Research Article

Digital UAE - a platform for demographic processes management

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This paper analyzes the existing demographic situation in the UAE, reveals current trends and main problems in this area. Successful foreign experience in solving demographic problems is also considered herein. Scenarios for the country were developed on its basis taking into account UAE state priorities. The paper describes the developed Digital UAE model, which allows carrying out scenario calculations to manage demographic processes in the UAE. Digital UAE was created on Tianhe-2 supercomputer (China) using an agent-based approach. With the help of Digital UAE, a forecast of the country's population was obtained within the framework of several scenarios: inertial, disurbanization, migration policy toughening, granting preferences to women, and an increase in health care costs. The developed tool can also be used to solve other related tasks to manage the socio-economic development of the UAE.

Current demographic situation

First of all, let's consider the state of affairs in the demographic sphere of the UAE. Fig. 1 shows data on the population of the UAE over a long period (from 1950 to 2022), which increased by more than 126 times. The growth rate has slightly decreased since 2011, but the dynamics is still positive.

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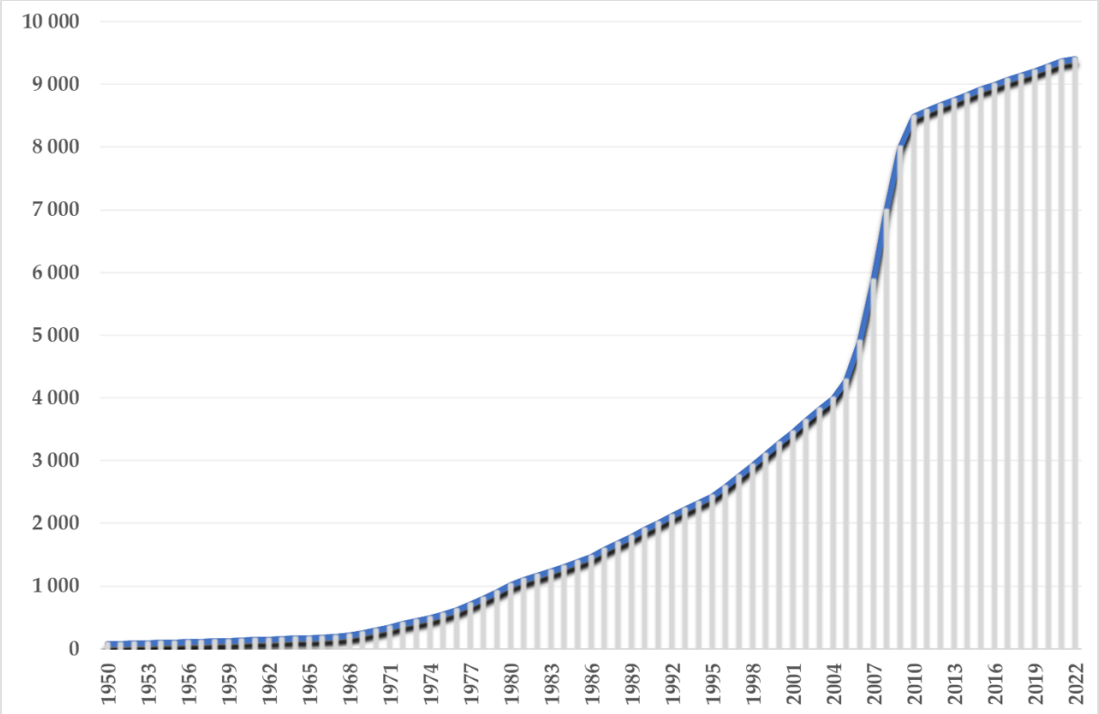

Fig. 1. Population (million people)[1]

It should be noted that the population growth was mainly due to migrants (Table 1). So, for the period from 1975 to 2022, the indigenous population increased by 25.2 times, and the number of migrants by 33.9 times. The share of migrants is constantly increasing: in 1985 it was 71.3% of the UAE population, by 2022 it had increased to 88.5%. The increase in the number of migrants is due to the growth of the UAE economy, which is one of the most developed in the Middle East. According to the IMF, the UAE ranks 6th in the world in terms of GDP per capita (in terms of the purchasing power parity), which amounted to $83.7 thousand/person in 2022.[2]

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	1975	1980	1985	1995	2005	2022
Number of indigenous people and migrants, thousand people						
Emiratis	42.8	290.5	396.1	587.3	825.5	1079.5
Migrants	245.3	751.6	983.2	1823.7	3280.9	8323.8
Proportion of indigenous population and migrants, as a percentage of total population						
Emiratis	14.8%	27.9%	28.7%	24.4%	20.1%	11.5%
Migrants	85.2%	72.1%	71.3%	75.6%	79.9%	88.5%

Table 1. Number and shares of Emiratis and migrants in the UAE[3]

UAE statesmen and researchers have repeatedly noted that the resulting imbalance between the indigenous population and migrants is a serious threat to national security[4].

Active development and diversification of the UAE economy, as well as high level of well-being of indigenous people hiring domestic staff, increase the demand for foreign labor, and therefore, it is unlikely that the problem will be resolved in the short term. It should be noted that Emiratis are dismissive of this situation. So, a sociological survey of the population showed that the created imbalance was assessed as the main challenge, more important than problems in the field of health care and the economy[5].

The decline in the birth rate contributes to a decrease in the growth of the indigenous population. Thus, the total fertility rate (TFR), the most important indicator determining the birth rate level, last time exceeded the value necessary for population replacement[6] in 2005, and has since decreased markedly – to 1.387 in 2021. It should be noted that the decline in the birth rate is characteristic of many countries. Fig. 2 and Table 2 show TFR data for 15 world leaders. Long-term dynamics shows that even countries that had high TFR a few decades ago (Saudi Arabia, China, India, Korea) had reached a new stage of demographic transition by 2021 characterized by a reduction in fertility and mortality. Human capital is one of the most important factors of international competition, so increasing the population and improving the quality of life is a priority for many states. Thus, the

number of countries which governments announced a goal to increase the birth rate almost tripled between 1986 and 2011[7].

