Dynamic analysis of health-related factors with its impacts on economic growth

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Abstract

The largest capital of a country is its human resources. Given that Iran is one of the richest countries in terms of human resources, economic growth of the country depends upon the performance and efficiency of its human resources. Special attention should be paid to the health of the society, especially the workforce. Health is one of the factors that can play a major role in enhancing productivity by reducing staff absenteeism due to illness as well as increasing concentration of staff, improving performance and ultimately enhancing staff productivity. It can provide for better and better production and services in the country, followed by growth and prosperity. The purpose of the present study is to investigate the impacts of health-related factors on economic growth of the country. Because of the complexity of the problem, we have used system dynamics approach to model problem. The model was simulated using VENSIM computer software, and the results showed that by increasing the per capita exercise among the people of the country as well as improving the nutrition habit contribution to the long-term economic growth of the country while improving the country's health can occur.

Keywords Dynamics · Health · Economic growth · Human resources · Productivity

1 Introduction

The health of society has a direct and indirect impact on the country's economic growth. The physical and mental health of a factory working person will increase the efficiency and quality of his/her work. As a result of that, the factory will generate more sales through producing quality products on a timely manner. This will lead to the country's economic growth and prosperity. As Alavi Rad et al. [1] stated in their research, it can be said that economic growth contributes to better health and then better health leads to better economy. In most societies, community health requires economic growth and sustainable development, because a healthy society directly

affects the physical, mental and social performance of the community.

Although we know that health affects economic growth, it is not clear to what extent factors affecting health can affect economic growth. That is, identifying the factors affecting health and how it can influence health structure and the configuration, at first glance, should be examined and then determine to what extent these factors alone affect economic growth.

Due to the fact that the health of a society as well as its economic growth are two important issues, many researchers are attracted to this research area. Onisawa [2] examined the health effects on Nigeria's economic growth. The results of this paper show that GDP is positively influenced by long-term health indicators and that

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health indicators have a long-term impact on economic growth, so health impact is a long-term phenomenon [2]. To demonstrate the long-term impacts of health factors on the GDP indicator by taking most of the key variables of the system into consideration, one may use system dynamics computer simulation. This is the approach that these authors have employed for showing the simulation results of such impacts.

Although some researchers have devoted their work to this study, few have considered the impacts of health-related factors on economic growth taking GDP and GDPH into consideration. Beyond that, due to the complexity of the problem these authors have employed system dynamics approach for modeling and simulation to demonstrate the economic growth indices by durations.

The rest of article is organized as below. Literature review is the topic of Sect. 2. The objectives of this study are described in Sect. 3. Section 4 is devoted to system dynamics modeling while formulation and validation of the model is the topic of Sect. 5. Scenarios are discussed in Sect. 6. Sections 7 and 8 are devoted to the analysis of results and conclusion of the article, respectively.

2 Literature review

System dynamics (SD) is a powerful methodology for looking into the complex problems such as health and economic combined to study dynamics behaviors of concerned indices of the problem. Researchers indicated that if a system under study is static and in need of optimization and having no feedback loops in its structuring, then optimization is the best technique to be used. Such condition rarely is true about the health and economic problem combined. The system used in this study is dynamic and comprising of many feedbacks. Therefore, system dynamics become the best possible choice for dealing with this problem. In their paper, David Cook and colleagues [3] introduced a system dynamics modeling for the health sector. The population growth in Alberta, Canada, has driven demand for health services to rise sharply. The results of that study show that the system dynamics approach provided many successes for Alberta's health sector strategic planners [3].

Bloom et al. [4] mentioned that: "our results indicate that health has a positive and statistically significant effect on economic growth. They also mentioned that a 1-year improvement in a population's life expectancy contributes to a 4 percent increase in output". Zare Mehrjerdi [5] presented a research aimed at providing a dynamic model for studying the relationship between human weight and health problems. In this paper, causal links that provide interrelationships between weight gain and health

problems are discussed. Subsequently, a flow model was constructed from this problem and mortality from heart attack was studied under both regular and trained conditions. This article illustrates the general health problems associated with weight using causal loops. The study found that educating people about their health had a significant impact on the number of deaths from heart attack. This article plays an important role in health study issues because it shows how a factor such as weight can affect heart attacks, hypertension and blood glucose [2]. Zare Mehrjerdi [6] has proposed a system dynamics approach to healthcare cost control. In this article, author shows that how key factors such as weight, eating habit, body fat, take-in medications and drug issues have impacts on the health of the people.

