Vol. 05, No. 3 (2023) 383-390, doi: 10.24874/PES05.03.003

Proceedings on Engineering Sciences

www.pesjournal.net

CREATED AND REALIZATION OF A DEMOGRAPHIC POPULATION MODEL FOR A SMALL CITY

Seyit Kerimkhulle[1]
Meruyert Koishybayeva
Assylzat Slanbekova
Zhanar Alimova
Nauryz Baizakov
Gulmira Azieva

Received 09.11.2022.
Accepted 11.06.2023.
UDC – 314.04

Keywords:

Mathematical model, System dynamics, Demographic process, Population, Housing construction industry

A B S T R A C T

Using a mathematical model of the system dynamics of the demographic process in the work, an assessment of the impact of the housing construction industry on the future population was obtained it was revealed that the share of occupied plots for housing construction is a leading indicator in ensuring stable reproduction of the demographic process both in urban agglomerations and small towns countries, for example, the city of Kosshy, Akmola region of the Republic of Kazakhstan.

1. INTRODUCTION

It is known that work (Balabanova et al., 2021; Gnap et al., 2018; Low et al., 2020; Sterman, 2000) is devoted to comprehensive studies of obtaining systemic solutions to the problems of the demographic situation of the city's population, but today many authors conduct an in-depth analysis of the methodology and use more modern technologies, in particular, among them, we note that the work (Avdeev & Troitskaya, 2021) revealed features and factors of demographic dynamics in the Kyrgyz Republic. Indeed, an analysis of the demographic dynamics in the Kyrgyz Republic has shown several interrelated problems and challenges arising from the rapid growth of the population and changes in its age structure and requiring urgent social and economic policy measures. Key among them is the mass departure of the active population, primarily young people (labor migration); growth in the population of retirement age; features of population resettlement with a concentration around the two largest urban agglomerations of the republic, the cities of Bishkek and Osh.

Further, in the article (Conti et al., 2021) validation studies were conducted for residents of nursing homes in England. The aim of this work is to explore a new methodology based on the association of unique identifiers of the home address of the elderly with the

[1] Corresponding author: Seyit Kerimkhulle
Email: kerimkhulle@gmail.com

registration data of patients in primary health care, allowing to routinely identify residents of nursing homes in health care data. And the obtained estimates of diagnostic efficiency, although showing a slight false-negative rate (21.98%), emphasize a significant true negative rate (99.69%) and positive predictive value (99.35%), as well as a satisfactory negative predictive value (88.25%). This leads to the conclusion that validation gives confidence in the reliability of the new address matching method as a viable and general alternative to manual address matching.

The article (Pilkauskas et al., 2020) is devoted on Problems in Determining Historical Trends for Multigenerational Children in the United States: 1870-2018. Over the past two decades, the proportion of American children under the age of 18 who live in multi-generational families (with grandparents and a parent) has increased dramatically. Using data from the decennial census from 1870 to 2010 and the 2018 American Community Survey, the authors found that in 2018, 10% of U.S. children lived in multi-generational families, with the last time a return to levels was seen in 1950. The current rise in the number of multi-generational families began in 1980 when only 5% of the children lived in such a household. And the results show that the associations between race/ethnicity and socioeconomic status and the multi-generational database have changed over time, and today the association between parental education and residence base varies across racial/ethnic groups.

In conclusion, we note that in (van Dalen & Henkens, 2021) received a consensus and disagreement were found among demographers on population problems and climate change. As a result, climate change was found to be at the top of the list of demographic concerns, but that their sense of urgency to act against global warming was not consistent with their belief that population policy could be crucial in reducing CO_2 emissions.

2. LITERATURE REVIEW

The positions of researchers on the problem of assessing the financial and economic ties of the industry's impact on the demographic process are diverse the article (Nwogu & Okoro, 2021) assesses mortality in lived person-years and life expectancy of the adult population in developing countries.