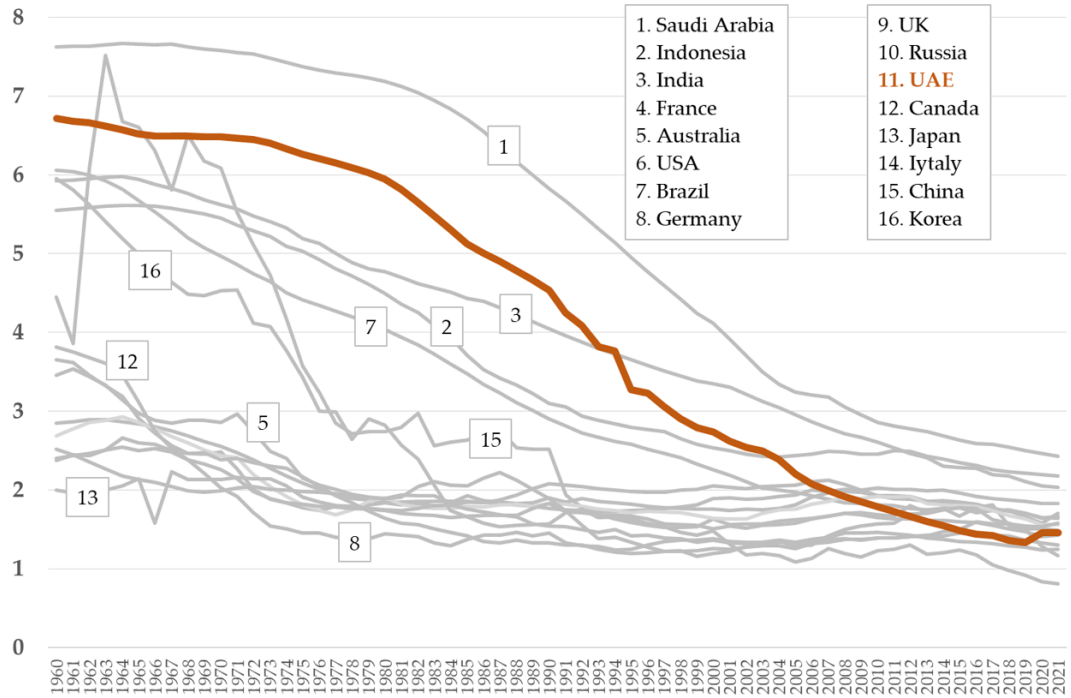

Fig. 2. Total fertility rate for 15 countries – worldwide leaders[8]

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Saudi Arabia	2.427
Indonesia	2.175
India	2.031
France	1.830
Australia	1.700
USA	1.664
Brazil	1.641
Germany	1.580
United Kingdom	1.560
Russia	1.493
UAE	**1.387**
Canada	1.430
Japan	1.300
Italy	1.250
China	1.164
Korea	0.808

Table 2. TFR for countries – worldwide leaders, 2021[9]

Literature analysis made it possible to identify the following main factors that negatively affect birth processes:

1. Lack of sustainable employment[10].
2. Unfavorable economic situation[11].
3. Growth of unemployment[12].
4. Focus on the career and professional growth of women [13][14][15].

5. Poor housing conditions[16].

6. Increased housing costs[17].

7. Social upheaval[18].

8. Delayed first-birth intentions[19].

9. Destruction of the institution of marriage[20].

The most relevant factor for the UAE is delayed first-birth intentions, which is a consequence of a change in the attitude to reproduction among women who want primarily to build their career, and not realize themselves in the family. So, according to the UN statistics, the mean age of new mothers in the UAE has increased from 28.5 years in 1950 to 31.4 years by now. The decrease in the birth rate among the indigenous population is due, among other things, to the increase in women's education and the more active participation of women in the labor market[21].

The slowdown in the UAE's population growth rate in recent years is also facilitated by the tendency to reduce the share of women in the total population (Fig. 3) and the increasing level of urbanization (Fig. 4). The noted gender imbalance in the UAE is mainly due to the influx of migrants, most of whom are men. The structure of the indigenous population of the UAE is also dominated by men, whose share is about 51%[22].

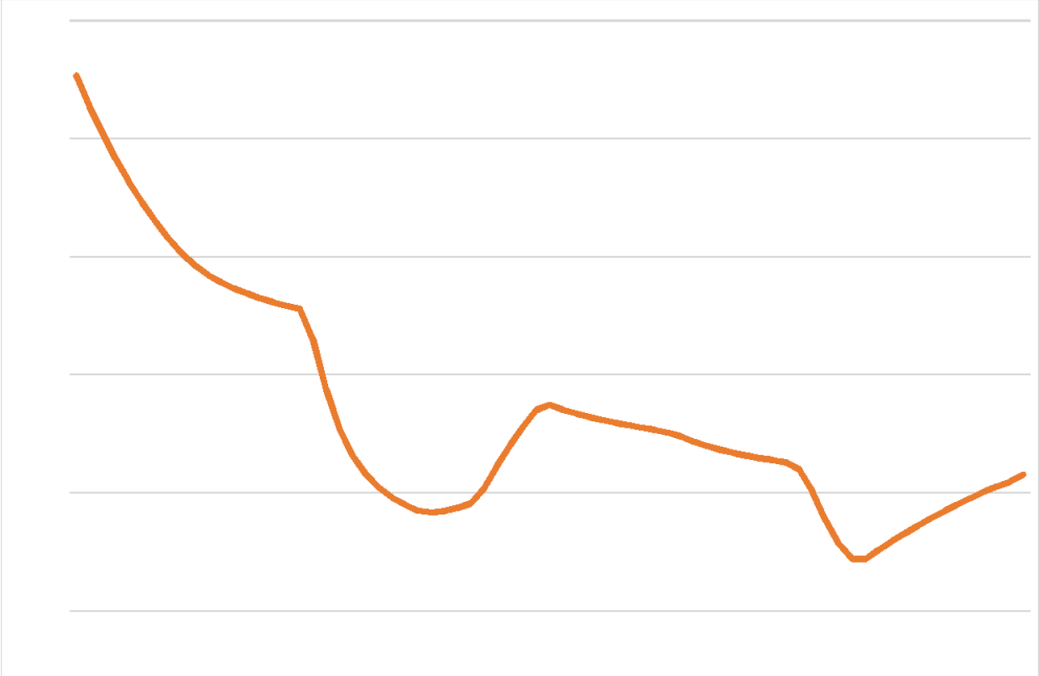

Fig. 3. Share of women in the total population of the UAE[23]

If in 1950 the share of women in the UAE was 47.7% of the total population of the UAE, in 2022 it was only 30.8%. For comparison, the global average in 2022 is significantly higher – 49.7%[24]. At the same time, the sex ratio at birth (males per 100 female births) in the UAE practically does not change (104 male births per 100 female births) and roughly corresponds to the world average.

