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How Does the Earthquake Affect Economic Growth with System Dynamics Approach (Case Study of Tehran)

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ABSTRACT

Natural disasters affect economic growth, and due to the location of Tehran, as the capital of Iran, on the Rey fault, Masha, and North of Tehran, the present research was conducted to investigate the effect of earthquakes on the Rey fault on the economic growth of Iran. The economic growth of Iran has been simulated for 40 years, starting from 2013, and through cause and effect cycles, the long-term economic effects of a possible earthquake have been simulated. The innovation of the current research is the economic growth model is designed in terms of product production, knowledge production, production of intermediate energy goods, and the performance of the insurance industry as a part of the financial sector. Also, the influence channels of the earthquake on Roemer's endogenous economic growth model have been simulated using the system dynamics method. The results show that causalties will lead to a reduction in human resources and, as a result, a slight decrease in Iran's economic growth in the long-term. Secondly, the destruction will lead to the reduction of physical capital and, as a result, the reduction of economic growth in the long term. Thirdly, reconstruction costs will have a negative effect on economic growth, which will diminish in the long run.

Keywords

Economic growth, Earthquake, System dynamics, Physical capital, Human capital.

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1. Introduction

One of the policymakers' most important economic goals is to achieve high economic growth. Many economists have tried to analyze the issues of economic growth and design their policies based on growth-inhibiting and growth-accelerating factors. Natural disasters are among these factors. Countries that have frequently experienced natural disasters have lower growth rates Benson and Clay (2004). Loayza et al. (2012) believe that natural disasters affect the economic growth of countries and this effect is more severe for developing countries. If the severity of natural disasters is high, they will have a negative effect on economic growth (Cavallo and Noy, 2011).

The importance of the present issue is due to the fact that Iran is located on one of the two earthquake-prone belts in the world. The city of Tehran is located on the Rey fault, the Masha fault, and the North Tehran fault, so a huge earthquake is likely. And due to the accumulation of many physical and human capitals in Tehran, in the event of an earthquake, these capitals will be damaged, and the activities of government bodies, organizations, and industrial and commercial sectors, including Tehran's Grand Bazaar, will be disrupted. Therefore, it is likely that the country's economic growth will be affected. Kirigia et al. (2004) shows that the death of each person due to natural disasters has reduced the gross domestic product of countries by one dollar. Also, Deng, et al. (2022), Noy et al. (2017), Isoré (2018), Rajapaksa et al. (2017), Hallegatte et al. (2016), Joseph, I. L. (2022), Hsiang and Jina (2014), Okuyama and Santos (2014), Barone and Mocetti (2014), Shahzad (2014), Cavallo et al. (2013), Fisker (2012), Rodriguez et al. (2013), Benali, N. (2022), Loayza et al. (2012), Kellenberg and Mobarak (2011) have investigated the effect of natural disasters on the economic growth of countries.

Chang-Richards (2018), Phonphoton and Pharino (2019), Potirakis, et al. (2013), Kachali et al. (2012), Bagheri et al. (2010), Ramezankhani and Najafiyazdi (2007), and Ho et al. (2006) have simulated the various effects of earthquakes through the system dynamics method.

Most of the studies show the negative effects of natural disasters on economic growth. In this study, the effects of earthquakes on economic growth have been investigated using the system dynamic method, which has provided the possibility to test the hypotheses. In the present study, Romer's endogenous economic growth has been simulated using the system dynamics method, which has made it possible to comprehensively examine economic growth and consider the knowledge production sector, goods production, energy, and the performance of the insurance industry at the same time.

The main purpose of this research is to simulate and investigate the long-term and short-term effects of an earthquake in the Ray fault in Tehran on the economic growth of Iran. Therefore, Romer's endogenous economic growth model is simulated in terms of a knowledge production function, goods production function, energy production function, and insurance industry for Iran. This model will be prepared for 40 years, starting from 2011. Then, the possible earthquake that occurred in 2019 in the Rey fault is entered into the model. So that physical capital and labor decrease. Then changes in the production function are investigated. The main contribution of this study is the construction of the economic growth simulation model in terms of good production, knowledge, production of intermediate energy, and the performance of the insurance industry as a symbol of the financial sector. Also, the further innovation of the present research is identifying the channels of earthquake influence on economic growth through the dynamic examination of economic cause and effect relationships.

2. The theoretical principles

Endogenous growth theories investigate the forces that cause growth and their dynamics. Endogenous growth theories were created by developing economic growth models and, consequently, endogenous technological changes by Romer (1986) and Lucas (1988).

