 2016). Most of the identified shrinking cities were located in four Polish voivodeships: Lower Silesia, Silesia, Łódź, and Lublin. In the past, these regions were hubs of industrial activity, including mining, quarrying, and mineral processing (Lower Silesia and Silesia), food processing and the automotive industry (Lublin), and the textile industry (Łódź). A decline in industrial competitiveness, political transformations, the transition from a centrally planned to a market economy, and cheap imports have led to the collapse of many industrial enterprises and forced local workers to migrate to other Polish regions or other countries in search of employment (Haase et al., 2021, p. 6; Runge et al., 2018) These observations indicate that urban shrinkage in Poland is also associated with regional factors.

In Polish cities, urban shrinkage was strongly linked with socioeconomic changes (see Haase et al., 2021, pp. 6–7). Eleven out of the 15 selected potential socioeconomic variables explained the variance in population decline in all identified groups of cities. These variables were related to public finance, business activity, unemployment, and access to public utilities, as well as variables associated with demographic changes: migration and population ageing. Similar observations were made by other authors whose studies were cited in the review of the literature (Guimarães et al., 2016; Wolff & Wiechmann, 2014; Wolff et al., 2013).

As regards the last criterion for identifying shrinking cities, namely the relationship between urban shrinkage and the indicators of local socioeconomic development, purely positive or purely negative implications of urban depopulation were not identified (both approaches have been used in the literature). The sign of the regression coefficient plays a particularly important role in this context (Table 2). For most variables, this relationship was obvious and confirmed in the literature. For instance, the linear regression analysis of all cities

revealed that an increase in the employment rate in the working-age population, ratio of newly registered companies to companies removed from the business register (REGON) per 10,000 population, internal migration per 1000 population, and the percentage of residents with access to the water supply network was accompanied by an increase in the rate of population decline. An analysis of variables with negative values of the regression coefficient revealed than an increase own-source revenues per capita and the proportion of the elderly population per 100 working-age population was accompanied by a decrease in the rate of population decline. Additional analyses are needed to explain the relationship between population decline and own-source revenues. In this case, the presence of a negative relationship could be attributed to numerous legislative changes which affected the distribution of personal income tax revenues between the central government and municipal authorities. Population plays a decreasing role in the tax allocation system.

5. Conclusion

In this article, an attempt was made to identify shrinking cities in Poland and to evaluate the relationship between urban shrinkage and the socioeconomic development of urban municipalities. The literature review revealed that the examined problem does not have a single, unifying definition and that three main criteria can be used to identify shrinking cities: urban depopulation, the accompanying phenomena (mainly socioeconomic), and their implications. These factors were considered in an empirical study.

An analysis of the rate of changes in the urban population based on the adopted lower percentage threshold of population decline revealed that urban shrinkage affected more than 50% of Polish urban municipalities in the analyzed period, i.e. between 2017 and 2021. An analysis of data for previous years demonstrated that urban shrinkage affected a growing number of Polish cities. Three groups of shrinking cities were identified based on the rate of population decline. On average, the annual population loss in Polish shrinking cities exceeded 1%, which indicates that urban shrinkage poses a considerable problem in Poland.

Urban shrinkage was closely associated with socioeconomic variables, in particular public finance, business activity, unemployment, and access to public utilities, as well as variables associated with demographic changes: migration and population ageing. This observation confirmed the research hypothesis and revealed a significant relationship between urban depopulation in each group of shrinking cities and the indicators of local socioeconomic development. The results of the study were consistent with other authors' findings presented in the literature review.

The study demonstrated that urban shrinkage is a valid and pressing problem. Research into urban shrinkage has important practical implications because urban depopulation significantly affects not only the social and economic status of a given city, but also, due to the scale of the problem, the performance

of the Polish economy. Adequate policies at the local, regional and central level are needed to effectively address this problem. Future research could focus on policy directions at the local, regional, and central level. Further research is also needed to evaluate the relationship between urban depopulation and socio-economic phenomena. Qualitative research into urban shrinkage could provide valuable insights about the practical implications of depopulation in shrinking cities. Effective strategies are urgently needed to minimize the negative consequences of urban population loss. Comparative analyses of other countries in the region and in the world would also generate valuable information for reversing the downward development of cities.

References

Beauregard, R.A. (2009). Urban population loss in historical perspective: United States, 1820–2000. *Environment and Planning A*, 41(3), 514–528. https://doi.org/10.1068/a40139a.