The article (Arpino & Tavares, 2013) is devoted to assessing the trend of fertility in Europe with changes in value. Particular attention is paid to Spain and Italy, which, along with other countries of Southern Europe, are often seen as a homogeneous group, sharing the same "traditional" values and demographic behavior. Thus, the paper shows that the similarity of the TFR (Total Fertility Rate) at the country level hides significant differences at the regional level. And given an analysis at the regional level, which is crucial for a better understanding of changes in fertility levels.

An article (Vanella et al., 2022) noted that in industrialized countries there is a decline in mortality along with low birth rates, a situation that is creating a situation that puts social security systems under serious pressure. And this, in turn, threatens the sustainability of existing pay-as-you-go social security systems for the implementation or further improvement of relevant reforms and projections of the future structure of the population. The paper proposes a probabilistic approach to predict the number of pensions in Germany until 2040, where the model considers trends in population development, labor force participation and early retirement, as well as the impact of pension reforms. It also provides an analysis of the main components that are used to manage the high degree of complexity associated with predicting trends in old-age and disability pension requirements, considering the correlation between old-age and disability pension rates, different age groups and gender. As a result, the model under study predicts that, on a medium trajectory, the number of old-age pensions will increase by almost 5 million between 2017 and 2036, along with an increase in the number of disability pensions by 2036.

This article (Mulder et al., 2022) explores the existing associations between migration and labor market rates in the widely studied countries of Northern and Western Europe and the United States. To do this, the researchers used a sample of labor market participants from the Attitudes and Expectations Regarding Mobility survey conducted in Spain in 2019. As a result, it was found that, firstly, the probability of becoming a professional is higher for women who have migrated than for those who have not migrated. Second, women who live close to family are less likely to be unemployed or find temporary work than those who do not, but none of these associations were found in men. Third, that living close to the family is consistent with the notion that the close family can protect women, from precarious positions in the labor market. Fourth, that migration differs from previous results for Northern and Western Europe and the US, which indicate that migration benefits men.

The article (Milton et al., 2022) argues that stillbirths were associated with low educational attainment, long distance from home to hospital, shack living, maternal hypertension, and a history of stillbirth after adjusting for all socio-demographic features and health status. Other factors associated with a higher chance of stillbirth included reports of complications during labor, duration of labor >=18 hours), prenatal hemorrhage, prolonged/obstructed labour, breech delivery, emergency delivery by caesarean section, and signs of trauma in the newborn. Also, the risk factors associated with stillbirth have been identified as relatively amenable to intervention, and a lot of work has been

done around the world, so developing an intervention with sufficient funding should be a relatively quick process.

3. METHODS AND MAIN RESULTS

To construct a mathematical model of the demographic development of the population of a small town, the mathematical theory of differential-difference equations (Kerimkhulle & Aitkozha, 2017) and models of the system dynamics of complex objects (Sterman, 2000) are used. And for the implementation of which algorithms, program codes in the AnyLogic software (AnyLogic, 2022) were developed and result-oriented computer experiments were carried out to reveal the hidden relationships between the values of the input indicators: initial population size, immigration and emigration rates, average life expectancy, household size, fertility rate reproductive women and outputs: population, newborns, deaths, emigration and immigration.

In this regard, in this paper, a demographic model of the systemic dynamics of the population is considered in order to reveal the hidden dependencies between the input parameters and the result-oriented output data of the demographic situation of the inflows and outflows of the population of the small town of Kosshy, Akmola region of the Republic of Kazakhstan.

3.1. Mathematical model of the population

Let t = 1,2,…, – forecasting time periods, year, then to construct a mathematical model of the population in the demographic process of a small town, the following are used:
– first-order difference scheme equations to ensure balanced population growth – $\mathrm{Population}_t$, and stability between inflows: $\mathrm{Immigration}_t$ – immigration numbers, Births_t – births number and population outflows: $\mathrm{Emigration}_t$ – emigration numbers, Deaths_t – deaths numbers:

$$= \mathrm{Immigration}_t + \mathrm{Births}_t - \mathrm{Emigration}_t - \mathrm{Deaths}_t ;$$

$$\frac{\mathrm{d}(\mathrm{Population}_t)}{\mathrm{dt}} = \mathrm{Immigration}_t + \mathrm{Births}_t - \mathrm{Emigration}_t - \mathrm{Deaths}_t ; \quad (1)$$