Heydari et al. [7] examined the relationship between social capital and health capital as well as their relationship to economic growth. This study was conducted for Middle Eastern countries using panel data between Years 1990 through 2010. The results of this study showed that health capital and social capital are effective on economic growth and that the promotion of self-help and subsequently public support fosters growth [7]. In his research, Onisanwa examined the health effects on Nigeria's economic growth. The results of this paper show that GDP is positively influenced by long-term health indicators and that health indicators have a long-term impact on economic growth, so health impact is a long-term phenomenon [2].

In their paper, Narayan et al. [8] investigated the relationship between health and economic growth through investments, exports, imports and research and development for 5 Asian countries, namely, India, Indonesia, Nepal, Sri Lanka and Thailand using panel data. The results of this study showed that in all four growth models, the variables have a long-term relationship; thus, they overlap. And that in the long run, while health, investments, exports and R&D have led to positive economic growth, imports have had a negative statistical effect [8]. Thoa et al. [9] conducted a study to examine how healthcare was used when changing economic conditions at the family level. In many developing countries, including Vietnam, indirect payments are the main source of health financing. Economic growth widens the gap between rich and poor in many aspects, including the use of healthcare. In this paper, panel data from 11,260 households in rural Vietnam were used. The result was that households with higher economic growth spent less on healthcare spending. In other words, households that were economically better off were less likely to use the health system [9]. Ghoraihi and Alavi-Rad [10] examined the relationship between health factors, economic growth and development. Economic development increases the income available to

people in the community, thereby improving the health of individuals. The results of this article show that increasing healthcare expenditures, per capita health spending and life expectancy will drive economic growth because people with better human abilities will be able to work and earn a living, resulting in higher growth rates [10]. Babakhani [11] examines the relationship between economic growth, income inequality and health in Iran during the Years of 1978 to 2006. In this research, the required data were obtained from the Iranian Statistical Center and analyzed by SPSS software. The results show that simultaneous attention to economic growth and reduction in income inequality is essential for improving health [11].

In a study, Lotfalipour et al. [12] use the Foucault-based growth model and the three-stage time equation and the three-stage least squares method, examined each of the human capital effects on the growth rate of income over a period of 61 years till 86 years. Investing in human resources and promoting it has the potential to increase human capital. Although a proper health can increase power. This will eventually lead to increased birth and growth. Finally, this paper showed that human capital and investment in human resources are significantly influenced by growth rates of 99% and 90%, respectively. Hypotheses and Truths in a research using time series for 1971–2012, we examined the impact of investment on human health and per capita income growth rate in Iran. Analysis was performed using ARDL model by MICROFIT software. The findings of the study showed that the gross impact of health care on economic growth depends on the relationship between physical capital and health levels, because over-investing in people's health may have a negative impact on economic growth. The results of the research on Iran showed that the impact of investment on the health of the workforce is far less than the impact of investing in physical capital on economic growth. In general, the short-term health growth rate has a significant impact on the economic growth of the country [12]. Najafi et al. [13] have concentrated on the integration of lean thinking in sustainability analysis of healthcare system using system dynamics approach.

In his thesis on the empirical study of health expenditure and economic growth for 14 provinces in 2001–2009, Rastegarnia [14] used linear regression with multiple regressors, multiple regressions and multidisciplinary approaches. The results showed the positive effects of construction costs, health costs and employment on economic growth. Faezipour and Ferreira [15] have concentrated on the healthcare system challenges with regard to the resources diminishing and demand increasing. Authors employed system dynamics approach to determine patient satisfaction in healthcare. A causal model is

the result of this article making it a good start for future researchers to work on the subject matter.

3 Objectives of the study

The objective of this research is the development of a dynamic model that can help to determine the effect of health-related factors on GDP and health-related GDP (GDPH) when changes in scope of the problem occur. For this purpose, systems dynamics would be used as a tool to understand the interrelationships between the key variables of the problem and GDP performance taking policy improvement into consideration. More specifically, we can identify following list of objectives for achieving the overall goal of this study: (1) identifying health-related factors within the health-economic system taking the principles of systems thinking into consideration; (2) generating the causal loop diagram for the health-economic model of the problem using identified variables from 1; (3) flow diagrams construction; (4) developing the mathematical formulation of the problem within Vensim scope of formulation design; (5) model simulation using predefined values for the parameters and initial values for the state variables; and (6) developing scenarios and analyzing the results (Table 1).

4 System dynamics modeling

System dynamics (SD) is a tool making the simulation of the dynamic model of the problem with feedback loops possible. This sort of dynamic modeling ponders all variables within the domain of study, known as system's boundary, into consideration. System dynamics allows us to look for the behavior of goal variables in the system that is known as state variables. More details on this sort of modeling are given in the sections that follow.