Berglund, L. (2020). Critiques of the shrinking cities literature from an urban political economy framework. *Journal of Planning Literature*, 35(4), 423–439. https://doi.org/10.1177/0885412220928507.

Brooks, C. (2019). *Introductory econometrics for finance* (4th ed.). Cambridge University Press. https://doi.org/10.1017/9781108524872.

Cui, L., & Walsh, R. (2015). Foreclosure, vacancy and crime. *Journal of Urban Economics*, 87, 72–84. https://doi.org/10.1016/j.jue.2015.01.001.

Cunningham-Sabot, E., Audirac, I., Fol, S., & Martinez-Fernandez, C. (2013). Theoretical approaches of shrinking cities. In K. Pallagst, T. Wiechmann, & C. Martinez-Fernandez (Eds.), *Shrinking cities: international perspectives and policy implications* (pp. 14–30). Routledge.

Faust, K.M., Abraham, D.M., & McElmurry, S.P. (2016). Water and wastewater infrastructure management in shrinking cities. *Public Works Management & Policy*, 21(2), 128–156. https://doi.org/10.1177/1087724X15606737.

Frazier, A.E., Bagchi-Sen, S., & Knight, J. (2013). The spatio-temporal impacts of demolition land use policy and crime in a shrinking city. *Applied Geography*, 41, 55–64. https://doi.org/10.1016/j.apgeog.2013.02.014.

Glaeser, E.L., & Gyourko, J. (2006). Housing dynamics. *NBER Working Paper Series*, 12787, 1–58.

Guimarães, M.H., Nunes, L.C., Barreira, A.P., & Panagopoulos, T. (2016). What makes people stay in or leave shrinking cities: an empirical study from Portugal. *European Planning Studies*, 24(9), 1684–1708. https://doi.org/10.1080/09654313.2016.1177492.

Haase, A., Bontje, M., Couch, C., Marcinczak, S., Rink, D., Rumpel, P., & Wolff, M. (2021). Factors driving the regrowth of European cities and the role of local and contextual impacts: a contrasting analysis of regrowing and shrinking cities. *Cities*, 108, 102942. https://doi.org/10.1016/j.cities.2020.102942.

Haase, A., Rink, D., & Grossmann, K. (2016). Shrinking cities in post-socialist Europe: what can we learn from their analysis for theory building today. *Geografiska Annaler: Series B, Human Geography*, 98(4), 305–319. https://doi.org/0.1111/geob.12106.

Haase, D. (2008). Urban ecology of shrinking cities: an unrecognized opportunity. *Nature and Culture*, 3(1), 1–8. https://doi.org/10.3167/nc.2008.030101.

Hall, S., & Jonas, A.E.G. (2014). Urban fiscal austerity, infrastructure provision and the struggle for regional transit in "Motor City". *Cambridge Journal of Regions, Economy and Society*, 7(1), 189–206. https://doi.org/10.1093/cjres/rst031.

Hartt, M. (2019). The prevalence of prosperous shrinking cities. *Annals of the American Association of Geographers*, 109(5), 1651–1670. https://doi.org/10.1080/24694452.2019.1580132.

Hartt, M. (2021). The elasticity of shrinking cities: An analysis of indicators. *The Professional Geographer*, 73(2), 230–239. https://doi.org/10.1080/00330124.2021.1871764.

Hartt, M., & Warkentin, J. (2017). The development and revitalisation of shrinking cities: a twin city comparison. *Town Planning Review*, 88(1), 29–41. https://doi.org/10.3828/tpr.2017.4.

Hoekveld, J.J. (2014). Understanding spatial differentiation in urban decline levels. *European Planning Studies*, 22(2), 362–382. https://doi.org/10.1080/09654313.2012.744382.

Hollander, J.B. (2011). Can a city successfully shrink: evidence from survey data on neighbourhood quality. *Urban Affairs Review*, 47(1), 129–141. https://doi.org/10.1177/1078087410379099.

Hollander, J.B., Hartt, M.D., Wiley, A., & Vavra, S. (2018). Vacancy in shrinking downtowns: a comparative study of Québec, Ontario, and New England. *Journal of Housing and the Built Environment*, 33(4), 591–613. https://doi.org/10.1007/s10901-017-9587-9.

Hollander, J.B., Pallagst, K., Schwarz, T., & Popper, F. J. (2009). Planning shrinking cities. *Progress in Planning*, 72(4), 223–232. https://doi.org/10.1177/004209801988554.