– initial population, – PopulationInitial:

$$\mathrm{Population}_t|_{t=0} = \mathrm{PopulationInitial} ; \quad (2)$$

– immigration numbers, – $\mathrm{Immigration}_t$, which is determined through the population, – $\mathrm{Population}_{t-1}$ and the number of attracting population inflows due to housing of the previous period, – $\mathrm{AttractionDueToHousing}_{t-1}$ with the immigration rate, – ImmigrationNormal:

$$\mathrm{Immigration}_t = \mathrm{Population}_{t-1} * \mathrm{ImmigrationNormal} * \mathrm{AttractionDueToHousing}_{t-1} ; \quad (3)$$

– births number, – Births_t, which is directly proportional to the population of the previous period, – $\mathrm{Population}_{t-1}$ with proportional coefficient, Fertility – fertility of reproductive women:

$$\mathrm{Births}_t = \mathrm{Fertility} * \mathrm{Population}_{t-1} ; \quad (4)$$

– emigration numbers, – $\mathrm{Emigration}_t$, which is determined through the population of the previous period, – $\mathrm{Population}_{t-1}$ with the immigration rate, – ImmigrationNormal:

$$\mathrm{Emigration}_t = \mathrm{EmigrationNormal} * \mathrm{Population}_{t-1} ; \quad (5)$$

– deaths numbers, – Deaths_t, which is directly proportional to the population of the previous period, – $\mathrm{Population}_{t-1}$ with proportional coefficient, $1/\mathrm{AverageLifetime}$ – inverse of the average life expectancy of the population:

$$\mathrm{Deaths}_t = \frac{\mathrm{Population}_{t-1}}{\mathrm{AverageLifetime}} ; \quad (6)$$

– attraction function value attractionDueToHousingLookupTable population inflows due to housing, – $\mathrm{AttractionDueToHousing}_t$ from the ratio of households to the number of houses, – $\mathrm{HouseholdsToHousesRatio}_t$ according to the given lookup table:

$$\mathrm{AttractionDueToHousing}_t = \mathrm{attractionDueToHousingLookupTable}(\mathrm{HouseholdsToHousesRatio}_t) ; \quad (7)$$

– the value of the ratio of households to the number of houses, – $\mathrm{HouseholdsToHousesRatio}_t$, which is directly proportional to the population, – $\mathrm{Population}_t$ and is inversely proportional to the number of houses, – Houses_t with proportional coefficient, $1/\mathrm{HouseholdSize}$ – inverse of the household size of the population:

$$\mathrm{HouseholdsToHousesRatio}_t = \frac{\mathrm{Population}_t}{\mathrm{Houses}_t * \mathrm{HouseholdSize}} . \quad (8)$$

3.2. Computer implementation of the population model

Let the input data of the parameters be given:
– PopulationInitial, – the initial value of the population size of a small town with an interval of acceptable values [30 000; 100 000] people, in particular $\mathrm{PopulationInitial} = 10\,000$ people;

– AverageLifetime, – average life expectancy with an interval of acceptable values [50; 80] years, in particular AverageLifetime = 67 years;
– Fertility, – fertility rate of reproductive women with an interval of acceptable values [0.01; 0.1] or from 1 % till 10 %, in particular Fertility = 0.03 or 3 %;
– EmigrationNormal, – the rate of normal emigration of the population with an interval of permissible values [0.05; 0.15] or from 5 % till 15 %, in particular EmigrationNormal = 0.07 or 7 %;
– ImmigrationNormal, – the rate of normal immigration of the population with an interval of acceptable values [0.05; 0.15] or from 5 % till 15 %, in particular ImmigrationNormal = 0.1 or 10 %;
– HouseholdSize, – average number of people in a household with an interval of acceptable values [2; 8] people, in particular HouseholdSize = 4 people.