Increasing urbanization also has a significant impact on decreased birth rates. Fig. 4 shows that the share of the urban population in the UAE increased from 73.5% in 1960 to 87.9% in 2022. Comparing this indicator with the dynamics of the TFR for the same period shows a significant negative relationship – the correlation coefficient is -0.78. Sure, the TFR is affected by a whole set of factors, but the level of urbanization is one of the main ones.

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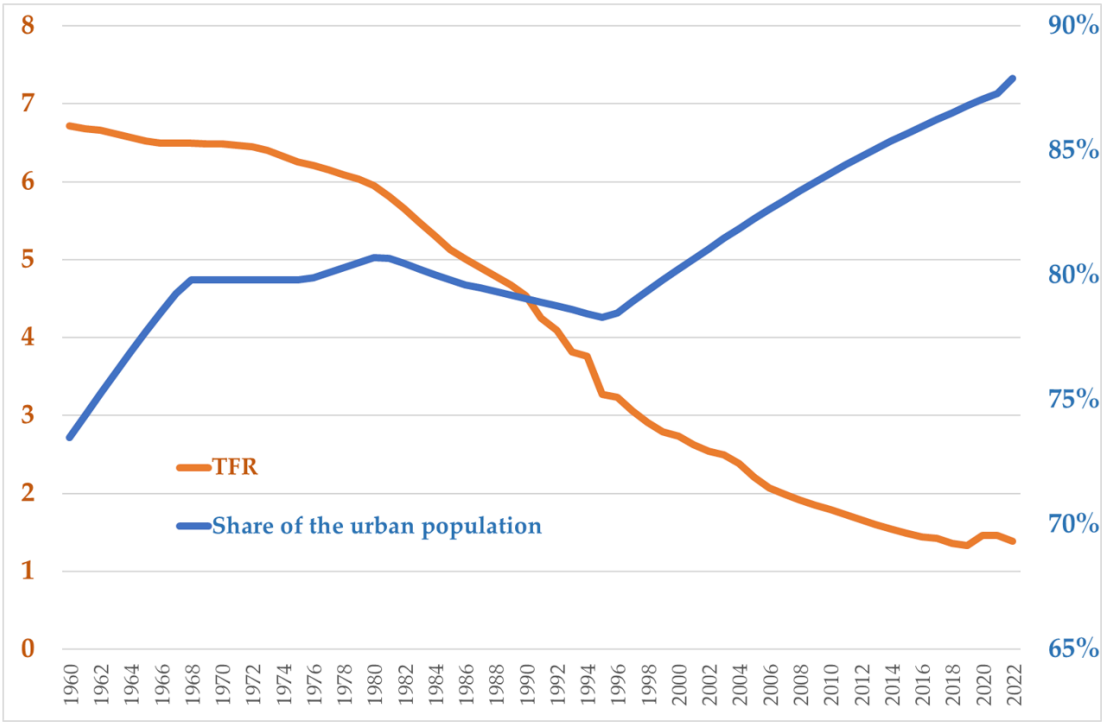

Fig. 4. Level of urbanization and TFR in the UAE[25]

The growing imbalance in the population of Dubai is also noteworthy. As can be seen from the data presented in Table 3, more than a third of the country's population is currently concentrated in Dubai, and this share has increased significantly in recent years.

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	1980	1985	1995	2005	2022
Abu Dhabi	*43.4*	*41.0*	*39.1*	*34.1*	*30.6*
Ajman	*3.5*	*4.0*	*5.0*	*5.0*	*5.3*
Dubai	*26.5*	*26.9*	*28.6*	*32.2*	*38.1*
Fujairah	*3.1*	*3.2*	*3.2*	*3.1*	*2.7*
Ras Al Khaimah	*7.1*	*7.0*	*5.9*	*5.1*	*3.6*
Sharjah	*15.3*	*16.6*	*16.7*	*19.3*	*19.0*
Umm Al Quwain	*1.2*	*1.4*	*1.5*	*1.2*	*0.6*

Table 3. Distribution of the UAE population by emirates, %[26]

The reasons for the growth of the UAE population are an increase in life expectancy and a decrease in mortality associated with an increase in the quality of medical care. Fig. 5 shows a comparison of key countries in terms of the overall mortality rate, which demonstrates a significant gap in favor of the UAE. Moreover, among 229 countries in the world, the UAE is second only to Qatar, where the value of the mentioned indicator is 1.42. It should also be noted that life expectancy in the UAE exceeds the world average by 7.38 years.