Jaroszewska, E. (2019). Urban shrinkage and regeneration of an old industrial city: the case of Wałbrzych in Poland. *Quaestiones Geographicae*, 38(2), 75–90. https://doi.org/10.2478/quageo-2019-0023.

Manville, M., & Kuhlmann, D. (2018). The social and fiscal consequences of urban decline: evidence from large American cities, 1980–2010. *Urban Affairs Review*, 54(3), 451–489. https://doi.org/10.1177/1078087416675741.

Marks-Bielska, R., Lizińska, W., & Wojarska, M. (2017). *Raport z wykonania projektu badawczego. Sprawność instytucjonalna vs. lokalny rozwój gospodarczy: czynniki kształtujące i interakcje.* Retrieved 31.10.2022 from http://www.uwm.edu.pl/konferencjakpgir/pliki/raport_z_projektu.pdf.

Martinez-Fernandez, C., Audirac, I., Fol, S., & Cunningham-Sabot, E. (2012). Shrinking cities: urban challenges of globalization. International *Journal of Urban and Regional Research*, 36(2), 213–225. https://doi.org/10.1111/j.1468-2427.2011.01092.x.

Murtagh, F., & Legendre, P. (2014). Ward's hierarchical agglomerative clustering method: which algorithms implement Ward's criterion. *Journal of Classification*, 31(3), 274–295. https://doi.org/10.1007/s00357-014-9161-z.

Oswalt, P., Rienitz T., & Schirmel, H. (2006). *Atlas of shrinking cities*. Hatje Cantz.

Rieniets, T. (2009). Shrinking cities: causes and effects of urban population losses in the twentieth century. *Nature and Culture*, 4(3), 231–254. https://doi.org/ 10.3167/nc.2009.040302.

Runge, A., Kantor-Pietraga, I., Runge, J., Krzysztofik, R., & Dragan, W. (2018). Can depopulation create urban sustainability in postindustrial regions: a case from Poland. *Sustainability*, 10(12), 4633. https://doi.org/10.3390/su10124633.

Schilling, J., & Logan, J. (2008). Greening the rust belt: a green infrastructure model for right sizing America's shrinking cities. *Journal of the American Planning Association*, 74(4), 451–466. https://doi.org/10.1080/01944360802354956.

Silverman, R.M., Yin, L., & Patterson, K. L. (2013). Dawn of the dead city: an exploratory analysis of vacant addresses in Buffalo, NY 2008–2010. *Journal of Urban Affairs*, 35(2), 131–152. https://doi.org/10.1111/j.1467-9906.2012.00627.x.

Sousa, S., & Pinho, P. (2015). Planning for shrinkage: paradox or paradigm. *European Planning Studies*, 23(1), 12–32. https://doi.org/10.1080/09654313.2013.820082.

Statistic Poland. (2022). *Local data bank*. Retrieved 31.10.2022 from https://bdl.stat.gov.pl/BDL/start.

Stryjakiewicz, T., & Jaroszewska, E. (2016). The process of shrinkage as a challenge to urban governance. *Quaestiones Geographicae*, 35(2), 27–37. https://doi.org/10.1515/quageo-2016-0013.

Szalanska, J., Gac, J., Jastrzebska, E., Poplawska, J. Z., & Moralli, M. (2023). Public policy towards immigrants in poland's shrinking cities: the case study of the city of Lomza. *International Migration*, 61(1), 256–272. https://doi.org/10.1111/imig.13013.

Tibshirani, R., Walther, G., & Hastie, T. (2001). Estimating the number of clusters in a data set via the gap statistic. *Journal of the Royal Statistical Society: Series B, Statistical Methodology*, 63(2), 411–423. https://doi.org/10.1111/1467-9868.00293.

Wang, Y., & Fukuda, H. (2019). Sustainable urban regeneration for shrinking cities: a case from Japan. *Sustainability*, 11(5), 1505. https://doi.org/10.3390/su11051505.

Wichowska, A. (2019). Shrinking municipalities and their budgetary revenues on the example of the Warmian-Masurian Voivodeship in Poland. *Oeconomia Copernicana*, 10(3), 419–432. https://doi.org/10.24136/oc.2019.020.

Wichowska, A. (2021a). Determinants affecting own-source revenues in the budgets of shrinking Polish cities in the context of local socio-economic development. *Studia BAS*, 4(68), 27–40. https://doi.org/10.31268/StudiaBAS.2021.34.