4.1 Model border diagram

The model boundary diagram is usually represented as a table containing endogenous, exogenous and omitted variables. Each of these three sets of variables is listed separately in Tables 2, 3 and 4, respectively.

4.2 Simulation steps

The steps to execute a project using the system dynamics approach are as follows:

1. Identify and define the problem.
2. System conceptualization.

Table 1 Research background focusing on the solution approach

Numbers	References	Research goal	Effective factors	Solution approach	Results
1	Babakhani [11]	Investigating the relationship between economic growth, income inequality and health	GDP, Gini coefficient	Correlation and regression tests (SPSS software)	Concurrent attention to economic growth and reduction in income inequality is needed to improve health
2	Heidari [7]	Investigating the relationship between social capital and health capital and their impact on economic growth	Labor, physical capital and human capital	LS, 2SLS (least squares)	Social capital and health capital affect economic growth
3	Rastegarnia [14]	Investigating the relationship between health expenditure and economic growth	Costs of construction, health, employment, number of doctors and number of pharmacies	Linear regression	Health and employment costs have a positive effect on economic growth
4	David Cook et al. [3]	Evaluation and improvement in health technology	Age, population, risk factors and capacity of health systems	System dynamics	System dynamics modeling provides many successes for Alberta's health sector strategic planners
5	Fareq and Zare Mehrjardi [16]	Identification of factors affecting medical tourist attraction	Historical works, proximity to high-income countries, public safety, health system level	System dynamics	The effect of factors affecting the development of therapeutic tourism can be seen over a period of 4 years
6	Lotfali Pour et al. [12]	The impact of health indicators on economic growth	Labor force, education, skills, migration, healthcare costs, mortality rate, etc.	Simultaneous equations and least squares method	Human capital health and health investment at significant levels of 0.99 and 0.90 have a positive effect on the per capita income growth rate
7	Narayan et al. [8]	Investigating the relationship between health and economic growth through investment, export, import and R&D for 5 Asian Countries	Health, Investment, export, import, R&D and...	Combined data (panel)	In the long run, while health, investment, exports and R&D have a positive effect on economic growth, imports have a negative effect on economic growth

Table 2 Endogenous variables of the present model

Variable name	Explanation	References
GDP rate	It is one of the most important indicators of economic growth in a country	[2, 17, 18]
Manpower	The number of workforce that can directly affect the economy of the country	[19]
Employment	People from different parts of society	[14, 20]
Unemployment rate	Unemployment rate per unit of time	[21, 22]
National income	Total income of a country in different sectors	[23]
Per capita income	The total income is divided by the population of a country	[2, 11, 12, 17, 24]
Saving	The amount of money that remains after deducting the expenses from each person's income	[17]
Productivity rate	Workforce returns or efficiency	[25–27]
Sickness	Prevalence of non-communicable diseases	[18, 26]
Health infrastructure	Level of desirability in essential sectors of health	[18, 27, 28]
Useful per capita	The amount of hours a person works effectively during the day or week	[From the present research]
Health indicators	Criteria that improve and enhance them can have positive effects on community health	[18, 25, 29]
Life expectancy rates	An indicator that can help measure a person's health in a community	[2, 10, 26, 30]
Investing in the health sector	The amount of money spent by public or private sectors to improve the quality of health services and technology	[12, 14, 31–33]
Quality of health services	Level of progress in the field of medical equipment and improvement in therapeutic methods	[3, 31, 34]
Per capita exercise	The level of physical activity of the community workforce	[35]
Paying labor	The amount of costs that people in the community have to pay for treatment	[9, 27, 36, 37]
Liquidity	Money accumulation in the country	[38–40]
Population	The sum of individuals in a society or country	[3, 41]
Death rate	It is a measure that affects the population	[17, 26]
Birth rate	It is a measure that affects the population	[17]
Gap	Determining the difference between the target level and the existing level	[Outcome of the present study]

Table 3 Exogenous variables of the present model

Variable name	Explanation	References
Total labor costs health	Total healthcare costs of the country	[42, 43]
Lack of occupational health education	Level of education related to occupational health or safety issues for employees or workers	[44]
Unhealthy nutrition	Unhealthy nutrition, the most important cause of disease	[18, 45]
Air pollution	One of the most important causes of many diseases	[46]
Education	Education level of human resources of the community	[Present research]
Labor experience	The experience gained over many years can have a huge impact on one's job productivity	[Present research]
Work experience	Work experience is a factor to gain experience	[Present research]
Occupational incident	Physical accidents at work in the country	[Present research]
Goal	Specifies the range of variable values to use	[Present research]

3. Model formulation.
4. Model simulation and validation.
5. Policy analysis and improvement.
6. Implementation of the policy.