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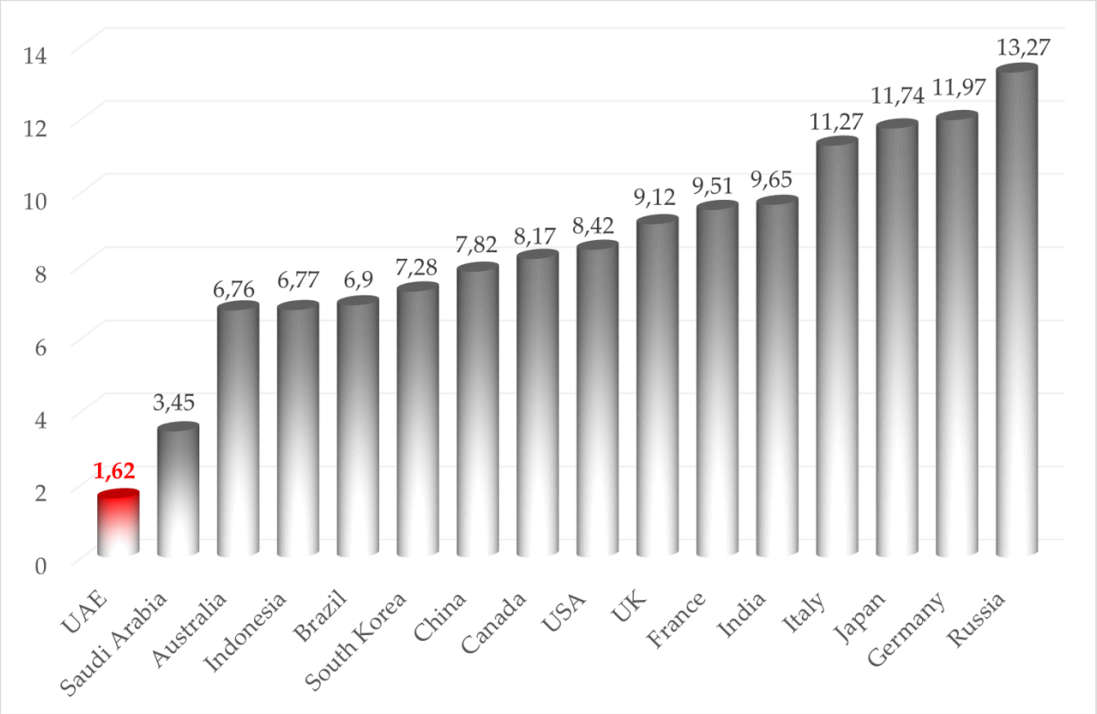

Fig. 5. Crude death rate for 15 key countries (number of deaths per year per 1000 people)[27]

The expectation of socio-economic crises is one of the factors having the greatest negative impact on birth processes. According to the report of the US National Bureau of Economic Research (NBER) based on an analysis of more than 100 million birth certificates over 20 years, the conception process is a key leading indicator of the crisis.[28] That is, people anticipating the impending problems decide not to have children. In this regard, the initiative of the UAE government to create a state body responsible for the level of happiness and improving the quality of life of the population seems very important and promising.

Measures to increase the birth rate

Now let's consider the successful foreign experience in increasing the fertility rate. The following measures are among the most effective ones:

1. Formation of value attitudes and motivation.
2. Financial support for families with children (various benefits, soft loans, tax preferences, etc.[29]).
3. Providing parents with flexible working hours and extended parental leave.

4. Ensuring the availability of childcare services[30,31].

5. Ensuring quality health care, access to assisted reproductive technology, and limiting abortion.

6. Providing affordable and comfortable housing.

7. Disurbanization and resettlement in rural areas[32].

It is very difficult to isolate the influence of any single factor. For example, a study by the Vienna Institute of Demography shows that one of the effective mechanisms of impact on the birth rate – financial support for families – is not permanent and does not work in all countries. So, for most OECD countries, a statistically significant correlation coefficient between these costs and the TFR for the period 2007-2013 was calculated, but for the crisis year of 2014 and subsequent years, the influence of other factors caused a decrease in the birth rate and the connection was broken. For the United States, this mechanism has never been decisive. The study of the Vienna Institute of Demography emphasizes that quantitative analysis carried out at the aggregate level often leads to erroneous results, and in this regard, it is advisable to use models that allow assessing effects at the micro level [33].

In February 2023, South Korean President Yoon Suk Yeol said that over the past 16 years about $200 billion had been spent on various measures to increase the birth rate (tax benefits, highly paid parental leave, construction of kindergartens, etc.). In addition, it is planned to increase monthly benefits for parents with children under 1 year by 3.3 times to $770 by 2024. The effectiveness of these measures turned out to be quite low – in 2012. The TFR actually increased to almost 1.3, but then fell sharply to 0.78 in 2022, which is one of the lowest rates in the world. Experts in the field of sociology consider the growing popularity of "liberal egalitarianism", which motivates women to build their careers, and not realize themselves in the family as one of the possible reasons[34].

The situation is similar in Japan, where the TFR is also quite low – 1.3. The government plans to increase the lump sum payment to new mothers from 420 thousand yen to 500 thousand yen, but this initiative caused negativity among the Japanese[35]. The fact is that payments are made through the state health insurance system of Japan after childbirth, which is paid from the mothers' own funds and on average exceed 470 thousand yen. Other measures taken in Japan to increase the birth rate are increasing the duration of maternity leave, compensating for part of the cost of childcare, providing free pre-school institutions[36]. However, these measures had almost no effect on the birth rate.

Experts attribute this to the increase in the number of Japanese women of fertile age who prefer building their career[37].

The government of Italy, where the birth rate is one of the lowest in Europe (TFR ≈ 1.27), in addition to financial incentives, provided for the provision of agricultural land to families with three children[38]. However, these mechanisms did not help to rectify the situation too.

In France, which has one of the highest fertility rates in Europe (TFR ≈ 1.87), public policy successfully combines several measures aimed at achieving gender equality, access to childcare services, financial support and improving the living conditions of families with children[39].

The UAE government's policy on promoting fertility among the indigenous population also included financial incentives for childbirth (a lifetime allowance of AED 600 per child) and marriage (payment of AED 70,000 to newlyweds and housing benefits), free education and health care. However, there was no significant effect from the implementation of these measures[40].

Based on the analysis of various studies and experience of different countries, the following main conclusions can be drawn:

1. Changing the birth rate is a complex process associated with the influence of many factors, including social pressure, the value system, financial support, the territory of residence (rural or urban), the level of education, demographic policy, the level of gender equality in society, etc.
2. The effect of government measures for fertility support has country-specific features, as well as is variable and decreasing over time.
3. Single measures of state policy in the field of demography do not bring long-term effect, while the simultaneous use of several mechanisms provides synergy and the best results.
4. To achieve the greatest effect, it is also important to coordinate public policy measures in the field of demography with decisions made in other sectors of the economy.

