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Using Trend Models for Analysis and Forecasting Basic Demographic Indicators (case study of Sumy Region, Ukraine)

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Abstract. The article is dedicated to the analysis of the demographic situation in Sumy region and possible scenarios for its development. The aim of the article is to carry out a demographic forecast of the main demographic indicators of Sumy region (Ukraine) till 2030. Forecasting is based on defining the tendencies in the dynamics of demographic indicators during 1990-

2021. It should be noted that the demographic situation in Sumy region is perhaps the most complicated in the national demographic dimension. According to many demographic indicators, the region holds the most negative positions in Ukraine. Besides, negative features continue to grow: over the past 10 years, the population of the region has decreased by 9.3%, urban – by 6.3%, and rural – by 15.4%. According to our forecast, the population of the region will decrease by another 12% and will amount to approximately 911 thousand inhabitants by 2030. Forecasting the number of the rural population showed a faster rate of its depopulation – up to 253.8 thousand people, or 18.8%. Besides, there will be negative changes in the population of certain age groups. For example, in the age group 0-17 years, there will be only 135 thousand people and the number of children will decrease by 17.7% by 2030. The main point is a significant decrease in the birth rate, which will be reduced by 14.5% during the forecast period. The fertility rate will decrease by 13.7% and it will amount to 0.7 children per woman. On the other hand, there is a tendency towards an increase in mortality, the level of which in 2021 reached the highest value – 20 ‰. According to our forecast, by 2030, the mortality rate will stabilize at the level of 19.6-19.7 ‰, and in the pessimistic scenario, it will increase by 16.2% (up to 23.2 ‰). As a result of the two demographic tendencies mentioned above, since the 1980s, there has been a natural decline in the population in Sumy region. By 2030, the rate of depopulation will increase by 2.4%, and its level will be -15.1% per year. The results of the demographic forecast can be used in assessing the balance of labor resources in the future, planning the development of the social sphere, housing construction, etc.

Keywords: forecasting, trend models, adaptive models, additive models, the birth rate, the mortality rate, natural population decline, Sumy region.

Використання трендових моделей для аналізу та прогнозування основних демографічних показників (на прикладі Сумської області, Україна)

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Анотація. Стаття присвячена аналізу динаміки чисельності та природного руху населення в Сумській області та можливостей трендових моделей, які відтворюють тенденції розвитку названих вище показників за роки незалежності і які можуть бути використані для прогнозування їх розвитку. Це прогнозування ґрунтується на з'ясуванні тенденцій динаміки демографічних показників протягом 1990-2021 років. Всі розрахунки та обчислення, а також графічні побудови отримано за допомогою можливостей комп'ютерної програми Microsoft Excel 2021. Варто відзначити, що демографічна ситуація, яка склалася в Сумській області на початок 2022 року, була чи не найскладнішою у національному демографічному вимірі; війна ж ще більше погіршила її. За багатьма демографічними показниками, що аналізувалися за підсумками 2021 року, регіон утримував найбільш негативні позиції в Україні. Крім того, негативні риси продовжують наростати: за останні 10 років чисельність населення регіону скоротилася на 9,3%, у міського – на 6,3%, а сільського – на 15,4%. Згідно нашого прогнозу, до 2030 року чисельність населення області скоротиться ще на 12% і становитиме приблизно 911 тис. жителів. Прогнозування чисельності

сільського населення показало пвидні темпи його депопуляції, – до 253,8 тис. осіб або на 18,8%. Крім того, відбудуться негативні зміни в чисельності населення окремих вікових групах. Наприклад, у віковій групі 0-17 років до 2030 року буде перебувати лише 135 тис. осіб, інакше кажучи, кількість дітей та підлітків зменшиться на 17,7%. Центральним моментом є суттєве зменшення рівня народжуваності, яка за прогнозний період скоротиться на 14,5%. Рівень фертильності знизиться на 13,7% і становитиме 0,7 дитини на одну жінку. З іншого боку, вираженою є тенденція до зростання смертності, рівень якої у 2021 році сягнув найвищого значення – 20‰. За нашим прогнозом до 2030 р. передбачається стабілізація смертності населення на рівні на 19,6-19,7‰, а за песимістичним сценарієм – її зростання на 16,2‰ (до 23,2 ‰). Для моделювання тенденцій природного руху населення добре підходять проста лінійна, логарифмічна, степенева та логістична модель, проте поліномні моделі краще згладжують нерівності вхідного ряду. Адаптивні моделі є більш чутливими до нових даних, а тому з їх допомогою можна обчислювати точніші прогнози. Згідно останніх, до 2030 року темпи депопуляції зростуть на 60%, а її рівень становитиме -25,1‰ на рік. Результати демографічного прогнозу можна використати при оцінці балансу трудових ресурсів у перспективі, плануванні розвитку соціальної сфери, будівництві житла тощо.

Ключові слова: прогнозування, трендові моделі, адаптивні моделі, адитивні моделі, народжуваність, смертність, природне скорочення населення, Сумська область.

Introduction

The analysis of world demographic indicators shows a tendency for population growth, although the pace of such growth is slowing down. According to the World Bank, the world's population at the end of the twentieth century increased by 1.7% per year, but at the end of 2021, this rate decreased by 0.9% per year (Population..., 2023). Demographers estimated that by 2050 the world population will be 9.7 billion people, and by the end of the century, this figure will grow to 11.2 billion people (Naseleennia, 2019). However, the UN's latest demographic report suggests that the world's population will peak at 10.4 billion in the 2080s and remain at this level until 2100 (World, 2022). At the same time, rapid depopulation is observed in Ukraine. At the end of 2021 the depopulation rate in Ukraine is 0.77% per year, while in its neighboring countries the process is much slower: Poland – 0.40%, Hungary – 0.41%, Slovakia – 0.21%, Belarus – 0.42%, the Russian Federation – 0.43% per year (Population..., 2023). It is believed that this is primarily due to some socio-economic and political factors (Kerbicova, 2019). This crisis state, which takes into account the deterioration of almost all demographic processes due to the Russian-Ukrainian war (ranging from killing the people, a decrease in the birth rate, a decrease in life expectancy, an increase in the death rate of working-age people, environmental degradation, appearance of new diseases and emigration), gives reasons to consider this situation a demographic catastrophe. The same nationwide demographic picture, at its worst, is typical for Sumy region. Therefore, taking into account the current situation, research into the possibilities of some methods of forecasting the further development of the demographic situation in Sumy region is of particular relevance.