4.3 The dynamic hypothesis

In general, the hypothesis is the expression of the relationship between two or more variables that the researcher

Table 4 The variables omitted in the present model

Variable name	Explanation	References
Embargo	Although sanctions have a significant impact on economic growth in the country, this variable has been overlooked in this study because of the impact of health on economic growth	[47]
Inflation	Inflation is an economic variable that influences the growth of a country's economy, so it is ignored in light of the issue at hand	[48]
Interest rate	Since there is no need to use interest rate factor in the present study, this variable is ignored in the present model	[49]
Exchange rate	Many studies have cited exchange rate as a factor affecting the economy, but because of their lack of relevance to the subject of the present study, this variable has been omitted in the problem model	[23, 47]
Export and Import	In economic models, two factors are important for export and import, but because of the human health aspects of the economy, the use of such variables is out of the question	[8, 23]

Fig. 1 Dynamic problem model hypothesis

expects to prove through his/her study. Hypothesis is important because it is the starting point and foundation of any scientific research. One of the most important benefits of drawing a basic hypothesis is that it allows the reader to have a better and more accurate understanding of the complex model. In general, it can be said that the simplified hypothesis will be the conceptual model of the problem. Verbal description of dynamic hypothesis in addition to the causal diagram presented by Fig. 1, which is more customary for this type of research, can be stated as follows:

H1 Health and Hygiene indices lead to higher workforce productivity rate and growth in health-related GDP (GDPH), and the overall GDP of the country.

H2 Investing in health of the people leads to higher life expectancy and hence GDP grows.

H3 Better nutrition and more exercise is equivalent to more GDPH, and hence the GDP.

4.4 Cause and effect diagram

In the present study, it is attempted to explore the relationships between the variables of the model and then to model it by examining the relationship between the model variables utilizing the experts' point of view as well as researching and studying the field. Figure 2 shows the causal diagram of the problem taking interrelationships between the proposed variables into consideration.

Loop A starts with the health indicator variable and ends with the primary variable after incorporating the variables of productivity, productivity per capita, GDP and investment in the health sector. Loop B begins with the life expectancy variable and ends with the primary variable after variables such as mortality rate, population, number of workers, employment, GDP, health sector investment and health indicators. Loop C starts from the sport per capita variable followed by disease variables, productivity per capita, GDP, national income, per capita income, savings, health sector investment, health infrastructure, health service quality and people's pay.

4.5 Stock and flow diagram

Stock and flow diagram of the present problem contain six state variables. The first state variable is the population affected by the variables of mortality and birth rates. The second variable is unemployment, which affects the rate of employment and the number of manpower. The third state variable is GDP, where the variables of employment, per capita productivity and liquidity affect its related rates. The fourth variable is life expectancy, which is related to the per capita variables of exercise, illness and health indicators. The fifth state variable is labor productivity, which affects the variables of labor experience, per capita exercise and related health indicators, and the sixth state variable, GDPH, is affected by variables related to health. Figure 3 shows the stock and flow diagram of the present problem.

Fig. 2 The causal graph of the problem

4.6 Level and rate variables

Dynamic systems deal with three types of variables known as level, rate and auxiliary variables. The 'level variable' refers to as a given element within a specific time interval. In dynamic systems, level-type variable is the one that accumulation occurs in that. It is the type of goal variable that management has eye's on and watches its behavior over time. Rate variable causes increase or decrease in level variable. A new value for level variable is calculated taking the algebraic sum of rate variables impacting the level variable adding to the old value of the level variable.

Determination of rate is not a simple task and requires a great deal of effort in almost all the cases for about every problem. Most of the time, a rate is calculated by finding the average value of the accumulated level over the total time taken to get that. In some cases, rates are defined according to following formula:

$$\text{Rate}(t) = \text{Constant} * \text{Level}(t - 1)$$

where constant = A value determined in advance.

Using the formula for the rate given above, one can determine the level variable at time t as follows:

$$\text{Level}(t) = \text{Level}(t - 1) + dt * \text{Rate}(t)$$

The above formula can also be written as follows:

$$d(\text{Level})/dt = \text{Level}(t) - \text{Level}(t - 1) = \text{Rate}(t)$$

5 Model simulation and validation

The proposed model has been simulated for a period of 180 months (15 years), from 2016 to 2030. In the following section, we will show some of the most important outputs for the base model and then review the results for it. We will also run two examples of the most important validation tests for the model to check the validity of the model.