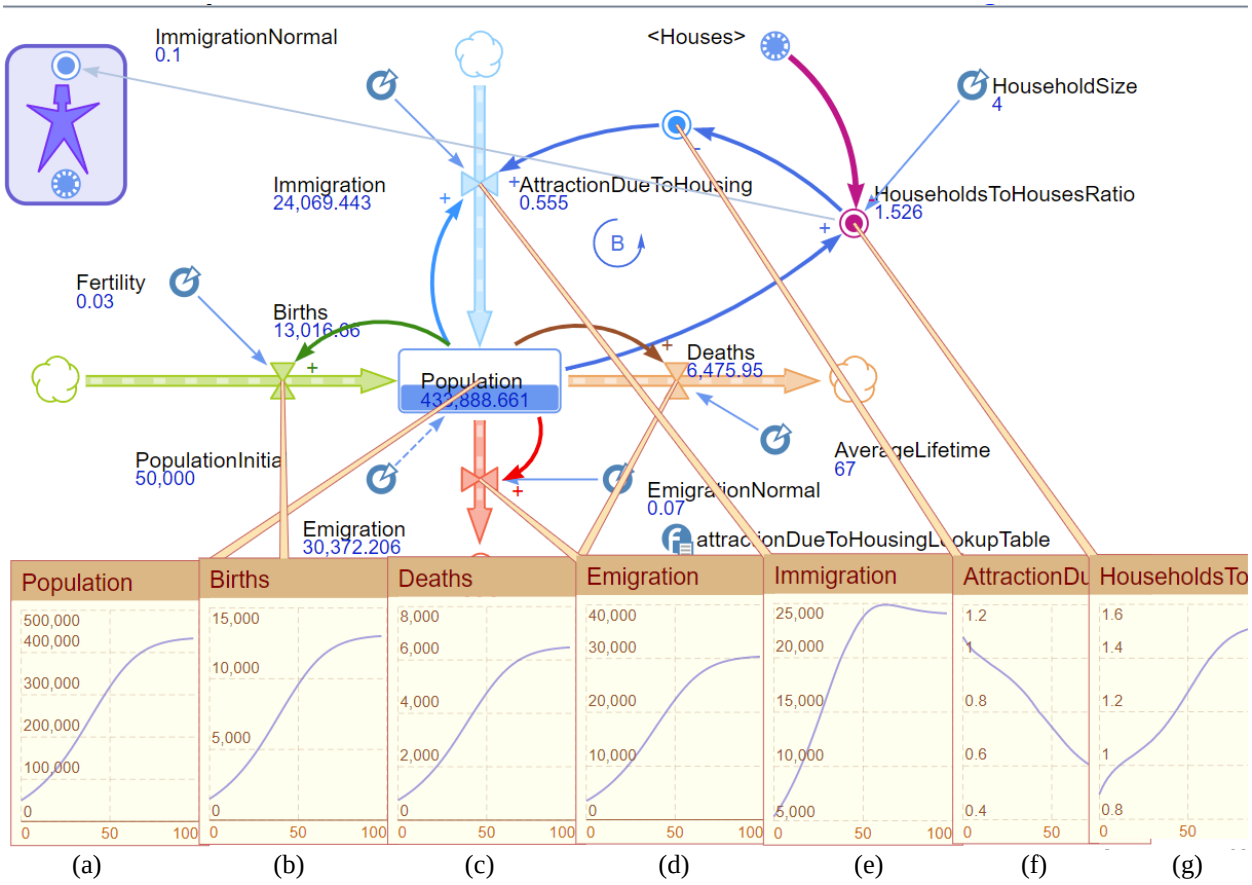

Figure 1. Input parameters, output data and computer implementation of a mathematical model of the demographic situation for a small town in the AnyLogic software