Review of previous research

Forecasting the demographic situation is in the field of view of many scientists since its results are necessary for the development and planning of socio-economic processes and the development of society as a whole.

First, methodological concepts, international data availability, and an overview of demographic projections are described by R. Vanella et al. (Vanella, 2020). The article of F. Petropoulos et al. (Petropoulos, 2021) provides an overview of a wide range of current theoretical models, methods, principles, and approaches for preparing, producing, organizing, and evaluating forecasts. The authors also recommend lists of free or open-source software tools and publicly available databases. The work by T. Wilson considers the same problem where methods of population forecasting in small areas were described, such as extrapolative and comparative methods, simplified cohort-component methods, model averaging and combining, incorporating socioeconomic variables and spatial relationships, «downscaling» and disaggregation approaches, linking population with housing, estimating and projecting small area component input data, microsimulation, machine learning (Wilson, 2022).

Some predictions are based on Bayesian probability. For example, Zhang J. L. and Bryant, J., in their paper (Zhang, 2020) consider Bayesian disaggregated forecasts for making forecasts at the local level using Iceland as an example. Another prediction of Icelandic abundance is described in V. Calian and Ó. Harðarson (Calian, 2015). It is based on the use of shorter time series in order to predict the (known) values of population components for recent years. A. Raftery (Raftery, 2023) describes probabilistic population prediction from short to very long-term using Bayesian methodology also. G. Abel et al. (Abel, 2013) analyzed the

population change in England and Wales from 1841 to 2007 and based on the use of Bayesian methods implemented forecasts by the year 2032.

Serious consideration should be given to fertility, mortality, migration, and population scenarios for 195 countries and territories from 2017 to 2100 obtained by S.E. Vollset et al. (Vollset, 2020). The authors modeled future populations in reference and alternative scenarios as a function of fertility, migration, and mortality rates as well as developed statistical models for completed cohort fertility at the age of 50. Age-specific mortality to 2100 using underlying mortality, a risk factor scalar, and an autoregressive integrated moving average (ARIMA) model were considered in this article. In the reference scenario, the global population was projected to peak in 2064 at 9.73 billion people and decline to 8.79 billion in 2100. The reference projections for the five largest countries in 2100 were India (1.09 billion, Nigeria (791 million), China (732 million), the USA (336 million), and Pakistan (248 million).

The forecasting of population change as well as the regional service sphere needed for 2 regional Councils of Queensland (Australia) was made by W. Athukorala et al. (Athukorala, 2010). This study uses the time series approach, namely the Box-Jenkins model to forecast population changes in the two regional councils out to the year 2025. H. Booth (Booth, 2006) making the forecast of the population of Germany considered in his article three approaches to forecasting demographic processes; extrapolation, expectation (individual-level birth expectations or population-level opinions of experts), and theory-based structural modeling involving exogenous variables.

At the same time, simpler methods, such as extrapolation and age shifting, are also used, as made by L. Spankulova (Spankulova, 2022) for forecasting the population of Kazakhstan until 2050.

In Ukraine, demographic forecasting is carried out by the Institute for Demography and Social Research, which periodically conducts new forecast calculations based on the latest available data. In 2006, scientists from the Institute of Demography and Social Research of the National Academy of Sciences of Ukraine (Libanova, 2006) carried out a detailed multivariate demographic forecast of the total number and sex and age distribution of the population of Ukraine till 2050. The authors analyzed the hypotheses and the main results of previous demographic forecasts developed for Ukraine and defined the most probable trajectories of the main components that determine the size and age structure of the population in the future.

Also, forecasting demographic development was considered in the article by S. Pirozhkov and others (Pirozhkov, 2006). According to its results, natural growth will remain negative, and the balance of migration will not cover demographic losses. Thus, the population of Ukraine in 2050 will be from 24.5 to 36.1 million people, and the most probable indicators will be in the range of 29.2-30.6 million. In the recent article by A. Yatsenko and others (Yatsenko, 2021) modern problems of the demographic situation in Ukraine are investigated and forecasts of its future changes are given. In particular, the dynamics of the population of Ukraine are analyzed and the main problems that will further negatively affect the demographic situation in Ukraine are identified. O. Rogozhyn (Rogozhyn, 2009) developed the forecast on the basis of computer experiments with the imitating model of the socio-economic mechanism of forming medical and demographic situation in the Ukrainian countryside. The forecast of the population of Ukraine was carried out by the United Nations specialists and is given in the analytical report «Demographic Processes» (Naseleennia, 2021). According to the United Nations forecasts, the population of Ukraine will decrease to 35 million by 2050.

A scientific publication by M. Luchko (Luchko, 2021) is devoted to statistical methods for forecasting the development of demographic indicators in Ukraine. The authors propose to use methods of demographic forecasting, such as extrapolation, methods of shifting ages, methods of statistical modeling (methods of mathematical modeling), and methods of expert evaluations. Y. Matviishyn and Y. Dziurakh in their article (Matviishyn, 2019) used an analytical model for forecasting the structure of the population in different age groups using MS Excel to obtain the projected values of the demographic burden in 2020. I. Dulyuk and Y. Matusov (Dulyuk, 2010) proposed a model for constructing a population forecast for Ukraine by using optimal Bayesian procedures of recognition on Markov chains are investigated. In the article by R. Voloshchuk (Voloshchuk, 2020), the author forecasts the indicators of the state of the demographic sphere of Ukraine using the methods of adaptive forecasting, autoregression, and exponential smoothing.

In general, there are few scientific publications on the demographic forecast for the regions of Ukraine. So, in the article by K. Sehida (Sehida, 2017) a short-term forecast of the population of Kharkiv region and its individual districts was carried out, and based on the results of modeling for each year of the forecast period (20 years), the number of the population by age

groups, the average age of the population, the number of migrants by each age group were calculated.

Regarding demographic forecasts for the regions of Ukraine, I. Baranyak (Baranyak, 2013) statistically modeled demographic forecasting in Lviv region in three variants (pessimistic, medium and optimistic) and calculated forecast trends until 2050. The article presents the theoretical foundations of the model for forecasting the population of the region and calculates forecast trends by 2050. According to the results of the study, a decrease in the population of the region is observed. Also, a demographic forecast was developed for certain districts of Zhytomyr region (Kukush, 2021). Assessment of the state and forecast of the development of the demographic potential of rural territories of Kherson region are presented in the article by O. Burova (Burova, 2017).