5.1 The relationships between variables and model formulation

In the present study, the following methods have been used to design the equations: the first method was to exploit the mathematical equations and relationships among related papers and research that were examined

Fig. 3 Stock and flow diagram of problem

in the research literature section. Many of the relationships between the variables in the present study were extracted from papers on health, economics and dynamics. The second source of data was past statistics and information gathered by the government and the global resources that could help in model development and formulation. However, this helped us to design a number of equations and suitable relationships between the variables for this study.

Since much of the information required for the present study, such as the country's economic statistics and health information, was not available in any of the previous articles and researches, utilizing the information available at reputable government sites and worldwide data banks had made great impacts on the model accuracy and in designing of the mathematical equations of this problem. A third approach was to use the views of experts in the design of equations and relationships exit between the variables used in the present study. Applying this method made the model more reasonable when simulating (Fig. 4).

5.2 Test of limit conditions

In the present study, we modified some values of the model variables and investigated the reaction of the problem model to it. For example, with the increase in health indicators, life expectancy in the community as well as human resource productivity increased significantly. The results indicate that the model of the present study shows significant reaction to these changes. The behavior of the model was also investigated and the logical and predictable responses of the model were observed.

5.3 Behavioral reproduction test

This test is one of the most important tests for model validation. The way this test works is that the behavior created by the model is compared with the behavior of the actual system. In other words, the output of the model is compared with system statistics and historical data. In this way, the extent of the model's ability to predict system behavior can be measured. In this section, we compare and contrast

Fig. 4 **a** Health-induced GDP in the base model. **b** The amount of manpower productivity in the base model. **c** Life expectancy in base model

Fig. 5 Predictive graph of country's GDP by proposed model relative to real values

the forecast of GDP behavior of the country with real GDP figures in recent years. The model run time for this test is 120 months (10 years). Since we consider the year 2015 as the base year for the present problem model, this test uses the data from the year 2007 to 2016. The real GDP figures are also taken from the World Bank.

Given that the World Bank estimates Iran's GDP in 2007 at around \$ 330 billion, the initial amount for real-world scenarios and forecasts is the same. The following figure shows the prediction of GDP values relative to real values, and it is observed that the dynamic model of the problem predicts the real behavior of the system with good accuracy (Fig. 5).

6 Designing and evaluating policies

In order to finally provide useful policies for this issue, we need to design different scenarios. After implementing and simulating the scenarios mentioned, we evaluate each of them thoroughly and then make the most effective and best decision.

6.1 Scenario one (improving nutrition style)

In this scenario, by reducing the coefficient on inappropriate nutrition, we will examine the effect of community health nutrition style on the key variables. So first we reduce the coefficient associated with inappropriate nutrition from 0.12 to 0.09 and then to 0.06 and then show the trend of changes made to the desired parameters (Fig. 6).

The results of the first scenario show that improvement in nutrition style has the greatest effect on life expectancy, per capita productivity and health-related GDP (Table 5).

Fig. 6 **a** Health gross GDP in the first scenario. **b** Manpower productivity in the first scenario. **c** Life expectancy in the first scenario

6.2 Second scenario (increasing health indicators)

In this scenario, we will examine the effect of increasing health indicators on the desired components. For this purpose, by increasing the coefficients related to health

indices, we analyze the effect of 5 and 10 units of health indices on the variables considered (Fig. 7).

To better understand and compare the results of this scenario with the baseline conditions, the figures for the

Table 5 Results of the last simulation period under the first scenario: improvement in feeding style

	GDPH (billion dollars)	Useful labor per capita (hours per year)	Employment (million people)	Unemployment (million people)	Life expectancy (year)	Productivity (present)
Continuation of current conditions	34.9789	812.643	28.0442	3.69869	81.7349	0.505285
Decrease in nutrition factor (9%)	35.2815	813.151	28.0658	3.69994	82.1641	0.505336
Decrease in nutrition factor (6%)	35.5685	813.66	28.0844	3.70105	82.4886	0.505386

results of this scenario during the last simulation period are shown in Table 6.

The results of the second scenario show that the first scenario has more impact on economic growth than the second one.

6.3 Scenario 3 (Exercise per capita increase)

In this scenario, by increasing the per capita sport of the country, we will examine the impact on other parameters. So by changing the coefficient of per capita exercise, we first discuss the effect of a 5-min increase and then the effect of a 10-min increase relative to the baseline on other variables in the problem (Fig. 8).

Table 7 summarizes the results of the third scenario and baseline conditions in the last simulation period.

The results of the third scenario show that in addition to exercising, it contributes to a significant increase in GDP due to health, it also improves other parameters to a great extent. In general, the impact of the third scenario is far greater than the first and second scenarios.

