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Original Article

Life Expectancy Forecast: Implications for Policy and Economy in Iran

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Abstract

Introduction: Forecasting health status of populations aims to explain the most likely future trends in health, such as the life expectancy trend. Life expectancy has grown notably during the past 150 years. Extended survival leads to population aging that is a world-changing event. Planning and investing in health and social services require anticipating future life expectancy and the corresponding drivers. As a developing country, Iran has experienced an improvement in health and longevity. This study aims to model and forecast life expectancy at birth up to 2035 and review the economic and policy implications of aging in Iran.

Methods: This study presents a dynamic simulation modeling of life expectancy and proposes a system dynamics model to give decision-makers an understanding of the interactions between different variables. The equations in the model are estimated using least-squares algorithms. The data are derived from the websites of "World Bank", "Our World in Data", and "United Nations Development Program."

Results: The computerized simulation results forecast that total life expectancy increases by about 4.5 years from 2018 to 2035, reaching 81.06.

Conclusion: Although improvement in life expectancy is a success and a key goal of a health system, it also suggests a rapid pace of aging in Iran with many social and economic challenges in managing the upcoming situations. However, executing appropriate policies can convert such threats into opportunities.

Keywords: Health trend, Socioeconomic system, System dynamics model

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Introduction

The intention of forecasting the health status or disease episode is to prepare for future events. It is a preventive medicine or preventive care that engages public health planning and requires taking the necessary measures to manage the peaks or extreme events (1). It also helps explain the most likely future health trends (2), such as life expectancy and health expectancy trends.

The future of human survival has attracted renewed interest in recent decades (3), with life expectancy showing noticeable increase during one and half a century ago. This success story seems to be never-ending. In the 1980s, many believed there was little potential for progress, but they were wrong. Still, it seems unlikely to believe this can persist forever (4). Increased survival causes population aging, a world-changing event with profound impacts on future generations (5).

Population aging is defined as "the process by which older individuals become a proportionally larger share of the total population" and is often measured "by increases in the percentage of elderly people in the retirement ages" (6). The population of many countries might undergo dramatic changes in the coming decades due to continuous increases in life expectancy (7) and declining fertility. This global phenomenon will certainly foster many challenges in the 21st century. Globally, life expectancy at birth increased from 66.5 years in 2000 to 72.6 years in 2018.

Projecting and exploring potential patterns in future life expectancy has been gaining ground among researchers. "How long will I live?" is a question of enduring interest to patients, physicians, public health officials, actuaries, and policymakers (8). Policymakers, service planners, and clinicians need reliable forecasts of future trends in life expectancy and the burden of disease and disability (9). Life expectancy estimates have profound economic, political, and social implications, so they are subject to significant scrutiny (10).

How long we live and what proportion of that life is spent in good health have important implications for individuals and societies (11). The significance of predicting how long an individual is expected to live is notable (12). Life expectancy and its changes are crucial for anticipating and planning for changing the age structures, resource and long term healthcare, environmental and economic landscapes, society, private-sector annuities, and government as they affect, among others, the old-age dependency ratio, social security, as well as pensions, insurance industry, disability benefits, and healthcare systems (13, 14).

Recent reforms in the pension systems in Europe, which were necessary to ensure pension sustainability, have made the link between pensions and life expectancy changes more prominent than ever (15). For example, improvements in longevity in the French prospective life tables in 2006, from the previously used tables from 1993, resulted in an average 8% increase of reserves by French insurers (16). Changes in life expectancy projections have significant consequences. Since forecasts are used in economic and social planning, these choices should be made carefully.

Iran is one of the developing countries whose population is experiencing an improvement in health and longevity, and statistical indices indicate the aging trend in Iran. Life expectancy at birth increased from 70.1 years in 2000 to 76.4 years in 2018, representing an average annual gain of 0.35 years. Also, the population of the elderly above 65 years reached 6.2% of the total population in 2018, and Iran is expected to outpace other countries. The speed of aging in Iran is truly remarkable; its population of 65-year-old and above will triple in 26 years (2023–2049) compared to 157 years in France, 100 years in the UK, and 89 years in the US (17). Besides, the fertility rate in Iran has experienced a sharp decline in recent decades (18). These changes in the population's demographic structure impact the society profoundly.