Then the computer implementation of the mathematical model of the population (1)-(8) makes it possible to obtain the following results of the output data – values, simulation, and visualization of the results of computer experiments:
– $Population_t$, – population growth with 50 thousand by 434 thousand 510 people (see Fig. 1, «S» shaped curve (a)),
– $Births_t$, – increase in births number with 1 thousand 500 by 13 thousand 35 people (see Fig. 1, «S» shaped curve (b)),
– $Deaths_t$, – increase deaths numbers with 746 by 6 thousand 485 people (see Fig. 1, «S» shaped curve (c)),
– $Emigration_t$, – рост численности эмиграции with 3 thousand 500 by 30 thousand 415 people (see Fig. 1, (d) – «S» shaped curve),
– $Immigration_t$, – increase immigration numbers with 5 thousand 401 by 24 thousand 68 people (see Fig. 1, curve (e)),
– $AttractionDueToHousing_t$, – decrease in the coefficient of attracting population inflow due to housing with 1.073 or 107.3 % by 0.554 or 55.4 % (see Fig. 1, curve (f)),
– $HouseholdsToHousesRatio_t$, – increase in the ratio of households to the number of houses with 0.897 or 89.7 % by 1.528 or 152.8 % (see Fig. 1, curve (g)).

4. DISCUSSION

Here, we note a row of articles that may be a development of this research work, in particular article (Preston & Vierboom, 2021) describes how the history of births, deaths and migrations influenced the age distribution in the United States in 2018. It also shows

how this story, combined with modern processes, actively caused changes in the age distribution between 2013 and 2018, migration and fertility - all of them contributed to the aging of the population during this period, with the leading factor being a decrease in the growth of fertility.

Finding an effective solution to alleviate the burden faced by mental health services is critical today. In this regard, the work (Makanjuola et al., 2022) proposes a Social Return On Investment (SROI) methodology for evaluating the Emotion Mind Dynamic (EMD) service. The goal of SROI analysis is to develop a theory of change at the program level to establish how inputs (e.g., costs, staff) translate into outcomes (e.g., number of clients) and then into outcomes that matter to clients affected by the EMD service (for example, improved mental well-being). The Welfare Assessment will quantify and evaluate outcomes using two sets of values. The mixed-method approach SROI collects quantitative and qualitative data from questionnaires and interviews with former EMD clients as well as new clients, executing a blended online learning program. As a result, a study result was obtained to analyze the SROI of a socially prescribed lifestyle coaching program aimed at improving mental well-being and resilience. And it is shown that the EMD lifestyle education program can create positive coefficients of social value. It also provides an analysis of the EMD online blended learning program that compares the effectiveness of two lifestyle coaching formats: personal and blended online for improving mental well-being and self-efficacy through participation in this innovative lifestyle coaching program.

A study (Tiwari et al., 2022) examines the impact of seasonal and permanent migration on inequality in rural India. The authors apply a counterfactual method to estimate income, and the results show that seasonal migration is a strategy of the poor, as opposed to permanent migration, which involves more affluent migrants. Further, using Gini decomposition and instrumental quantile regression, it was found that both seasonal and permanent migration reduces intra- and inter-group inequalities, seasonal migration benefits the poorest of the poor. It is also noted that the impact of migration follows a roughly U-shaped pattern for permanent migration and a decreasing trend for seasonal migration.

The article (Agadjanian & Nedoluzhko, 2022) investigates the difference in fertility between minorities and majorities in Western countries with low fertility, usually focusing on the cultural characteristics of minority groups and on the socioeconomic disadvantages associated with minority status. However, the formation and functioning of ethnic complexes outside the Western world are often at odds with the standard Western model, and therefore can influence fertility preferences, behaviors, and outcomes. As a result, the authors, analyzing the ethnic variability of completed and desired fertility in the multi-ethnic transitional environment of Kyrgyzstan, where ethnic groups and their ethno-linguistic parts are characterized both by different stages of the demographic transition, and by different positioning in socio-economic and political terms.