6.4 Scenario four (improving nutrition and increasing health and exercise indicators)

In the previous scenarios, we examined the effects of nutrition, health and exercise indices on the parameters. In this section, we will examine the simultaneous impact of previous scenarios on the economic variables considered relative to the baseline. In fact, the fourth scenario is a combination of past scenarios. So in this scenario we will consider the ones that have the most positive effect on the variables identified. As a result, we will see a nutrition factor of 0.06, an increase in health indices of 10 units, and an increase in exercise per capita of 10 min. The following diagrams compare the diagrams for this scenario with the best of the previous scenario conditions as well as the baseline conditions (Fig. 9).

To better compare the results of this scenario and the previous scenarios, the results are detailed.

As shown in the charts and table of results, the fourth scenario shows the best performance among the scenarios. The table of the final results of this scenario shows that simultaneous increase in per capita exercise, health indicators and nutritional status can have the greatest impact on economic indicators. Since the fourth scenario is a combination of past scenarios, it was expected to have the greatest impact on economic factors.

7 Analysis of results and conclusion

The results of the scenarios showed that although improvement in nutrition status as well as improvement in health indices increase the economic factors considered, it seems that the effect of per capita increase on exercise is far more than the previous two scenarios. This is also due to the fact that increasing per capita exercise not only increases health indicators but also reduces the prevalence of diseases and increases the life expectancy among individuals. To this end, it is suggested that our first priority in the field of health is to raise economic indicators, to encourage more people in the community, especially the country's workforce, to exercise. Creating public sport and recreation venues, advertising and culture, as well as greater attention by agencies and organizations to staff sports are measures that can achieve this goal.

One of the innovations in the present study can be considered the integration of two issues of health and economics using dynamic approach. Many studies that examine the relationship between health and other topics have used variables in the health section that are duplicate in most related articles. For this reason, the present study has attempted to increase the innovation and the innovation of the current model by using new and effective variables in the field of health. Since most of the articles related to economics focus on the effect of the economic variables

Fig. 7 **a** Health-induced GDP in the second scenario. **b** Man-power productivity in the second scenario. **c** Life expectancy in the second scenario

Table 6 Results of the last simulation period under the second scenario: Increasing health indicators

	GDPH (billion dollars)	Useful labor per capita (hours per year)	Employment (million people)	Unemployment (million people)	Life expectancy (year)	Productivity (percent)
Continuation of current conditions	34.9789	812.643	28.0442	3.69869	81.7349	0.505285
A 5-point increase in health indicators	34.9972	812.832	28.0456	3.69874	81.8441	0.506419
10-point increase in health indicators	35.1271	813.558	28.0548	3.69915	82.1751	0.510774

Fig. 8 **a** Health gross domestic product in Scenario III. **b** Man-power productivity in the third scenario. **c** Life expectancy in the third scenario

Table 7 Results of the last simulation period under the third scenario: Increasing per capita exercise

	GDPH (billion dollars)	Useful labor per capita (hours per year)	Employment (million peo- ple)	Unemployment (million people)	Life expec- tancy (year)	Produc- tivity (percent)
Continuation of current conditions	34.9789	812.643	28.0442	3.69869	81.7349	0.505285
A 5-min increase in per capita sports nation- wide	35.8584	819.589	28.0562	3.69918	82.1573	0.545753
10 min increase in per capita sports in the country	36.7319	826.09	28.0675	3.69967	82.5035	0.583453

Table 8 shows the figures for the results of graphs of this scenario, past scenarios as well as baseline conditions in the last simulation period

Table 8 Results of the last simulation period under scenario 4: Improving nutrition, health and exercise indices

	GDPH (billion dollars)	Useful labor per capita (hours per year)	Employment (million peo- ple)	Unemployment (million people)	Life expec- tancy (year)	Productivity (percent)
Continuation of current conditions	34.978	812.643	28.044	3.698	81.735	0.505
Decrease in nutrition factor (6%)	35.568	813.660	28.084	3.701	82.488	0.505
10 point increase in health indicators	35.127	813.558	28.055	3.699	82.175	0.511
10 min increase in per capita sports in the country	36.732	826.090	28.067	3.699	82.503	0.583
Combine previous scenarios with each other	37.410	827.818	28.107	3.702	83.098	0.588

on economic growth, one of the innovations of this study can be considered the impact of non-economic variables and factors on economic growth.