Wichowska, A. (2021b). Economic aspects of shrinking cities in Poland in the context of regional sustainable development. *Sustainability*, 13(6), 3104. https://doi.org/10.3390/su13063104.

Wiechmann, T. (2008). Errors expected: aligning urban strategy with demo-graphic uncertainty in shrinking cities. *International Planning Studies*, 13(4), 431–446. https://doi.org/10.1080/13563470802519097.

Wiechmann, T., & Bontje, M. (2015). Responding to tough times: policy and planning strategies in shrinking cities. *European Planning Studies*, 23(1), 1–11. https://doi.org/10.1080/09654313.2013.820077.

Wiechmann, T., & Pallagst, K.M. (2012). Urban shrinkage in Germany and the USA: a comparison of transformation patterns and local strategies. *International Journal of Urban and Regional Research*, 36(2), 261–280. https://doi.org/10.1111/j.1468-2427.2011.01095.x.

Wolff, M., & Wiechmann, T. (2014). Indicators to measure shrinking cities. In C. Martinez-Fernandez, S. Fol, T. Weyman, & S. Musterd (Eds.), *A conceptual framework for shrinking cities* (pp. 1–19). COST Action TU0803: Cities Re-growing Smaller (CIRES).

Wolff, M., & Wiechmann, T. (2018). Urban growth and decline: Europe's shrinking cities in a comparative perspective 1990–2010. *European Urban and Regional Studies*, 25(2), 122–139. https://doi.org/10.1177/0969776417694680.

Wolff, M., Fol, S., Roth, H., & Cunningham-Sabot, E. (2013). Shrinking cities: measuring the phenomenon in France. *European Journal of Geography*, 661 https://doi.org/10.4000/cybergeo.26136.

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Appendix

Table 1.
Shrinking cities in identified groups of cities by voivodeships in Poland

*	Group			Number of cities
	I (89)	II (55)	III (30)	
1	Bolesławiec, Bielawa, Dzierżoniów, Piława Górna, Głogów, Piechowice, Kamienna Góra, Kłodzko, Chojnów, Lubań, Lubin, Oleśnica, Świdnica, Boguszów-Gorce, Szczawno-Zdrój, Legnica	Karpacz, Kudowa-Zdrój, Nowa Ruda, Polanica-Zdrój, Jedlina-Zdrój, Zgorzelec, Jelenia Góra	Jawor, Kowary, Duszniki-Zdrój, Zawidów, Złotoryja, Wałbrzych	29
2	Nieszawa, Chełmno, Inowrocław, Grudziądz, Włocławek	Aleksandrów Kujawski, Chełmża, Wąbrzeźno, Bydgoszcz	–	9
3	Hrubieszów, Krasnystaw, Kraśnik, Puławy, Świdnik, Włodawa, Chełm, Zamość	Stoczek Łukowski, Tomaszów Lubelski	Międzyrzec Podlaski, Lubartów, Łuków, Radzyń, Podlaski, Dęblin	15
4	Nowa Sól, Gozdnica, Żagań, Żary	Gubin	Łęknica	6
5	Bełchatów, Kutno, Łęczyca, Łowicz, Sieradz, Tomaszów Mazowiecki, Zduńska Wola, Głowno, Ozorków	Pabianice, Radomsko, Zgierz, Łódź	Rawa Mazowiecka, Piotrków Trybunalski	15
6	Gorlice, Bukowno	Bochnia, Oświęcim, Sucha Beskidzka, Tarnów	–	6
7	Ciechanów, Łaskarzew, Sierpc, Sochaczew, Płock, Radom	Ostrów Mazowiecka, Płońsk, Żyrardów	Maków Mazowiecki, Raciąż, Pionki	12
8	Brzeg	–	Kędzierzyn-Koźle	2
9	Dębica, Radymno, Sanok, Stalowa Wola, Przemyśl, Tarnobrzeg	Jarosław, Jasło, Lubaczów, Przeworsk	–	10
10	Brańsk, Hajnówka, Sejny, Siemiatycze	Bielsk Podlaski, Grajewo, Kolno	–	7
11	Wejherowo, Słupsk	Człuchów, Kwidzyn, Malbork, Starogard Gdański	Łeba, Hel, Ustka, Sopot	10
12	Knurów, Myszków, Pszów, Wodzisław Śląski, Zawiercie, Chorzów, Częstochowa, Jastrzębie-Zdrój, Piekary Śląskie, Siemianowice Śląskie, Sosnowiec	Będzin, Czeladź, Cieszyn, Lubliniec, Łaziska Górne, Poręba, Żywiec, Dąbrowa Górnicza, Gliwice, Jaworzno, Katowice, Ruda Śląska	Racibórz, Bytom, Świętochłowice, Zabrze	27
13	Sandomierz, Skarżysko-Kamienna, Starachowice, Kielce	–	Ostrowiec Świętokrzyski	5
14	Bartoszyce, Górowo Iławeckie, Giżycko, Nowe Miasto Lubawskie, Elbląg	Mrągowo, Szczytno	Lidzbark Warmiński	8
15	Gniezno, Kalisz, Konin	Chodzież, Czarnków, Sulmierzyce, Ostrów Wielkopolski, Piła	Koło, Turek	10
16	Sławno, Szczecinek, Wałcz	–	–	3