In the article by N. Gunko et al. (Gunko, 2022), the authors propose to carry out demographic forecasting using spline functions of demographic indicators for territorial communities on the example of the Vyshgorod territorial community based on MATLAB version R2021a. According to the authors, for the population size, the most adequate forecasts of population numbers can be obtained via cubic splines, while the most reliable forecasts of birth rate and mortality can be obtained via linear continuous splines).

The aim of the article is to explore the possibilities of trend modeling, to build such trend models that reproduce the dynamics of the population of Sumy region as well as the trends of natural movement during the years of Ukraine's independence, and can be used for their detailed analysis and forecasting.

Material and research methods

To explore the possibilities of trend modeling as well as to build a trend for the dynamics of the total population of Sumy region and population natural movement trends, we took a time series of observations during 1990-2021.

On the basis of dynamic series, it is possible to make forecasts taking into account the patterns that have developed in previous periods. Trend models are the most common models of this type (Susmann, 2022). A trend equation is a relationship of the form $y_t = f(t) + \varepsilon_t$ where $f(t)$ – a deterministic (non-random) component of the process (phenomenon); ε_t – a stochastic (random) component of the process; t – the period number $t = \underline{1, n}$, where n – the number of periods under study.

The most often used in demographic studies are additive models (parameters are estimated by least

squares method) of dependencies describing equations of trends, for example, linear $y = a_0 + a_1 t$ or logarithmic $y = a_0 + a_1 \ln t$. Multiplicative models (which are reduced to additive models by logarithm) are also widely known, for example power $y = a_0 t^{a_1}$ or exponential $y = a_0 t^{a_1}$, where y – observed demographic indicators (Sussman, 2022). In order to reproduce the behavior of a dynamic series, additive polynomial models are used, such as the linear polynomial $y = a_0 + a_1 t + a_2 t^2 + \dots + a_m t^m$.

In order to reproduce the behavior of a dynamic series, additive polynomial models are used, the simplest among which is the linear polynomial model. This model smooths fluctuations in the input data well, and the unknown parameters of the equations are calculated using the method of least squares by solving the normal system of equations. Methods of adaptive forecasting include the exponential smoothing method. The essence of this method is that each level of the time series is smoothed by means of moving average with mathematic weights, which obey the exponential law and are calculated by formulas (Dobuliak, 2019):

$$\begin{aligned} \{S_1^{[1]} &= a_0 - \frac{1-\alpha}{\alpha} a_1 \quad S_1^{[2]} = a_0 - \frac{2(1-\alpha)}{\alpha} a_1 \\ \{S_t^{[1]} &= \alpha y_t + (1-\alpha) S_{t-1}^{[1]} \quad S_t^{[2]} \\ &= \alpha S_t^{[1]} + (1-\alpha) S_{t-1}^{[2]} \end{aligned}$$

where $S_t^{[k]}$ – the exponential mean of the k -th order at point t , α is the smoothing parameter ($\alpha \in [0; 1]$), a_0, a_1 , – the linear trend parameters calculated by the least squares method.

The corrected values of the adaptive linear model $y = a_0 + a_1 t$ are calculated for each t by the formulas: $y = \hat{a}_0 + \hat{a}_1 t$.

$$\{\hat{a}_0 = 2S_t^{[1]} - 2S_t^{[2]} \quad \hat{a}_1 = \frac{\alpha}{1-\alpha} (S_t^{[1]} - S_t^{[2]})$$

Usually forecasting uses a 95% confidence interval, a range around each predicted value that the forecast (under a normal distribution) is likely to fall within 95% of the points in the future. The confidence interval helps to determine the accuracy of the forecast. The smaller it is, the higher the reliability of the forecast for this point.

All the calculations, the figures and the graphic images were obtained using Microsoft Excel 2019.

Results and discussion

Any forecast begins with an analysis of the current state of the forecasting object. In forecasting, this procedure is called pre-forecast orientation. To carry

out a demographic forecast, it is necessary to assess the current demographic situation in Sumy region and the place of the region in the national demographic rating. Analyzing the data table, we should confess that the region occupies a leading position in many negative indicators, in particular, low birth rate, high mortality, etc. (table).

Table. Place of Sumy region in the national demographic dimension*(Source: Naseleennia, 2021)

Demographic indicators	Place region
Population, incl.	22
urban population	13
rural population	23
Resident population by age group:	
0-15 years old	23
15-64 years old	10
65 years and older	15
Sex structure	
the number of males	14
the number of females	12
Birth rate (per 1,000 people), incl.	23
in urban areas	21
in the rural areas	22
Death rate (per 1,000 people), incl.	4
in urban areas	8
in the rural areas	2
Natural increase (decrease) (per 1,000 people), incl.	2 place
urban population	6
rural population	2
Dependency ratio	20
Middle age	
total	5
male	4
female	5
Median age	
total	4
male	4
female	5
Life expectancy	
total	12
male	13
female	11
Number of marriages registered (per 1,000 people), incl.	23
in urban areas	23
in the rural areas	15
Number of divorces (per 1,000 people)	16
Migration rate (per 1,000 people)	5

*Data are given without the temporarily occupied territories of the Autonomous Republic of Crimea, Luhansk, and Donetsk regions.

Depopulation has become a typical feature of the demographic situation in Sumy region, where there is a low birth rate, a high mortality rate, and a large migration outflow of the population, which causes a

decrease in the population. During the years of the existence of the region, the largest population was registered at the time of the creation of the region in 1939 – 1 706.1 thousand people. Then there was a gradual decrease in the population and as of January 1, 2021, the population already amounted to 1 053.5 thousand people. In the period from 1990 to 2020 alone, the population decreased by 26.3%, including urban (by 18%) and rural (by 40.4%) population. Over the past 10 years, the population has decreased by 9.3%, the urban population by 6.3%, and the rural population by 15.4% (Fig. 1).