Based on data analysis, the author of the work (Chen, 2022) made a few attempts to assess the impact of women's education on fertility in China, for example, the author noted that more educated women have higher fertility, but it remains unclear whether education obviously affects female fertility. Here, the time and various aspirations of women for higher education are seen as exogenous sources of increasing the level of education of women in China. According to a study based on data from China (2010-2012), an increase in the number of women with higher education adds 10% to the number of newborns. Also, for each additional year of women's education, the number of newborn children is added with a probability of 0.14%, and the probability of having one child by 3% and the probability of having two or more children by 4% increase. The positive effect of education is due to the causes of occurrence: first, education does not lead to middle age at an early age; second, among ever-married women, education increases their need for children.
The article (Diter et al., 2021) aims to highlight the influence of school-related determinants on children's life satisfaction and its variation across social classes. Indeed, over the past fifty years, the topic of child well-being has attracted attention in political and academic debates. These multiple determinants of children's life satisfaction, as well as their relative importance depending on the cultural context, include consideration of the school environment for children's subjective well-being and the achievement of a positive education. It was also noted that the well-being of children is influenced by the school environment, the quality of children's relationships with peers and teachers at school, as well as the participation of parents in the lives of their children. Thus, based on the French part of the Program for International Student Assessment (PISA) 2015 (n = 4804), the authors defined a two-stage inequality expression. It is first shown that class differences influence the likelihood that children will have both a school environment and relationships with peers and parents that increase their levels of life satisfaction. Further, it is noted that social inequality also manifests itself when studying the influence of school-related factors on the overall life satisfaction of children. School bullying, anxiety, and parental involvement in school seem to affect children differently depending on their social background.

5. CONCLUSION

Thus, studying the demographic model of the systemic dynamics of the population of the small town of

Kosshy, Akmola region of the Republic of Kazakhstan, a latent relationship was revealed between the input parameters and the output data of the indicators of inflows and outflows of the population as the share of occupied lands for housing construction, which is a leading indicator in ensuring stable reproduction of the demographic process.

Based on the results of the study, an assessment was made of the impact of the housing construction industry on the future population of such outputs as population, newborns, deaths, emigrants and immigrates.

Acknowledgement: This research was funded by the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan (Grant No. AP09259435).

Referenes:

Agadjanian, V., & Nedoluzhko, L. (2022). Group Normative Propensities, Societal Positioning, and Childbearing: Ethno-linguistic Variation in Completed and Desired Fertility in Transitional Central Asia. *Population Research and Policy Review, 41*(4), 1571-1596. doi: 10.1007/s11113-022-09701-x

Avdeev, A. A., & Troitskaya, I. A. (2021). Features and factors of demographic dynamics in the Kyrgyz Republic. *Journal of Population Economics, 5*(2), 29-54. doi: 10.3897/popecon.5.e67183

Arpino, B., & Tavares, L. P. (2013). Fertility and Values in Italy and Spain: A Look at Regional Differences within the European Context. *Population Review*, *52*(1), doi: 10.1353/prv.2013.0004

Balabanova, A., Keschyan, N., Borisova, T., & Hachemizova, E. (2021). Using digital platforms for environmental management. *E3S Web of Conferences*, 244, 07006. doi: 10.1051/e3sconf/202124407006

Chen, S. (2022). The Positive Effect of Women's Education on Fertility in Low-Fertility China. *European Journal of Population, 38*, 125-161. doi: 10.1007/s10680-021-09603-2

Conti, S., Oliveira dos Santos, F., & Wolters, A. (2021). A Novel Method for Identifying Care Home Residents in England: A Validation Study. *International Journal of Population Data Science*, *5*(4). doi: 10.23889/ijpds.v5i4.1666.

Diter, K., Martin, C., Buzaud, J., & Perron, Z. (2021). The Socially Differentiated Impact of School-related Factors on Children's Life Satisfaction: The French Example. *Population Review, 60*(2), 89-117. doi: 10.1353 /prv.2021.0012.