Since health policies have been exposed to particular scrutiny in the context of the millennium development goals (MDG), it seems reasonable to take an interest in health forecasting. The issues raised and research conducted call for an urgent need to investigate and project Iran's population aging and its implications for national policies and decision-making processes. In this regard, this study aims to model and forecast life expectancy at birth up to 2035 and review the economic and policy implications of aging in Iran.

Health forecasting is a dynamic process and requires frequent updates enabled by novel techniques and data (1). From about the 1980s, a growing number of techniques for forecasting life expectancy became available (19, 20). Social and biological scientists, economists, demographers, and many researchers from other disciplines (12) have proposed new approaches to project mortality rates and life expectancy for different populations and regions, for example with the use of life table methods (21), lee carter model (22), and time series analysis (23).

The social, economic, health, cultural, and political consequences of higher increases in longevity are highly significant; accordingly, it is a top priority to develop more powerful forecasting methods (24). This study presents a dynamic simulation modeling of life expectancy in Iran and proposes a system dynamics (SD) model to allow decision-makers to understand the interactions between different variables. Despite the notable interdisciplinary application of the SD method, the present study is the first attempt to apply this method to model future trends in life expectancy in Iran.

Section 2 presents the method, and Section 3 elaborates on the results. Discussion and conclusion are presented in Sections 4 and 5.

Methods

System Dynamics Method

SD have been applied to multiple issues ranging from corporate strategy to diabetes, from the Cold War arms race between the US and USSR to the combat between HIV and the human immune system. This method can be applied to any dynamic system, with any time and spatial scale. In business and public policy, SD has been applied by various sectors, such as the aircraft or processing industries, and different issues, including AIDS and welfare reforms (25). Notably, the SD approach is increasingly gaining recognition as a powerful method for understanding and addressing complex health issues (26).

In the SD thinking approach, loop thinking views causality as an ongoing process, with effect feeding back to influence the causes and the causes affecting each other. This skill can complement the classical approach of straight-line thinking (27).

SD has three general steps: articulation of the problem or conceptualization, dynamic hypothesis formulation, and testing and analysis (28, 29).

Data and Model

In this study, SD model based on computer simulation is used to estimate life expectancy performance in Iran. It involves the relationships and interactions between society, the economy, and health. Among several simulation methods, this

Table 1: Variables

Variables	Label
- Life expectancy at birth (total)	LEB
- GDP per capita (current international $)	GDPC
- Health expenditure per capita (current international $)	HEPC
- Liberal Democracy index	DEM
- Literacy rate (% of adults above 15 years old)	LIT
- Urban population (as a proxy of urbanization)	URBP
- HDI index	HDI
- Population aged 65 and above (% of the total population)	POP65
- Government expenditure on education (% of GDP)	GE

approach is practical for socioeconomic systems.

The first step, selecting the key variables of the SD model and identifying causal relationships among them are based on the review of previous studies and theoretical concepts. The availability of data is also considered when identifying the key variables. The variables are listed in Table 1.

The data for the years 2000 to 2018 are derived from the websites of "World Bank" (30), "Our World in Data" (31), and "United Nations Development Program" (32).

Descriptive statistics of the variables are reported in Table 2.

In the second step, each variable incorporated in the integrated causal relationships should be represented in the dynamic diagram. If the relationship between the variables is not pre-established, the equation will be obtained from the historical data (33). A set of equations was defined, and the relationships between the input and output variables were estimated to describe the dynamics of a socioeconomic system. The simultaneous consideration of these equations assists in understanding the whole dynamics of the system.