For the given dynamic series of the Sumy region population for the period from 1990 to 2021 (yt, t = 1, 32) the best results were obtained when extrapolating by such trend models as: linear (Fig. 2a) with the coefficient of determination (R^2) = 0.987, logarithmic (Fig. 2b) R^2 = 0.9871, power (Fig. 2c) R^2 = 0.9876, exponential R^2 = 0.9877 (fig. 2d). Considering the population in Sumy region during 1990-2021, we have observed a decrease by 27.6%. According to the forecasting results, the population of the region is to decrease by 12% by 2030 and the number will be about 911,000 inhabitants. At the same time, the boundaries of the 95% confidence interval of the forecast indicator allow both a decrease in the population by 18.2% (or 846,530 people) and its increase by 5.8% (or 975,630 people).

As can be seen from Fig. 1, a linear trend models are good at approximating changes in an indicator over time, and thus are suitable for modeling a time series. They make it possible to make a preliminary assessment of the process under study and predict possible future changes in key indicators of natural population movement.

The birth rate is one of the main demographic indicators that directly affect the demographic situation. In demographic policy, fertility is given a special place, because the prospects for demographic dynamics, changes in the population, its composition and the future of Ukraine depend on it (Kornus, 2009). In Sumy region the dynamics of the birth rate has had an oscillatory tendency over the past 30 years. Therefore, 11.5 people were born per 1000 of the population and this was the highest birth rate for the studied period in 1990. The lowest birth rate – 6.7% was registered in 2002. Further, there was a tendency towards an increase in the birth rate – 7.2% by 2005. The birth rate peaked in 2012 when 9.7 children per 1000 were born in the region during the year. This trend stayed unchanged until 2014, and starting from 2015, due to the difficult socio-economic, political, and military situation in Ukraine,

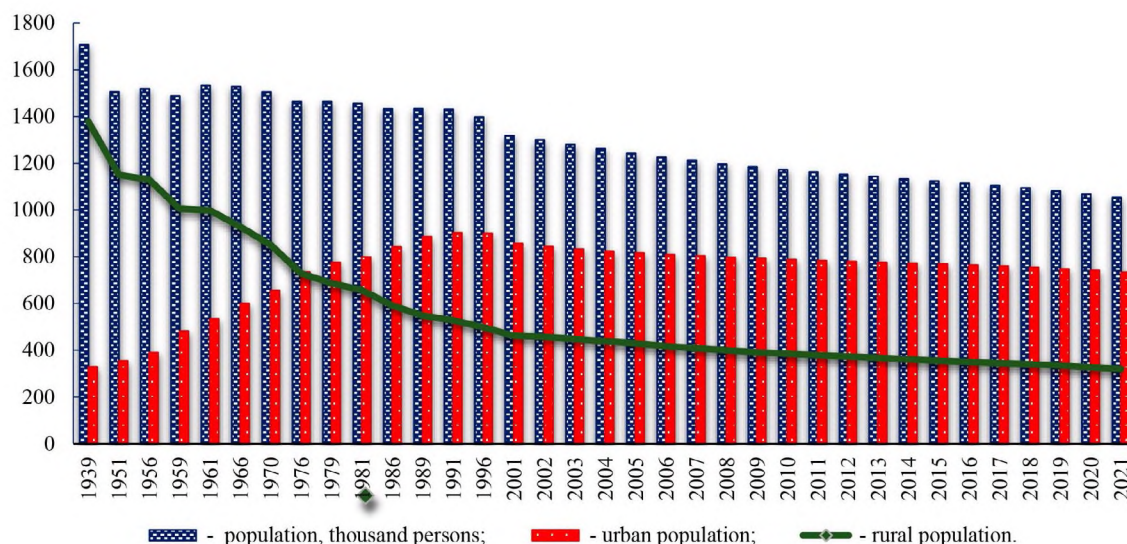


Fig. 1. Dynamics of the population of Sumy region (Source: Demohrafichna, 2022, Statystychnyi, 2022).

the birth rate began to fall. In 2021, the lowest indicator over the past 30 years was recorded – 5.2 babies per 1,000 people. According to forecasts the birth rate will decrease by 14.5% by 2030. The boundaries of the confidence interval of the forecast indicator allow both a reduction in the birth rate of the population by 41.5% (or up to 3.04%) and its growth by 12.4% (5.58%) (Fig. 3).

We predict a 13.7% decline in fertility by 2030, with a fertility rate of 0.7 children per woman compared to 0.75 today. Considering the boundaries of the confidence interval of the predicted indicator, it was found out that the fertility rate under favorable conditions can increase by 9.3% and amount to 0.9 children

per woman or decrease by 36.8% or to 0.5 children per woman (Fig. 4).

Over the past 30 years, the mortality rate in the region has also been fluctuating. The death rate was 14.6‰ in 1990. The general upward trend in mortality remained unchanged until 2021 when its highest rate was recorded – 20‰. The boundaries of the 95% confidence interval of the predicted indicator allow both a reduction in the mortality of the population by 19.3% (or up to 19.7%), and its growth by 16.2% (23.2%) (Fig. 5).

When selecting a trend function, it is important to consider whether it will be used only for retrospective analysis, or also for forecasting (i.e. beyond the period