Notes:

* Voivodeship: 1 — dolnośląskie; 2 — kujawsko-pomorskie; 3 — lubelskie; 4 — lubuskie, 5 — łódzkie, 6 — małopolskie, 7 — mazowieckie, 8 — opolskie, 9 — podkarpackie, 10 — podlaskie, 11 — pomorskie, 12 — śląskie, 13 — świętokrzyskie, 14 — warmińsko-mazurskie, 15 —wielkopolskie, 16 — zachodniopomorskie.

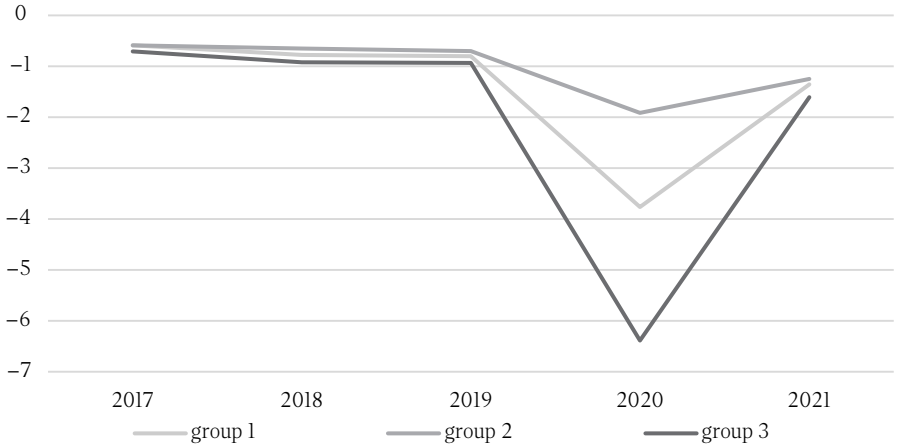
Source: Own preparation based on the Statistic Poland (2022).

Table 2.
The results of multiple linear regression analysis — variables explaining population decline in shrinking Polish cities in 2017–2021 and information about the conducted statistical tests

Independent variables	Coefficient of regression	P-value in Student's test	P-value in F-test	P-value in RESET Ramsey'test	P-value in Doornik-Hansen's test	P-value in White's test	R^2 (%)
Group 1:							
X_1	0.0003	0.004	0.004	0.12	0.17	0.12	9
Group 2:							
X_5	0.012	0.019	1.43e-10	0.31	0.48	0.73	69
X_6	0.054	2.07e-05					
X_7	−0.002	1.22e-07					
X_9	0.003	0.032					
X_{10}	−0.032	1.61e-07					
X_{14}	0.075	2.31e-09					
Group 3:							
X_1	0.001	2.79e-05	1.73e-06	0.15	0.32	0.34	78
X_3	−0.0007	1.63e-05					
X_7	0.006	0.032					
X_8	−0.087	0.043					
X_{10}	−0.023	0.02					
X_{12}	0.035	0.003					
Analyzed cities							
X_3	−0.0002	1.12e-06	1.04e-31	0.27	0.79	0.51	61
X_5	0.013	0.042					
X_9	0.013	6.94e-013					
X_{10}	−0.031	1.46e-07					
X_{13}	0.003	0.013					
X_{14}	0.127	5.66e-028					

Source: Own preparation based on the Statistic Poland (2022).

Chart 1.
Average population decline in the identified groups of Polish shrinking cities in 2017–2021 (%)



Source: Own preparation based on the Statistic Poland (2022).