The equations were selected using ordinary least-squares algorithms, the statistical R^2, adjusted R^2, t-statistic, and F-test. Additionally, the forecast errors had to be calculated. The relationships with fewer errors were regarded as eligible. The SD model for simulating life expectancy is shown in Figure 1. Substantial estimated equations of the model are presented as follows. ln is the natural logarithm,

*In(LEB)=3.3081+0.1226*In(LIT)+0.0142-In(HEPC)+0.24*DEM+0.4283*HDI* (1)

t-statistic: (17.47) (2.53) (2.03) (3.55) (7.98)

R^2: 0.9910 $\bar{R}^2$: 0.9885 F: 386.62 (0.0000)

*In(HEPC)=-3.282495+0.5136*In(GDPC)+3.2033*In(POP65)* (2)

t-statistic: (-2.47) (3.37) (13.72)

R^2: 0.9505 $\bar{R}^2$: 0.9443 F: 153.55 (0.0000)

*In(GDPC)=10.4180+36.2542*In(LEB)+7.5118*In(LIT)-10.6934*In(URBP)* (3)

t-statistic: (1.70) (2.23) (3.21) (-2.35)

R^2: 0.6037 $\bar{R}^2$: 0.5244 F: 7.62 (0.0025)

*In(LIT)=-2.6804+0.017*GE+0.3698*In(URBP)+0.0486*In(GDPC)* (4)

t-statistic: (9.69) (2.42) (9.69) (2.21)

R^2: 0.9353 $\bar{R}^2$: 0.9224 F: 72.30 (0.0000)

The simulation time horizon of the SD model is 36 years, from 2000 to 2035. The software Vensim is used to simulate life expectancy performance in Iran. The validity test and analysis of the simulation are presented in the next sections. Life expectancy affects the economic growth through an increase in the investment in human capital. Health and education are the most important constituents of human capital (34).

Results

Simulation Result and Model Validation

Figure 2 displays the simulation results of life expectancy in Iran from 2000 to 2035.

Table 2: Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
LEB	73.4779	2.0770	70.176	76.479
GDPC	14348.89	2188.893	10300.53	18008.8
HEPC	1033.136	396.3861	510.0156	1758.991
DEM	0.1536	0.0141	0.1342	0.1829
LIT	82.34539	3.2166	75.6868	86.3
URBP	5.13e+07	5923135	4.20e+07	6.13e+07
HDI	0.7301	0.0458	0.658	0.787
POP65	5.1631	0.5459	4.4	6.2
GE	3.7940	0.5463	2.7973	4.5968

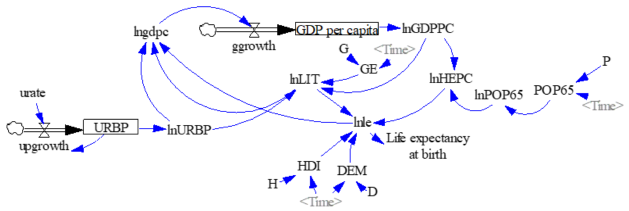

Figure 1: The dynamic diagram of simulating life expectancy

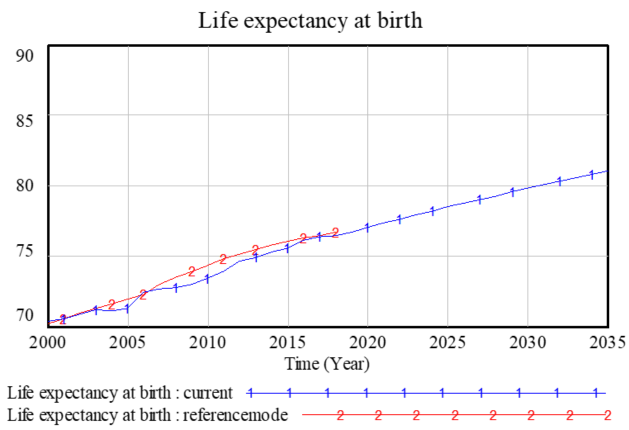

Figure 2: Simulation result of Life expectancy

Real values (reference mode) and simulated values (current) of life expectancy are provided. The forecasts of the present study suggest continued progress in improving life expectancy. The total life expectancy will reach 81.06 years by 2035.