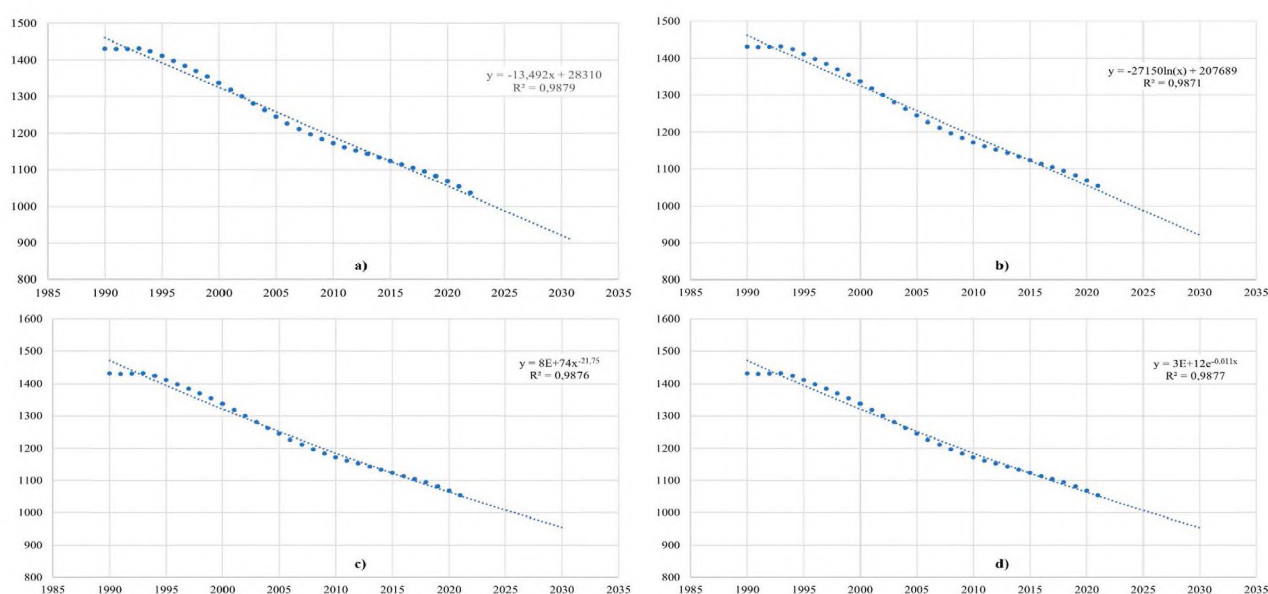


Fig. 2. Trend models of the dynamic series of the population of Sumy region: a) linear, b) logarithmic, c) power, d) exponential (Source: Demohrafichna, 2022, Statystychnyi, 2022).

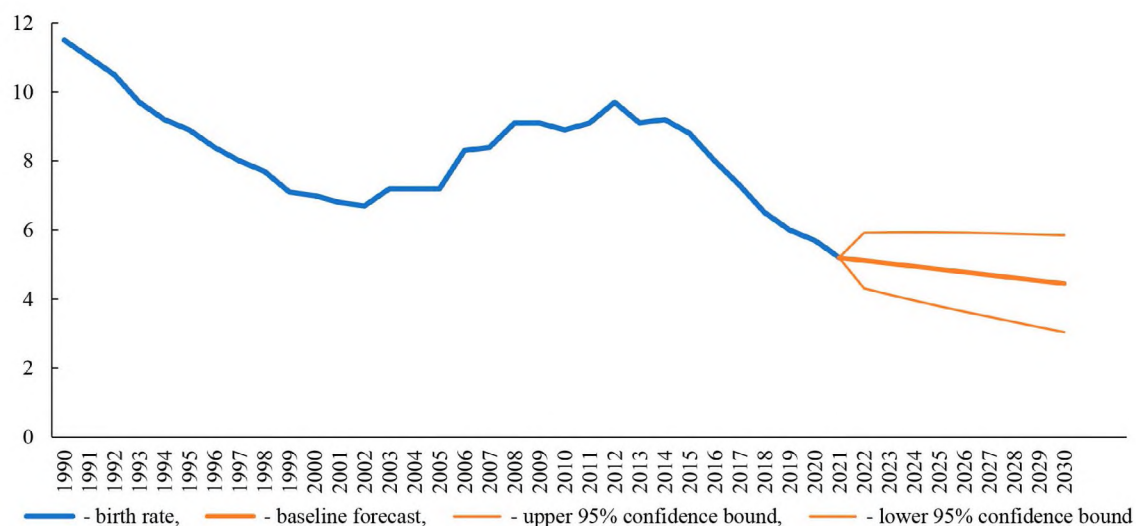


Fig. 3. Forecast of the birth rate of the population in Sumy region by 2030 (Source: Demohrafichna, 2022, Statystychnyi, 2022).

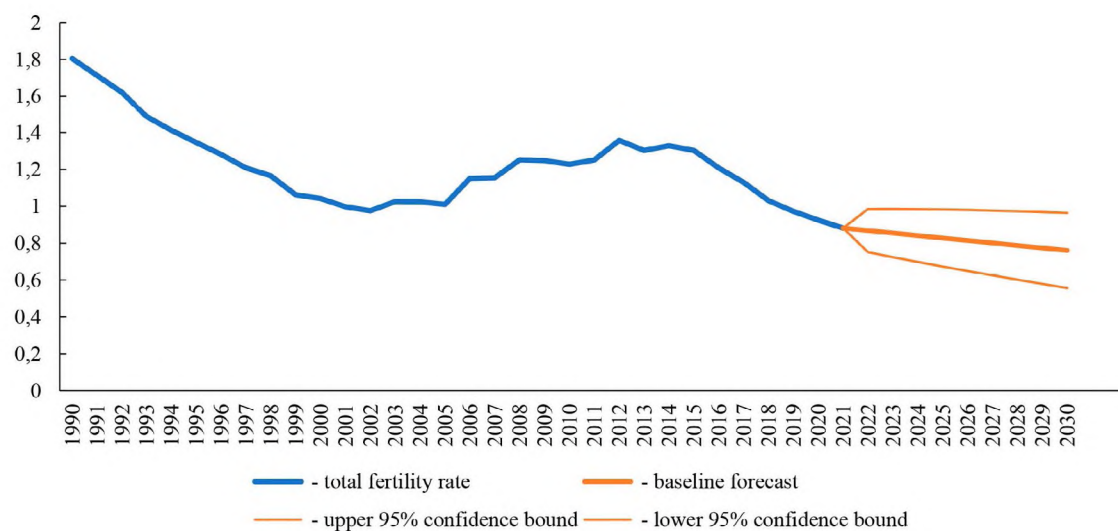


Fig. 4. The forecast of the level fertility rate in Sumy region by 2030 (per one woman) (Source: Statystychnyi, 2022).