Demographic forecasting

The world's most cited organizations dealing with demographic projections are the Population Division of the Department of Economic and Social Affairs of the United Nations, the Institute for Health Metrics and Evaluation, and the Wittgenstein Centre for Demography and Global Human Capital in Austria.

Experts of the most authoritative source – the UN Population Division - put forward the postulate of the immutability of the three phases of demographic dynamics for all countries as the main hypothesis for population forecasting:

Phase I. High birth rate.

Phase II. Transition to low birth rate (logistic functions and Bayesian hierarchical models are used for forecasting).

Phase III. Stabilization and reaching the level of reproduction (autoregression models, Bayesian hierarchical models are used) [41][42].

At the same time, in our opinion, it is impossible to assert that these phases are mandatory for all countries of the world. Some countries (for example, France) have indeed reached the phase of conditional stabilization, but others (South Korea, Japan, etc.), despite the passage of the first two phases, cannot make the next transition.

As for the accuracy of demographic forecasts, the average deviation of UN forecasts for 10 years is 6%, for 20 years – 11%, and for 30 years – 15%[43]. Among the main reasons for the rejection of forecasts are the complexity of forecasting demographic transitions for a number of countries, urbanization, uneven income distribution, migration flows, etc.[44]

Interestingly, the research groups listed above point to the need to take into account the *heterogeneity of human society* in models for greater realism of the reproduced processes. In our work, we will use an agent-based approach, which, in addition to the heterogeneity of the individuals considered in the models, has some advantages:

1. The possibility of simultaneous assessment of mutually influencing processes – not only demographic, but also many other components of social, ecological, economic systems.
2. The complexity of the behavior of agents, the group behavior of which can generate bifurcations, and the model itself in this case will allow identifying the moment of onset of transitional moments that are difficult to identify by other methods (autoregressive models, etc.).

Review of agent models

Agent-based models make it possible to take into account changes in the operating conditions of agents (residents of the country) and differentiated mechanisms of influence on various population

groups. To date, there are many examples of using agent models to solve demographic problems, some of which are given below.

Researchers from Oxford University and the University of Southern Denmark built an agent-based model for South Korea, using which fertility processes were investigated. The model demonstrated a number of interesting results: (1) despite a decrease in parents' preferences for the birth of boys in the family (estimated by researchers at 30%), abortions depending on the results of sex tests have a significant impact on the sex ratio at birth (114 boys per 100 girls); (2) adaptation of this model for India showed similar results, but the sex ratio changed significantly less; (3) exogenous parameters of the model (access of agents to sex determination technology, preference for the sex of the future offspring, etc.) had practically no effect on fertility rates[45].

The agent-based model, developed by specialists from the Max Planck Institute for Demographic Research (Germany), the University of Bologna (Italy) and the University of Lund (Sweden), showed that depopulation processes usually begin in large cities and then spread to other territories[46]. It was also shown that the reproductive behavior of the most affluent part of society, defined by the developers as the "elite", gradually influenced other groups (farmers, workers, etc.).

Calculations based on the model built by researchers of the Pompeu Fabra University (Spain) and the University of Southern Denmark, in which the algorithm for making an agent's decision on the birth of a child on the example of Spain is considered very thoroughly, showed that the delay in this matter is explained by several main reasons: (1) increasing economic instability in the labor market; (2) the need to obtain additional education; (3) social interaction of agents, which affects their reproductive strategy[47].

An agent-based model developed by researchers from Harvard and Brown Universities made it possible to conclude that it is possible to promote fertility in Japan by transferring part of the work of men to a remote mode and supporting peers in their decision to have children[48].

UAE digital twin

Based on an agent-based approach, our international research group from China and Russia has developed a demographic model (SED-R) that is a digital twin of the UAE's socio-economic system – Digital UAE. We tried to reproduce the simulated society as accurately as possible, which made it possible to recreate the artificial society of the UAE.

SED-R model, a joint fruit of China and Russia research cooperation, which is able to simulate the international, national, and regional socio-economic system, as well as the UAE's socio-economic system. Currently, it can simulate the overall economic performance of each country or region among more than 200 countries. Each national model consists of micro-subsystem, meso-subsystem, and macro-subsystem. Micro-subsystem has complete, systematic, and abundant heterogeneous economic agents, including enterprises, banks, shops, and securities that provide products or services with different grades, residents with different preferences, and the government with different functional departments. Meso-subsystem comprises dozens of different industries and several markets, where commodities are exchanged between enterprises in different industries and between enterprises and residents through the corresponding market. Macro-subsystem affects on meso-subsystem and micro-subsystem through macroeconomic decisions and interact with every micro-economic agent. In the model, each simulation step runs for one day, which can run iteratively for more than 20 years. The current model has performed a large number of low-cost, low-latency, and near-reality simulations in thousands of segmented economic scenarios.

Each resident (agent) acts in a certain national economic system, subject to the macroeconomic decisions, population policy, and national economic development status of this country, so as the entire national demographicdevelopment. That is to say, each Digital UAE agent is a person residing in the UAE who is an instance of the relevant software class with a set of *characteristics:*

- gender;
- age;
- emirate of residence;
- home ownership;
- provision with medical services;
- level of education;
- number of children;
- income;
- type of reproductive behavior;
- social connections (a collection of agents that have a connection to a particular individual are meant).

The main software *methods* that implement the behavior of agents in Digital UAE are the following:

- family formation;
- childbirth;
- migration;
- death of the agent.

Fig. 6 shows a general scheme of Digital UAE operation that involves the software implementation of several stages.