The performance or accuracy of the forecast can be empirically assessed by withholding data from recent periods and comparing the forecasts generated without these data with what actually happened. Nonetheless, even forecasts based on models with optimum out-of-time performance cannot anticipate all future drivers of health change (2). It should be noted that determining future health trends or situations involves uncertainty to some extent, as it is practically impossible to have an error-free prediction.

Model Validation

Firstly, it is necessary to test the accuracy and feasibility of the SD model. This can be done by obtaining a match between the simulated results (SR) and historical data (HD) of the variables in the system. To validate the SD model, was set the time horizon for the variables to 19 years, from 2000-2018. The matching results of the variables of LEB, LIT, ln(GDPC), and ln(HEPC) were selected for demonstration of the SD model validation.

The matching results are shown in Table 3, in which the simulated values of variables are greatly close to the real values, with very low relative errors, indicating the high validity of the SD model. Therefore, the established SD model is reliable for representing the causal feedback relationships among the variables and simulating life expectancy.

Simulation Scenarios

The SD models allow for obtaining relevant simulation results and formulating appropriate policies by adjusting the variables and parameters based on different scenarios. In this study, three

Table 3: Verification with historical data

Year	LE			LIT			ln(GDPC)			ln(HEPC)		
	HD	SR	error%	HD	SR	error%	HD	SR	error%	HD	SR	error%
2000	70.17	70.33	0	75.68	75.91	0	9.24	9.24	0	6.23	6.21	0
2001	70.55	70.54	0	76.34	76.61	0	9.25	9.26	0	6.33	6.29	0
2002	70.92	70.89	0	77.00	77.80	0.01	9.33	9.28	0	6.31	6.37	0
2003	71.26	71.17	0	78.81	78.30	-0.02	9.42	9.31	-0.01	6.48	6.38	-0.01
2004	71.59	71.14	-0.01	80.62	78.87	-0.02	9.47	9.33	-0.01	6.53	6.46	-0.01
2005	71.91	71.28	-0.01	82.44	79.20	-0.03	9.52	9.35	-0.01	6.62	6.54	-0.01
2006	72.25	72.39	0	82.33	80.16	-0.02	9.59	9.36	-0.02	6.67	6.55	-0.01
2007	72.62	72.7	0	82.64	81.28	-0.01	9.68	9.39	-0.02	6.72	6.63	-0.01
2008	73.02	72.72	0	82.96	81.03	-0.02	9.70	9.42	-0.02	6.78	6.71	-0.01
2009	73.45	73.02	-0.01	83.12	81.61	-0.02	9.70	9.44	-0.02	6.99	6.72	-0.03
2010	73.90	73.39	-0.01	83.29	82.09	-0.02	9.76	9.46	-0.03	7.08	6.79	-0.04
2011	74.35	73.94	0	83.46	82.46	-0.01	9.79	9.48	-0.03	7.09	6.92	-0.02
2012	74.77	74.64	0	83.62	82.70	-0.01	9.67	9.5	-0.01	7.02	7	0
2013	75.16	74.91	0.01	84.62	83.29	-0.01	9.63	9.52	-0.01	6.92	7.07	0.02
2014	75.50	75.31	0	84.70	83.59	-0.01	9.63	9.54	-0.01	7.10	7.14	0
2015	75.79	75.53	0	85.12	84.28	-0.01	9.51	9.56	0	7.20	7.26	0
2016	76.04	76.13	0	85.54	85.82	0	9.54	9.59	0	7.45	7.33	-0.01
2017	76.27	76.41	0	85.9	87.20	0.01	9.58	9.61	0	7.74	7.39	-0.04
2018	76.47	76.45	0	86.5	88.19	0.02	9.53	9.64	0.01	7.43	7.51	0.01