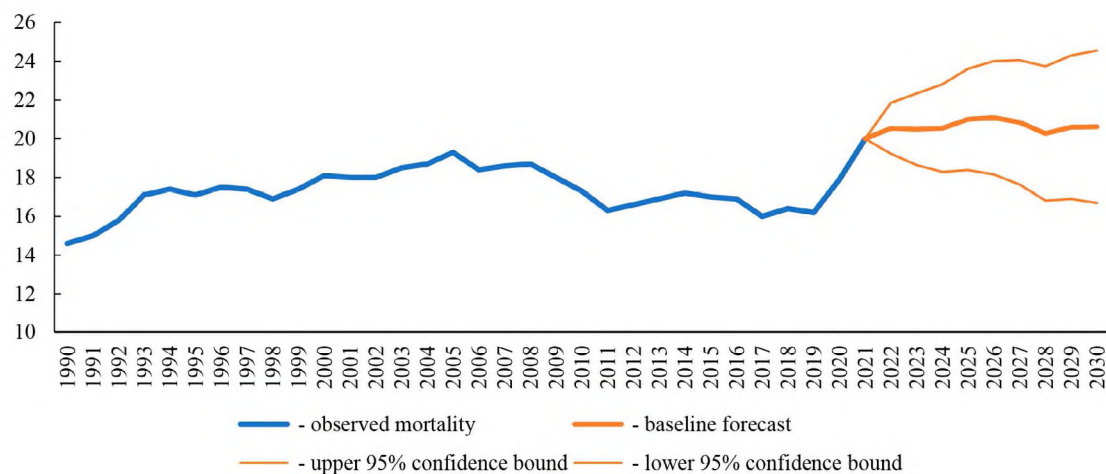


Fig. 5. The forecast of mortality in Sumy region by 2030 (Source: Demohrafichna, 2022, Statystychnyi, 2022).

for which the function parameters are estimated). In the first case, it is necessary for the function to smooth the entire initial dynamic series well. In the case when a trend function is intended for making forecasts, preference is given to the function which has the best approximation characteristics for the last part of a dynamic series. This is explained by the fact that development trends which are formed at the end of the retrospective period have, as a rule, the greatest impact on future development. For better adaptation of the models to the new data, it is reasonable to apply adaptive methods, in which the prediction results mainly depend on the values of the series, which are located closest to the beginning of the forecasting period.

In order to reproduce the behavior of a dynamic series, additive polynomial models are used. Let us demonstrate the approximation of natural population decline using a linear polynomial trend of the 6th order (Fig. 6), the coefficient of determination $R^2 = 0.9527$. The prediction of dynamic series is more appropriate to build with an adaptive model that provides exponential smoothing, rather than using simple trend models. The essence of this method is that each level of the time series is smoothed by means of a moving average with weights that obey the exponential law. The results of exponential smoothing are shown in Fig. 7. Multiple correlation coefficient for the obtained adaptive model is $r = 0.9671$.

We should point out that since 1980, a natural decrease in the population has been recorded in Sumy region. It should be mentioned that among the urban population, the natural population decline began only in 1995 (-4.1‰), while in rural areas this phenomenon began as early as 1970 and then it was -0.9‰

(Kornus, 2009). As the forecast shows, this tendency will remain unchanged in the future. The rate of population decline will increase by 60% by 2030, and the rate of depopulation will be -25.1‰ (Fig. 7). The upper boundary of the 95% confidence interval indicates the rate of natural population decline by -10.2%. At the sometimes lower boundary of this interval a more pessimistic forecast is shown, according to which the natural contraction will be -36.1‰, which is 2 times more than in 2021.

Conclusions

Predicting the trends of various demographic processes is an important scientific task for both social geography and practice because in this way one can reduce the uncertainty of the future and try to manage these processes. The construction of time trends based on dynamic series is one of the simplest methods of statistical forecasting. This is the method of modeling which, as a rule, it is recommended to apply at the beginning of demographic analysis for preliminary estimation and finding out which models for approximation of this process should be applied in the future.

Simple linear, logarithmic, power, and logistic models are well suited for modeling trends in the development of small businesses in Ukraine, but polynomial models better smooth out inequalities in the input series. Adaptive models are more sensitive to new data, and therefore they can be used to calculate more accurate forecasts.

Due to the forecasting method, information on future changes in the population of Sumy region and the main indicators of its natural movement was ob-

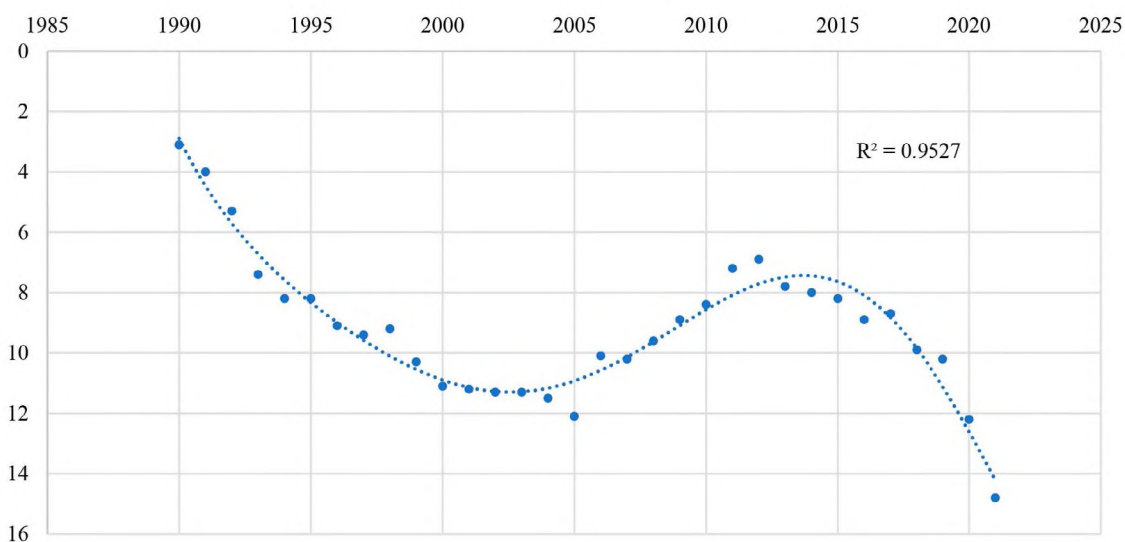


Fig 6. Linear polynomial model of the 6th order of the population natural decline of Sumy region