Gnap, J., Konečný, V., Slávik, R., & Beňová, D. (2018). Possible impacts of regulating the weekly rest of road freight drivers on logistics in EU countries. *Nase More, 65*(4), 259-265. doi: 10.17818/NM/2018/4SI.18

Kerimkhulle, S., & Aitkozha, Z. (2017). A criterion for correct solvability of a first order difference equation. *AIP Conference Proceedings, 1880*, 040016. doi: 10.1063/1.5000632

Low, S., Ullah, F., Shirowzhan, S., Sepasgozar, S. M. E., & Lee, C. L. (2020). Smart digital marketing capabilities for sustainable property development: A case of Malaysia, *Sustainability, 12*(13), 5402. doi: 10.3390/su12135402

Makanjuola, A., Lynch, M., Hartfiel, N., Cuthbert, A., & Edwards, R. T. (2022). A Social Return on Investment evaluation of the Emotion-Mind Dynamic (EMD) two phase social prescribing life coaching intervention to support mental health and wellbeing. *International Journal of Population Data Science, 7*(2). doi: 10.23889/ijpds.v7i2.1743

Milton, R., Modibbo, F., Gillespie, D., Alkali, F., Mukaddas, A., Sa'ad, F., ... & Walsh, T. (2022). Sociodemographic, living environment and maternal health associations with stillbirth in a tertiary healthcare setting in Kano, Northern Nigeria. *International Journal of Population Data Science, 7*(2). doi: 10.23889/ijpds.v7i2.1739.

Mulder, C. H., Palomares-Linares, I., & Vidal, S. (2022). Internal Migration, Living Close to Family, and Individual Labour Market Outcomes in Spain. *Comparative Population Studies*, 47. doi: 10.12765/CPoS-2022-01

Nwogu, E., & Okoro, C. (2021). Estimation of Adult Mortality in Developing Countries Using an Application Based on the Variable-r Method. *Population Review*, 60(2), doi: 10.1353/prv.2021.0010

Pilkauskas, N. V., Amorim, M., & Dunifon, R. E. (2020). Historical Trends in Children Living in Multigenerational Households in the U.S.: 1870-2018. *Demography, 57*(2), 1-28. doi: 10.1007/s13524-020-00920-5

Sterman, J. D. (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World*. McGraw-Hill Inc.

The AnyLogic Company. Homepage, www.anylogic.com, last accessed 2022/04/05.

Tiwari, C., Bhattacharjee, S., Sethi, P., & Chakrabarti, D. (2022). Internal Migration and Rural Inequalities in India. *Population Research and Policy Review*, doi: 10.1007/s11113-022-09707-5

van Dalen, H. P., & Henkens, K. (2021). Population and Climate Change: Consensus and Dissensus among Demographers. *European Journal of Population, 37*(3), 551-567. doi: 10.1007/s10680-021-09580-6

Vanella, P., Rodriguez Gonzalez, M., & Wilke, C. B. (2022). Population Ageing and Future Demand for Old-Age and Disability Pensions in Germany – A Probabilistic Approach. *Comparative Population Studies*, *47*. doi: 10.12765/CPoS-2022-05

Seyit Kerimkhulle
L.N. Gumilyov Eurasian National University,
Nur-Sultan,
Kazakhstan
kerimkhulle@gmail.com
ORCID 0000-0002-5886-6064

Meruyert Koishybayeva
L.N. Gumilyov Eurasian National University,
Nur-Sultan,
Kazakhstan
meruyert_r@mail.ru
ORCID 0000-0001-9171-441X

Assylzat Slanbekova
L.N. Gumilyov Eurasian National University,
Nur-Sultan,
Kazakhstan
slanbekovaae@mail.ru
ORCID 0000-0001-9658-7288

Zhanar Alimova
L.N. Gumilyov Eurasian National University,
Nur-Sultan,
Kazakhstan
jarasovajanar@mail.ru
ORCID 0000-0002-6115-5941

Nauryz Baizakov
L.N. Gumilyov Eurasian National University,
Nur-Sultan,
Kazakhstan
nauryz.b@mail.ru
ORCID 0000-0003-1346-400X

Gulmira Azieva
L.N. Gumilyov Eurasian National University,
Nur-Sultan,
Kazakhstan
gulmira_azieva@mail.ru
ORCID 0000-0002-7329-6768