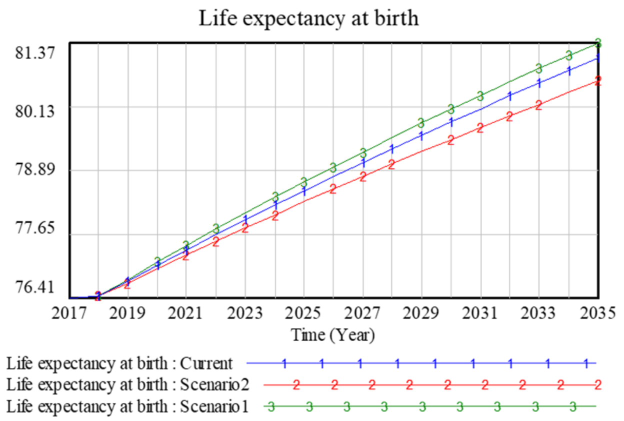

Figure 3: The simulation results of life expectancy scenarios

scenarios were considered based on different economic growth rates as economic growth is an influential factor with relative uncertainty. The current scenario is that the current economic growth rate of 2% is maintained. In scenarios 1 and 2, the economic growth rates are assumed to be 5% and -1%, respectively. By 2035, life expectancy will have reached 81.06 in the current scenario, 81.8 in scenario 1, and 79.95 in scenarios 2. The result of the simulation of three scenarios is provided in Figure 3. It indicates that an increase in economic growth rate improves the life expectancy and vice versa.

Discussion

As expected, the results of this study indicate considerable improvement in life expectancy; thus, Iranian population is ageing in coming decades. Likewise, the studies of Khang et al., (22), Foreman et al., (2), and Kontis et al., (21) have predicted improvements in life expectancy for other populations.

Policymakers rely on population projections to guide long-term investments and plans for future food, water, and energy demands, as well as services, such as health care and education. Fundamental reforms in welfare policy have been taking place in many countries due to forecasts of an increasing life expectancy and elderly population (35). Iran needs to take more serious measures in this regard as well. Since many choices have long lag periods between initial investments and coming to fruition, for instance, training in different medical specialties, health system infrastructure construction, and health insurance (2), it seems crucial to consider these alarming projections in Iran. Moreover, it is required to adapt to many aspects of life, such as the lifestyle and how people work, to overcome demographic transition challenges.

The population of retirees is increasing by decreasing mortality of persons above the pension age, while the size of the economically active population relative to that of the aged population is reducing. The public pension system remains a major driver of costs in many countries, including Iran. During recent decades, improving future life expectancy has been underestimated, meaning that current pension plans are under-financed. Pension funds are one of the most important areas exposed to damage due to the increase in life expectancy in Iran. Therefore, it is necessary to redesign the national pension systems that adapt to the aging process. Redesigning public pension systems has increasingly been directed toward creating financially sustainable schemes, such as public life-cycle savings and demographic transition plans (4).

Furthermore, as the world population is aging, many countries find the consequent demand for healthcare services challenging. The social care needs of older adults (i.e., aged ≥65 years) are driven by their inability to self-care and live independently (36). One of the challenges faced by Iranian families will be providing care for elderly.

Any major demographic change poses challenges which can undermine the potential benefits of higher longevity, if ignored. The effects of population aging are not straightforwardly predictable, as the phenomenon raises some serious and fundamentally unseasoned challenges that, although seemingly overwhelming, are surmountable. These changes also can present some new opportunities to individuals and society because people experience longer, healthier lives, resulting in increased human capital and extended working years (37).

Any forecasting study is subject to several limitations and extremely challenging. In the present study, many factors excluded from the models could change the nature of the future life expectancy trend. Moreover, due to the availability of data, the time horizon of the estimations is limited. The proposed model was performed well from 2000 to 2018; however, similar model performance cannot be ensured in the coming years.

Conclusion

Based on computerized simulation results, it is forecasted that the total life expectancy with about 4.5 years increase from 2018 to 2035 will reach 81.06 in Iran. Although this is a success and a key goal of the health system, it also suggests a rapid pace of aging in Iran that is a feature of low and middle-income countries and threatens the social and economic performance of the nation in the upcoming years. Iran should plan, implement appropriate policies, and take necessary measures to benefit from this demographic shift to overcome its current and future economic and social problems.

Conflict of Interest: None declared.

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