Although we all know that nutrition and exercise are good for our body and health but it is not very clear for people to see the impacts of these factors on GDPH and the overall GDP of the country. In this article, an integrated modeling driven by the systems thinking methodology and system dynamics approach is used to demonstrate the interrelationships between major variables of the problem. Now, with the results obtained from scenarios of this research, we are at the place to say that exercise contributes to better health and better health contributes to better economy and prosperity for all. The growth of population although would bring more innovation and growth for the society but also would lead to having some more people under the line of poverty. The leaders in every country could take initiative in encouraging people to do exercise on a daily bases and use nutritious food to empower the body-system for doing good tasks on day-to-day basis. Countries that do not pay attention to the health of their people and the nutrition that they use should expect to have ill working population with large number of absenteeism and low productivity at work.

Given that the actual system has many complexities, the use of all the possible variables affecting the actual system for the present model will make modeling and formulation of the problem very complicated and somewhat impossible, so in the present study variables such as currency rate, interest rates, inflation rate and sanctions have been disregarded. As a result, one or more of the excluded variables can be added to the model to develop a new research model.

1. In the present study, the impact of the health sector on the economic growth of the country has been investigated. Future research can assess the impact of other areas such as culture and politics on the country's economic growth.
2. The present study focused on the issue in a large way, namely that the impact of public health on the economic growth of the country has been considered. Therefore, in future researches, for better comparison, we can measure the economic growth of the country by province. Using a dynamic approach to determine the health of each province contributes to boosting the country's overall economic growth.

Fig. 9 **a** Health gross domestic product in Scenario four. **b** Manpower productivity in the fourth scenario. **c** Life expectancy in the fourth scenario

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interests.