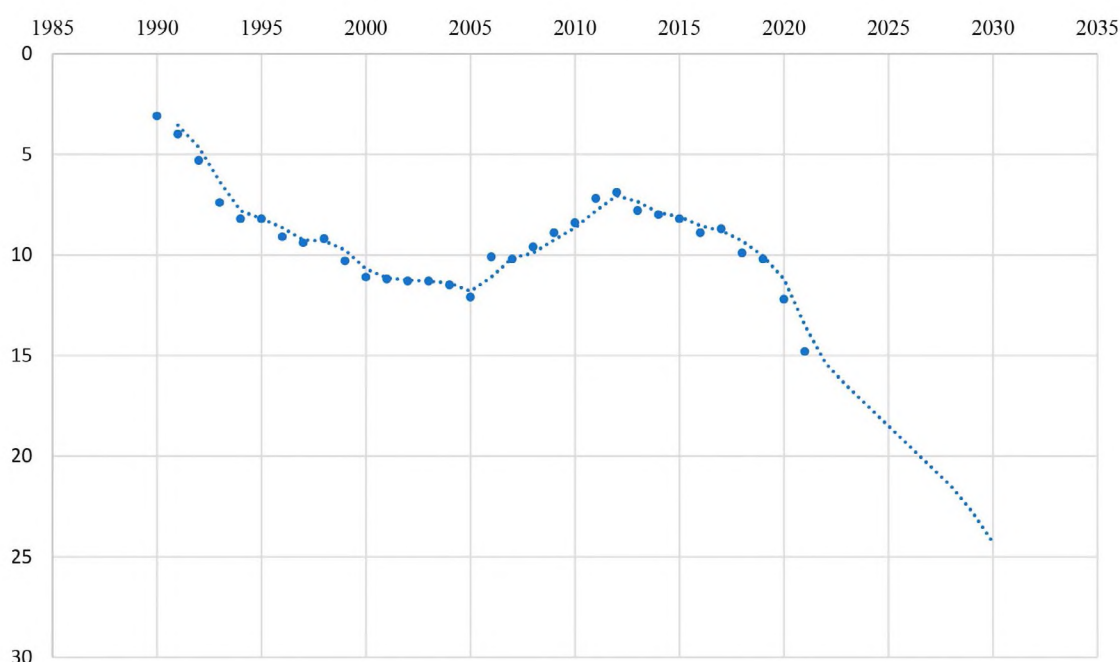


Fig. 7. The adaptive linear model of natural population declines in Sumy region by 2030 (Source: Demohrafichna, 2022, Statystychnyi, 2022).

tained. To sum up, we would like to mention that having made a forecast based on the main demographic indicators by 2030, it was found that the most likely demographic situation will only worsen in almost all indicators, only the mortality rate of the population may slightly decrease. We should confess that without a preliminary forecast of the demographic situation, it is impossible to determine the prospects for

the socio-economic development of the region, and the need to develop the healthcare system, education, social insurance, and other areas of the public service system. Besides, the results of the demographic forecast can be used in assessing the balance of labor resources in the future, planning the development of the social sphere, housing construction, etc.

References

- Abel G. J., Bijak J., Forster J. J., Raymer J., Smith P.W.F. Wong J.S.T. (2013). Integrating uncertainty in time series population forecasts: An illustration using a simple projection model. *Demographic Research*. 29(43): 1187-1226. DOI: 10.4054/DemRes.2013.29.43
- Athukorala W., Neelawela P. et al. (2010). Forecasting Population Changes and Service Requirements in the Regions: A Study of Two Regional Councils in Queensland, Australia. *Economic Analysis & Policy*. 40(3): 327-349. DOI: 10.1016/S0313-5926(10)50033-X
- Baraniak I. Ie. (2013). Prohnozuvannya tendentsii rozvytku demohrafichnykh protsesiv u rehioni (na prykladi Lvivskoi oblasti). [Forecasting the Trends of Demographic Processes Development in the Regional Dimension (on the example of Lviv Region)]. *Regional economy*. 1. 131-137. (in Ukrainian).
- Booth H. (2006). Demographic forecasting: 1980 to 2005 in review. *International Journal of Forecasting*. 22(3): 547-581. DOI: 10.1016/j.ijforecast.2006.04.001
- Burova O. B. (2017). Assessment of development and forecast demographic potential rural Kherson region. *Economic Innovations*, 19(2), 64: 47-53. DOI: [https://doi.org/10.31520/ei.2017.19.2\(64\)](https://doi.org/10.31520/ei.2017.19.2(64))
- Calian V., Harðarson Ó. (2015). Methodology of population projections. *Statistical Series Working papers*. 100(43). Retrieved from URL: https://www.hagstofa.is/media/49266/hag_151118.pdf
- Demohrafichna ta sotsialna statystyka (2022). [Demographic and social statistics]. Retrieved from URL: <http://sumy.ukrstat.gov.ua/?menu=608> (in Ukrainian).
- Dobuliak L.P., Kostenko S.B. (2019). Vykorystannia trendovykh modelei dlia doslidzhennia tendentsii rozvytku maloho pidpriemnytstva v Ukraini. [Using trend models for analysis of small business development tendencies in Ukraine]. *Uzhorod National University Herald. International Economic Relations and World Economy*. 24(1): 147-152 (in Ukrainian).
- Dulyuk I., Matusov Y. (2010). Modeliuvannya demohrafichnykh protsesiv na Ukraini za dopomohoiu optymalnykh protsedur rozpoznavannia. [Modeling demographic processes in Ukraine with the help of optimal recognition procedures].