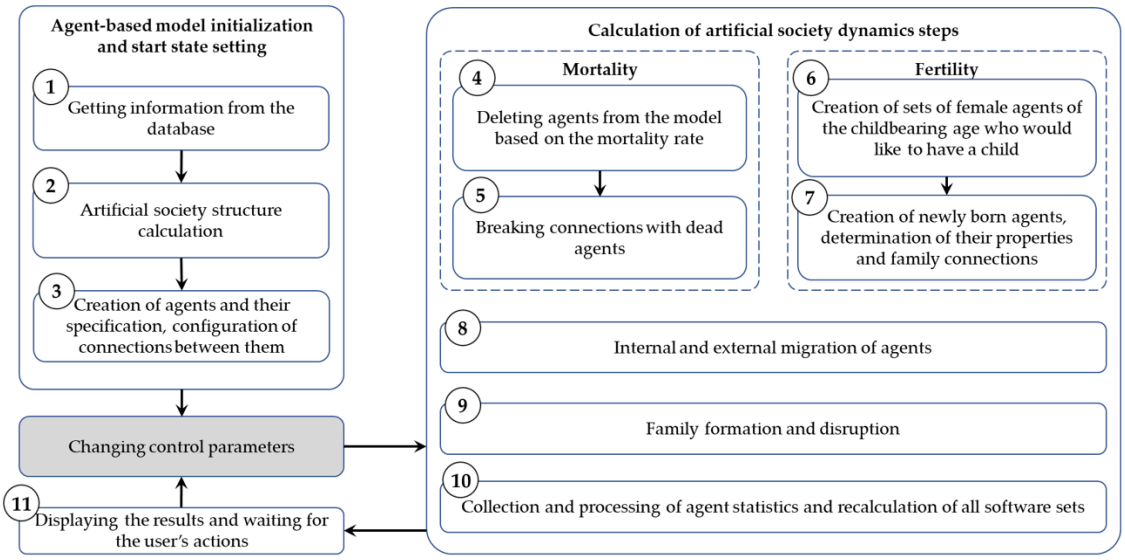

Fig. 6. Conceptual diagram of Digital UAE agent-based model operation [49]

Computer simulation consists of two main areas of work.

I. *Initializing the agent-based model and setting the start state*

Three main steps are implemented within the first block.

1. Reading information from the database and forming arrays in the program for further configuration of model agents.
2. Formation of artificial society structures, which consists in the selection of correct probability distribution functions for various properties of agents (gender, age, emirate of residence, income, etc.) under the macroeconomic decisions, population policy within the national economy from external artificial society. Properties are assigned to agents in such a way that the structures of the digital twin coincide with the structures of the real society.

3. Creation of agents, which involves the formation of instances of program classes. This step can be difficult in the case of implementing a parallel version of the model and running it on a supercomputer. The features of the development and launch of high-performance agent-based models have been discussed in detail in a number of publications[50].

   After the implementation of these steps, the model interface is displayed. It is an interactive map of the UAE. When its regions are activated, you can get demographic information about them as of the last reporting date (sex and age pyramid, TFR, number of births and deaths for a certain period of time, average age, etc.). After changing the control parameters, the system proceeds to calculate the next steps of the model simulation, which relate to several important blocks of work – simulation of mortality, fertility, migration and family formation.

II. *Calculation of artificial society dynamics steps.*

The *"mortality"* block includes the following steps:

4. Based on tables containing mortality rates differentiated for agents by gender, age, region and type of settlement, the probability of death for all Digital UAE members is calculated, and then, depending on the implementation of this event, either the relevant agents are removed or their age is increased by 1 unit (year).
5. In live Digital UAE agents, connections with deceased agents deleted in the previous step are destroyed.

   The *"fertility"* block includes the following steps:

6. Formation of collections of female agents of fertile age who would like to have a child. Such a decision is influenced by several factors (in addition to gender and fertile age): provision with housing, type of reproductive behavior, income, parental status of agents from their social group, as well as having their own parental status and type of settlement.
7. In the case of the "birth" event, the procedure for assigning values to properties (gender, region of residence, family ties, type of settlement, etc.), partially dependent on the properties of the parent agent, is triggered for the new agent.

   The "*migration"* block provides for the following steps:

8. In the case of moving to another region of the UAE, the agent retains all his connections, and when leaving the country for permanent residence in another country, the agent is

removed from the model (similar to the simulation of mortality).

And, finally, the block responsible for the dynamics of *family relations*.

9. With some probability (varying by age groups and regions), free agents can pair up if they are both over 18 years of age and the age difference is less than 20 years. In turn, existing couples may break up, and agents receive the status of "unpartnered".
10. Simulation of the UAE's socio-economic system, macroeconomic decisions and population policy in the future 5-30 years, with decision-making experiments and comparison analysis which consist in the selection of correct probability distribution functions for various properties of agents (gender, age, emirate of residence, income, etc.).

    After the simulation of the listed steps, the following occurs:

11. Collection and processing of statistics on agents, as well as recalculation of all software sets, and comparison analysis of different simulation schemes, so as to forecast the UAE's demographic development.
12. Displaying results on the screen and waiting for actions from the user. When conducting experiments, this step is automated: the cyclic conduct of multiple experiments is set, after which the results are averaged.

Since Digital UAE (SED-R) is a complex model with a large number of agents, we used Tianhe-2 supercomputer located in the National Supercomputer Center of the People's Republic of China for computational experiments. A separate task was the implementation of program code parallelization. To adjust the load between processes, METIS / ParMETIS algorithms were chosen[51], which are usually used to decompose large graphs (up to 10^9), computational grids and matrices. These algorithms allow dividing the graph of agents and the relationships between them into parts of similar size with the smallest possible number of relationships between the parts. Dynamic decomposition and redistribution of agents allows using thousands of processor cores of modern supercomputers[52].

Experiments

The UAE Government's demographic priorities include the following[53]:

1. Stimulation of fertility among the indigenous population.
2. Stimulating the labor market in favor of the indigenous population.
3. Stricter migration policy.

4. Life quality improvement.

Based on these priorities, we will form the following calculation scenarios, and we forecast their consequences until 2050. Digital UAE can provide calculations for longer periods, but we are limited by this time interval, since the quality of longer-term forecasts will be lower due to the dynamic nature of the modern world.