References

- Alavi Rad A et al (2014) Comparison of health effects on economic growth in Iran and the countries of the documentary landscape. *Mon J Res* 13(3):136–146
- Onisanwa D (2014) The impact of health on economic growth in Nigeria. *J Econ Sustain Dev* 5:159–166
- Cooke DL et al (2007) Introducing system dynamics modeling to health care in Alberta. In: International conference of the system dynamics society, pp 1–17
- Blood D, Canning D, Sevilla J (2001) The effect of health on economic growth: theory and evidence. National bureau of economic research, working paper 8587, November 2001
- Zare Mehrjardi Y (2013) A dynamic systems approach to weight related health problems. *Int J Qual Reliab Manag* 30(5):571–589
- Zare Mehrjardi Y (2012) A system dynamics approach to health-care cost control. *Int J Ind Eng Prod Res* 23:175–185
- Heidari H et al (2013) Social capital, health capital and economic growth in the middle east. *Econ Growth Dev Res* 3(11):57–74
- Narayan S, Narayan PK, Mishra S (2010) Investigating the relationship between health and economic growth: empirical evidence from a panel of 5 Asian countries. *J Asian Econ* 21(4):404–411
- Thoa NTM, Thanh NX, Chuc NTK, Lindholm L (2013) The impact of economic growth on health care utilization: a longitudinal study in rural Vietnam. *Int J Equity Health* 12(1):12–19
- Ghorashi N, Alavi Rad A (2013) Health economics analysis and economic growth. In: Second national conference on sustainable development in arid and semi-arid areas, Abarkuh, pp 1–12
- Babakhani M (2009) The relationship between economic growth, income inequality and health in Iran: 1357–1385. *Iran J Spec Epidemiol* 5(1):9–16
- Lotfali Pour MR et al (2011) The effect of health indicators on Iran's economic growth. *Health Manag* 14(46):57–70
- Najafi V, Honarvar M, Zare Mehrjardi Y, Sadat S (2019) Exploring the role of lean thinking in sustainability of healthcare supply chain with system dynamics approach. Department of Industrial Engineering, University, Yazd
- Rastegarnia R (2013) Experimental study of health expenditures and economic growth (case study of 14 provinces of Iran). Master's thesis, Faculty of Economics and Accounting, Islamic Azad University, Tehran Central Branch
- Faezipour M, Ferreira S (2013) A system dynamics perspective of the patient satisfaction in healthcare. *Proc Comput Sci* 16:148–156
- Faregh F, Zare Mehrjardi Y (2014) Identifying effective factors on the promotion of therapeutic tourism industry using systemic approach. In: National conference on national tourism, national capital and future perspectives, pp 1–15
- Nasrollahi Vosta L, Aghayari Hir T (2017) Dynamic population analysis and its economic consequences using a system approach. *Soc Dev Quart* 3:167–194
- Bhargava A et al (2001) Modeling the effects of health on economic growth. *J Health Econ USA* 20:423–440
- Falihi N (2010) Investigating the effects of higher education on economic growth in the country: combining dynamic system patterns and econometric models. *Financ Econ Quart* 5:36–61
- Jahani F, Dehghani A (2015) The impact of expanding insurance industry on economic growth in MENA countries. *J Econ Sci* 32:123–138
- Grösser S (2005) Modeling the health insurance system of Germany: a system dynamics approach. In: 23rd International conference of the system dynamics society, pp 1–30
- Zarghamiyanpour F, Barani Laghab S (2016) "The causality relation of economic growth and unemployment in Iran: the law of Ukan. In: The first national conference on accounting and economics, pp 1–22
- Ali Heidari Boyuki T, Amrollahi Boyuki E (2015) The impact of tourism on Iran's economic growth with the system dynamics approach. In: Second international management conference, economics and humanities, Istanbul, pp 1–12
- Farzi N, Haghighat J (2015) The effect of physical capital accumulation and investment on health on Iran's economic growth. In: International conference on management and humanities, Dubai, pp 1–8
- Abdolmaleki H, Mahdavi M (2013) Analysis of the impact of health indicators on regional development in Iran: integrating data econometric approach. *J Bioethic Ethics* 8:11–42
- Arora S (2001) Health, human productivity, and long-term economic growth. *J Econ Hist* 61(3):699–749
- Babatunde MA (2012) The relationship between health and economic growth in Nigeria. Department of Economics, University of Ibadan, Nigeria, Ibadan, pp 1–8
- Ghorbani M et al (2014) The impact of infrastructures on Iran's economic growth during the years 1355–1391. *J Econ Growth Dev* 17:49–60
- Akram N et al (2008) The long term impact of health on economic growth in Pakistan. In: Twenty-fourth annual general meeting and conference of the Pakistan Society of Development Economists Islamabad, vol 47, No. 4, pp 487–500
- Bloom DE, Canning D, Sevilla J (2004) The effect of health on economic growth: a production function approach, vol 32, 32nd edn. Harvard School of Public Health, Boston, pp 1–13
- Atkinson JAM et al (2015) Applications of system dynamics modelling to support health policy. *Public Health Res Pract* 25(3):1–8
- Fattahi S et al (2013) Relationship between human capital, health and economic growth in OPEC countries. *Health Manag* 3(4):37–51
- Einzinger P, Zauner G, Ganjeizadeh-Rouhani A (2010) A system dynamics model of health insurance financing in Austria. *SNE* 20(2):59–62
- Jankuj M, Voracek J (2015) Dynamic modelling of national healthcare system. *Meas Bus Excell* 19(3):76–89
- Sepaseh F et al (2016) The role of exercise in employees health and the improvement of organizations. In: Ninth pioneering progress congress, pp 1490–1493
- Tsan Sheng Ng A, Sy C, Li J (2011) A system dynamics model of Singapore healthcare affordability. In: Proceedings of the winter simulation conference (WSC), pp 1–13
- Sarlak A (2015) The effects of health indicators on economic growth in provinces of the country. *Health Manag* 6(1):7–17
- Samsami H et al (2016) Comparison of the efficiency of liquidity growth on GDP, private investment and employment with the bubble of the market of assets. *Econ Res* 51(2):457–492
- Barkur G, Varambally KVM, Rodrigues L (2007) Insurance sector dynamics: towards transformation into learning organization. *Learn Organ* 14(6):510–523
- Prakash Pradhan R, Bahmani S, Uday Kiran M (2014) The dynamics of insurance sector development, banking sector development and economic growth: evidence from G-20 countries. *Glob Econ Manag Rev* 19(2):16–25
- Shah Mohammadi Heidari F (2015) Presentation of life-efficiency evaluation model using system dynamics (case study: Iran)

- insurance company). Master's thesis, Payame Noor University of Karaj
42. Yousefinejad V et al (2015) Simulation of the financial health insurance system with the dynamics of systems approach. *Hakim Health Res J* 18(4):306–315
43. Ihori T et al (2011) Health insurance reform and economic growth: simulation analysis in Japan. *Int Univ Jpn* 23(4):227–239
44. Governmental Healthcare Policy (2008) Deputy Director of the Center for Health and Environment, Ministry of Health and Medical Education, pp 1–14
45. Rahmani M et al (2014) The role of nutrition in the health of the society. In: Third national conference on food science and technology, pp 1–6
46. Mohammad Zadeh Y et al (2015) Environmental, health and health costs. *Health Inf Manag* 12(4):495–505
47. Yahia Abadi A et al (2013) Analysis of oil price variability, exchange rate and economic sanctions on economic growth. In: The first national electronic congress of the Iranian economy with a view to supporting national production, vol 1, pp 1–20
48. Soltan Tooye M et al (2012) The relationship between inflation and economic growth in Iran using the linear regression model. *Monet Bank Res* 6(14):49–68
49. Abounoori E, Ghasemi A (2008) Investigating the causal relationship between interest rates and economic growth using panel data. In: Islamic economics and development conference, pp 1–13

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