- graphic processes in Ukraine using optimal recognition procedures]. *Economic Bulletin of National Technical University of Ukraine «Kyiv Polytechnic Institute»*, 7: 250-255 (in Ukrainian).
- Gunko N. V., Kukush, O. G., Melekestseva, A. A. (2022). Yakby ne bulo viiny: prohnoz de mohrafichnykh pokaznykiv dlia hromad Vyshhorodskoho raionu Kyivskoi oblasti [If there were no war: Demographic indicators forecast for Vyshgorodsky District, Kyiv Oblast]. *Demography and Social Economy*, 3 (47): 46-64. DOI: 10.15407/dse2022.03.046
- Kerbikova A.S., Pysmenna O.O., Tkachenko N.I., 2019. Analiz pryrodnoho vidtvorennia naselennia Ukrainy. [Analysis of natural reproduction of the population of Ukraine]. *Market infrastructure: Electronic Scientific and Practical Journal*, 37: 515-522 (in Ukrainian).
- Kornus O.H. at al., 2009. Sfera obsluhovuvannia naselennia Sumskoi oblasti: suspilno-heohrafichni aspekty: Monohrafiia. [Service industry of the population of Sumy region: socio-geographical aspects]: monograph. Kharkov-Sumy, 228 (in Ukrainian).
- Kukush O.H., Melekestseva A.A., Hunko N.V. (2021). Prohnozuvannia demohrafichnykh pokaznykiv z dopomohoiu splainiv. [Forecasting demographics with splines]. *Statistics of Ukraine*, 4: 76-86 Doi:10.31767/su.4(95)2021.04.08 (in Ukrainian).
- Libanova, E. M. (Ed.). (2006). Kompleksnyi demohrafichnyi prohnoz Ukrainy na period do 2050 r. [Complex demographic forecast of Ukraine for the period till 2050]. Kyiv: Ukrainskyi tsentr sotsialnykh reform. Retrieved from <http://idss.org.ua/monografii/Prohnoz%20Ukrain.pdf> (in Ukrainian)
- Luchko M., Shesterniak M. (2021). Statistical methods for forecasting the development of demographic indicators in Ukraine: application context. *Journal of European Economy*. Vol. 20. 1 (76): 183-204. DOI: 10.35774/jee2021.01.183
- Matviishyn Ye. H., Dziurakh Yu. M. (2019). Rezultatyprohnozuvannia demohrafichnoho navantazhennia na naselennia pratsездatnoho viku v silskii mistsevosti v oblastiakh Ukrainy. [Forecasting results of demographic burden on the working-age population in the countryside in regions of Ukraine]. *Democratic Governance*, 1(23). DOI: 10.33990/2070-4038.23.2019.181482 (in Ukrainian).
- Naselennia svitu zrostaie, stariie i pereizhdzhaie v mista. Informatsiinyi prostir staloho rozvytku (2019). [The world's population is growing, aging and moving to cities. Information space of sustainable development]. Retrieved from URL: <https://responsiblefuture.com.ua/naselennya-svituzrostaye-stariye-i-pereizhdzhaie-v-mista/> (in Ukrainian).
- Naselennia Ukrainy skorotytsia do 35 mln do 2050 roku – prohnoz OON (2021). [The population of Ukraine will decrease to 35 million by 2050 – UN forecast]. Retrieved from URL: <https://mind.ua/news/20233736-naselennya-ukrayini-skorotitsya-do-35-mln-do-2050-roku-prognoz-oon> (in Ukrainian).
- Naselennia Ukrainy za 2020 r.: demohrafichnyi shchorichnyk (2021). [Population of Ukraine in 2020: Demographic Yearbook]. Kyiv: State Statistics Service of Ukraine. 184 (in Ukrainian).
- Petropoulos F. at al. (2022). Forecasting: theory and practice. *International Journal of Forecasting*, 38(3): 705-871. DOI: 10.1016/j.ijforecast.2021.11.001
- Population growth (annual %). The World Bank Data. Retrieved from URL: <https://data.worldbank.org/indicator/SP.POP.GROW>
- Pyrozhkov S.I., Shcherbov S.Ia., Shevchuk P.Ie. (2006). Ukraina 2050: Perspektyvy demohrafichnoho rozvytku. [Ukraine 2050: Prospects for Demographic Development]. Retrieved from URL: https://ukrstat.gov.ua/Novyny/new_old/new2006/zmist_novin/demogr/rozv.htm
- Rohozhyn O. (2009). Prohnozuvannia narodzhuvanosti silskoho naselennia na osnovi imitatsiinoi modeli. [Forecasting the birth rate of the rural population based on a simulation model]. *Birth rate in Ukraine at the beginning of the XXI century*. 113-123. Retrieved from URL: <https://dse.org.ua/arhcive/13/14.pdf> (in Ukrainian).
- Sehida K. Yu. (2017). Otsinочно-prohnostychni modeliuvannia heodemohrafichnoi systemy Kharkivskoho rehionu. [Evaluation and prognostic modeling of the geodemographic system of Kharkov region] *Bulletin of Kharkiv National University named after V. N. Karazin, series «Geology. Geography. Ecology»*, 46: 136-145 (in Ukrainian).
- Spankulova L.S., Chulanova Z.K. (2022). Demographic processes in Kazakhstan: current trends and forecasting the future development. *Bulletin of «Turan» University*, 3: 60-71. DOI: 10.46914/1562-2959-2022-1-3-60-71
- Statystychnyi shchorichnyk Sumskoi oblasti za 2020 rik (2021). [Statistical yearbook of Sumy region for 2020]. Sumy: Sumy Regional Department of Statistics. 448 (in Ukrainian).
- Sussman H., Alexander M., Alkema L. (2022). Temporal Models for Demographic and Global Health Outcomes in Multiple Populations: Introducing a New Framework to Review and Standardise Documentation of Model Assumptions and Facilitate Model Comparison. *International Statistical Review*, 90: 437-467. <https://doi.org/10.1111/insr.12491>
- Vanella P., Deschermeier Ph., Wilke Ch.B. (2020) An Overview of Population Projections – Methodological Concepts, International Data Availability, and Use Cases. *Forecasting*, 2(3): 346-363. DOI: 10.3390/forecast2030019
- Vollset S.E., Goren E., Yuan Ch.-W. et al. (2020). Fertility, mortality, migration, and population scenarios for

- 195 countries and territories from 2017 to 2100: a forecasting analysis for the Global Burden of Disease Study. *Global Health Metrics*. 396: 1285–1306. DOI: 10.1016/S0140-6736(20)30677-2
- Voloshchuk R.V. (2020). Assessment and Forecasting of the Demographic Sphere of Economic. *Security Control Systems and Computers*, 6 (290): 35-45. DOI: 10.15407/csc.2020.06.035
- Wilson T., Grossman, I., Alexander M., Rees P., Temple J. (2022). Methods for Small Area Population Forecasts: State-of-the-Art and Research Needs. *Population Research and Policy Review*. 41: 865–898. DOI: 10.1007/s11113-021-09671-6
- World Population Prospects 2022. Summary of Results. United Nations. New York. Retrieved from URL: https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022_summary_of_results.pdf
- Yatsenko A.M., Vitkovska K.V. (2021). Problemy ta demohrafichni prohnozy dlia Ukrainy. [Problems and demographic forecasts for Ukraine]. *Statistics – a tool for socio-economic research: a collection of sciences. stud. works*. 7. 83-87. Retrieved from URL: <http://dspace.oneu.edu.ua/jspui/handle/123456789/14677> (in Ukrainian).
- Zhang J. L., Bryant, J. (2020). Bayesian disaggregated forecasts: Internal migration in Iceland. In S. Mazzucco, N. Keilman (Eds.), *Developments in demographic forecasting* 193–215. DOI: 10.1007/978-3-030-42472-5_10