Scenario (1) *Disurbanization and uniform settlement of people throughout the country.*

The process of internal migration of people from rural settlements to cities has economic reasons: the development of trade and industry in cities, higher wages and quality of life. On the other hand, urbanization has a negative impact on the people's reproductive strategy and also poses an increased threat to national security in the event of terrorist attacks, epidemics, etc.

Increasing urbanization is a global trend. So, the size of the largest cities of China increased markedly[54]: the population of Beijing increased from 13.6 million people in 2000 to 21.9 million people in 2020; the population of Shanghai – from 14.2 million people to 24.9 million people, etc. According to forecasts, the population of the most densely populated cities in the world by the end of this century will reach 100 million. For example, it is expected that 88.3 million people will live in Lagos; 83.5 million people - in Kinshasa; 73.7 million people - in Dar es Salaam, etc.[55]

The same urbanization processes are taking place in the UAE – the share of the urban population in the country's population increased from 87.9% by 2022. The number of individual cities in the country is dynamically increasing. So, the population of Dubai increased from 354 thousand people[56] in 1985 to 3,621 thousand people[57] by now, that is, by more than 10 times.

For calculations using Digital UAE, it is assumed that the share of non-urban population will increase to make it get back to the values of 1960 (73.5%) by 2050. It is assumed that more sparse living of people will adjust their reproductive strategies in such a way that the TFR will return to the value of 2000 (2.74), the period before the acceleration of urbanization processes. The scenario considers smooth disurbanization and an increase in the TFR up to 2050.

Generally speaking, the process of disurbanization is complex, requires the development of production and infrastructure, the provision of incentive payments, etc. But at the same time, numerous risks of large cities (epidemiological, environmental, etc.), as well as the digital transformation of the economy, can catalyze the processes of disurbanization.

Some manifestations of the disurbanization process are currently observed. So, according to the Brookings Institution, during the pandemic, the population of 20 largest megacities in the United States of America decreased by 900 thousand people.[58] In 2020, VisaNet studied the activity of 6.5 million debit cards, namely expenditures in places where people lived in 2019-2020. It was found that migration from city centers to suburban areas increased significantly, which was also confirmed by the US Census Bureau[59]. There are estimates showing that the trend towards disurbanization in the USA began to manifest itself in the early 2010s, and the pandemic only consolidated this process[60].

Scenario (2) *Tightening migration policy.*

It has already been noted above that the share of migrants in the UAE is extremely high (88.5% of the total number in 2022), which may pose a threat to national security. Table 4 shows data on the world's largest migration corridors and shows that the UAE is in the top three, being a recipient country in relation to India.

1	Mexico → United States of America	10,853
2	Syrian Arab Republic → Turkey	3,793
3	India → United Arab Emirates	3,471

Table 4. The largest migration corridors between countries of departure and arrival, million people, 2020[61]

Within the framework of this scenario, Digital UAE simulated tightened migration policy in the UAE providing for a gradual reduction in the capacity of migration corridors and a decrease in the share of migrants by 2050 to 80% (2005 level), while stimulating the labor market in favor of the indigenous population.

Scenario (3) *Granting preferences to women.* Currently, the share of women in the UAE population, which is about 30%, is significantly lower than the world average. This scenario assumes a gradual increase in the share of women to 40% by 2050. This can be achieved, for example, through preferences in obtaining long-term visas for women of fertile age, including highly educated women

of interest to the country's economy. In other words, preference should be given to specialists in the field of science, education, innovation-active companies, etc.

Scenario (4) *Increase in the volume of medical services provided*. Table 5 shows data on health expenditures by individual developed countries. As you can see, in the UAE the share of health expenditure in GDP is significantly lower than that of most developed countries and the global average.

World rating	Counties	Indicator value
2	United States of America	18.82
6	Canada	12.94
7	Germany	12.82
10	France	12.21
11	United Kingdom	11.98
13	Switzerland	11.80
17	Austria	11.47
19	Norway	11.42
20	Sweden	11.38
22	Netherlands	11.14
23	Belgium	11.06
24	Japan	10.90
	World	**10.89**
...		
≈110	**United Arab Emirates**	**5.67**

Table 5. Current health expenditure by countries (% of GDP)[62]

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It should be noted that over the past 20 years it has grown significantly – almost by 2.4 times (Fig. 7). However, there is also potential for further growth. Increased government financing of health care can be an effective mechanism for increasing life expectancy and reducing mortality in the country.

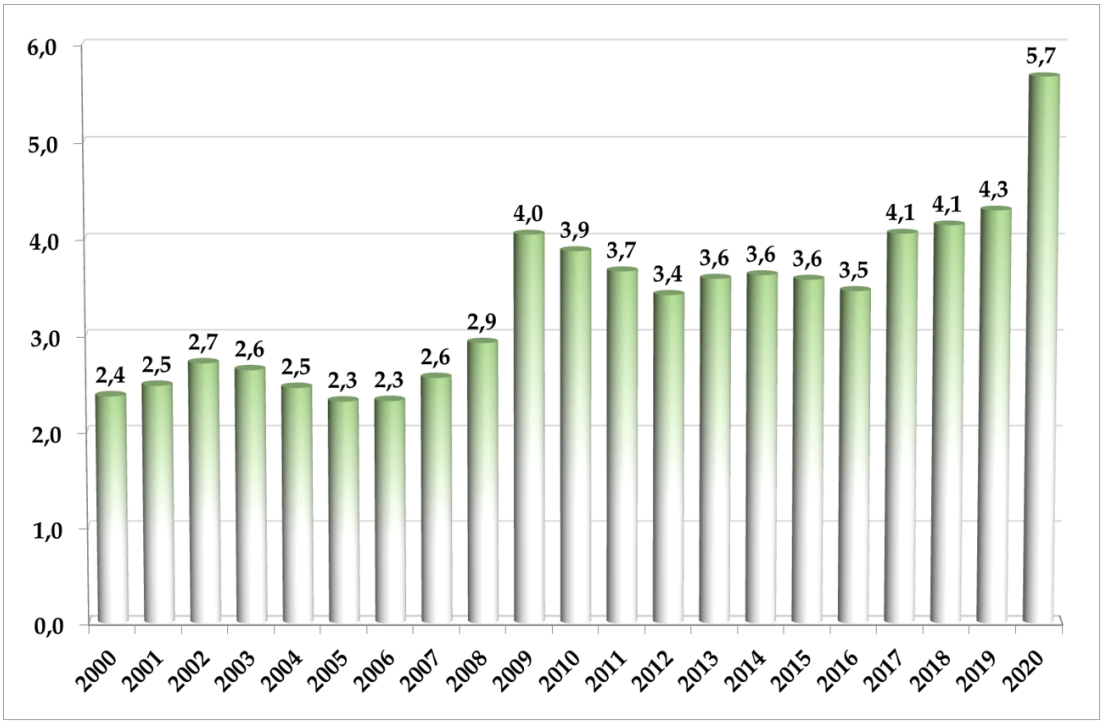

Fig. 7. Current health expenditure in UAE (% of GDP)[63]

Our assumption is that sensible macroeconomic decisions will improve the national economic situation, leading to an increase in healthcare costs, so that increased health care costs will contribute to saving and increasing the country's population. In the course of the experiment, this indicator gradually increases, and after 10 years reaches the world average level. In Digital UAE, rising health care costs affect the level of health care provision for each agent and, ultimately, reduce the likelihood of their death. Furthermore, high-quality medical care is one of the factors increasing the birth rate, and therefore, in the course of this experiment we assume an increase in the TFR by the current UAE's macroeconomic decisions and population policy.

Results

Using Digital UAE, calculations were carried out according to scenarios, which results allow comparing the effects of various population policy measures in the UAE (Table 6). In addition to the four scenarios listed above, the base-case scenario (No. 0) was also calculated. It assumes the inertial dynamics of UAE population taking into account the current birth rate, mortality rates, migration and without the implementation of additional measures.

doi.org/10.32388/NFZ2JG.2

Year	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4
2024	9,603	9,607	9,576	9,613	9,612
2025	9,647	9,655	9,581	9,662	9,663
2026	9,691	9,704	9,592	9,718	9,716
2027	9,768	9,785	9,636	9,794	9,799
2028	9,839	9,859	9,674	9,876	9,877
2029	9,910	9,935	9,709	9,952	9,957
2030	9,984	10,014	9,753	10,031	10,039
2031	10,061	10,094	9,798	10,116	10,123
2032	10,135	10,171	9,836	10,189	10,204
2033	10,207	10,247	9,874	10,274	10,283
2034	10,282	10,326	9,920	10,353	10,365
2035	10,360	10,406	9,966	10,438	10,450
2036	10,442	10,492	10,010	10,516	10,538
2037	10,528	10,579	10,060	10,613	10,631
2038	10,617	10,673	10,113	10,703	10,730
2039	10,709	10,768	10,169	10,799	10,830
2040	10,805	10,871	10,237	10,910	10,936
2041	10,905	10,974	10,303	11,020	11,044
2042	11,008	11,081	10,364	11,126	11,155
2043	11,115	11,193	10,433	11,235	11,271
2044	11,225	11,306	10,506	11,352	11,389
2045	11,338	11,423	10,583	11,471	11,511
2046	11,453	11,543	10,656	11,592	11,636
2047	11,571	11,665	10,736	11,715	11,763
2048	11,692	11,791	10,810	11,853	11,894

Year	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4
2049	11,816	11,920	10,895	11,980	12,028
2050	11,942	12,050	10,977	12,115	12,164

Table 6. Projections of the population in the UAE until 2050 in various scenarios, million people[64]

The results showed that in the long term all scenarios show population growth, but the effects of the measures differ significantly.

Compared to inertial scenario No.0, scenario No.1 (disurbanization) shows an additional population growth of about 100 thousand people over the forecast period. In turn, scenario No.3, which provides preferences for women, provides an even greater increase of 173 thousand people, and scenario No.4 (improvement of medical care) shows a maximum increase of 222 thousand people. As for scenario No.2 aimed at migration policy tightening, the results are also quite expected – the population will decrease by 965 thousand people compared to inertial scenario No.0, but the overall positive population dynamics will also be preserved.

So, the results of calculations confirmed our hypotheses that such measures as a more even resettlement of people, preferences in favor of women, and an increase in the volume of medical services provided have a positive impact on the population growth. In turn, the reduced capacity of migration corridors negatively affects the dynamics of the population, since the UAE is one of the main countries – recipients of the labor force.

The experiments carried out are only part of the possible design scenarios and demonstrate the potential of an agent-based approach for managing demographic processes.

Conclusion

Although the Digital UAE model demonstrated adequate results and wide application opportunities in the field of demographic management, its potential has not been fully unlocked.

The scenarios considered in the study provide for regulatory actions aimed at adjusting the demographic trend, but they also cover related issues in the economic, budgetary, educational,

environmental, transport and other spheres. By integrating and linking all these spheres within Digital UAE, it will be possible to assess the mutual influence of many social processes, which will significantly improve the forecast quality.

The authors have examples of such calculations. For such purposes, we successfully used analytics software – a simulator of socio-economic dynamics for more than 100 countries of the world (Social Economic Dynamics, SED model) developed by Guangzhou Milestone Software Co., Ltd with the support of the National Supercomputer Center of China and the Chinese Academy of Social Sciences. The SED model is used to calculate more than 3 thousand indicators.

In this regard, it is planned to assess the impact of the above and other scenarios (for example, the increase in the level of education of indigenous people) on the dynamics and structure of the UAE economy in the future using the SED model and Digital UAE. It is also planned to supplement these calculations with an assessment of the happiness index of model agents. In addition, since the SED model considers all countries of the Arab world, it is also planned to use it for relevant cross-country comparisons and analysis of migration flows.

Footnotes

[1] Source: World Bank database – https://data.worldbank.org

[2] Source: IMF database https://www.imf.org/en/Publications/WEO/weo-database/2023/April/download-entire-database

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[24] https://data.worldbank.org/indicator/SP.POP.TOTL.FE.ZS

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[63] Source: World Bank database – https://data.worldbank.org

[64] Calculated by the authors using Digital UAE.

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