In the second generation of endogenous growth models, Romer (1990), Grossman and Helmpman (1991) consider innovations as the basis of the economic growth process. In these models, innovations are the result of research and development activities in firms, and the overflow of international knowledge due to international trade and research and development are the main determinants of economic growth rate.

In this paper, the endogenous economic growth of Romer is considered. Production of goods (Y) is assumed as a function of human capital (H), physical capital (K), technology (a), and energy (E). The pattern has a continuous time. Labor and capital are employed in three parts of goods production, research and development production, and intermediate goods of energy production. Insurance performance indirectly improves economic growth through its impact on capital. Economic growth also affects insurance performance through the amount of public and private sector spending on premium payments.

In this model, the ratio θ_1 of the workforce is used in the final product manufacturing sector. θ_2 of the labor force is used in the intermediate goods production sector of energy. ($\theta_3 = 1 - \theta_1 - \theta_2$) of the labor force is used in the research and development(R&D) sector. η_1, η_{21}, and (η_3=1-η_1-η_2) are the share of capital in the final product manufacturing sector, intermediate goods production sector of energy, and the share of capital in the R&D sector. All three sectors use the whole knowledge inventory because knowledge in one sector does not prevent its usage in other sectors. Therefore, the function of the product is at the time (t) is according to Eq.1.

$$\mathrm{Y(t)} = B_2[(\eta_1)\mathrm{K(t)}]^{\beta_1}[(\theta_1)\mathrm{H(t)}]^{\beta_2}[E(t)]^{\beta_3}[A(t)]^{\beta_4} \tag{1}$$

In this model, knowledge production is a function of the share of physical capital and the share of human resources and knowledge inventory as follows:

$$\dot{\mathrm{A}}(\mathrm{t}) = B_1\mathrm{A(t)}[(1-\eta_1-\eta_2)\mathrm{K(t)}]^{\alpha_1}[(1-\theta_1-\theta_2)\mathrm{H(t)}]^{\alpha_2}$$
$$\mathrm{B} > 0 \quad , \quad \alpha_1, \alpha_2 \geq 0 \tag{2}$$

It assumes that increasing the current knowledge inventory leads to improving new discoveries directly. Therefore, the knowledge inventory appears in the above equation exponent 1. The energy production function is considered according to Eq.3, which is a function of the share of physical capital and human resources, knowledge inventory, and primary energy supply.

$$\mathrm{E(t)} = B_3[(\eta_2)\mathrm{K(t)}]^{\Upsilon_1}[(\theta_2)\mathrm{H(t)}]^{\Upsilon_2}[A(t)]^{\Upsilon_3}[IES(t)]^{\Upsilon_4} \tag{3}$$

The capital function is as Eq.4:

$$\dot{\mathrm{K}}(\mathrm{t}) = \mathrm{sY(t)} - \delta\mathrm{K(t)} \tag{4}$$

We consider population growth as endogenous and assume no negative population growth exists (Eq.5).

$$\dot{\mathrm{L}}(\mathrm{t}) = \mathrm{nL(t)} \qquad \mathrm{n} \geq 0 \tag{5}$$

It should be noted that in eq.2, the parameters α_1, α_2 are the elasticity of knowledge growth relative to the physical and human capital, and in Eq.3, the parameters Υ_1, Υ_2, Υ_3, and Υ_4 are energy production elasticity relative to the physical capital, workforce, Knowledge level, and basic energy levels.

Schumpeter (1911) and Hicks (1969) studied the importance of the financial sector in support of economic growth for the first time. King and Levine (1993), Berg and Schmidt (1994), Soo (1996), Arena (2008), and Pietrovito (2009) confirmed the effect of financial development on economic growth by endogenous growth models.

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3. Methodology

We use system dynamic methodology to analyze the rescue team's impact of earthquakes on Iran's economic growth. Effective decision-making and learning in a world of dynamic complexity growth force us to be system thinkers to expand the mental model's boundaries and limits. In the system dynamic, the long-term effects of the decisions acquire experience and speed up learning (Sterman, 2001).

The system dynamics is based on control theory and nonlinear dynamics modern theory. So, there is an exact mathematical foundation for theory and models, and it is also a technical tool that policymakers can solve problems in societies. In this method, as shown in figure 1, the model is formulated after expressing the problem and defining dynamic hypotheses. After testing and validating the model, policies are designed and evaluated.

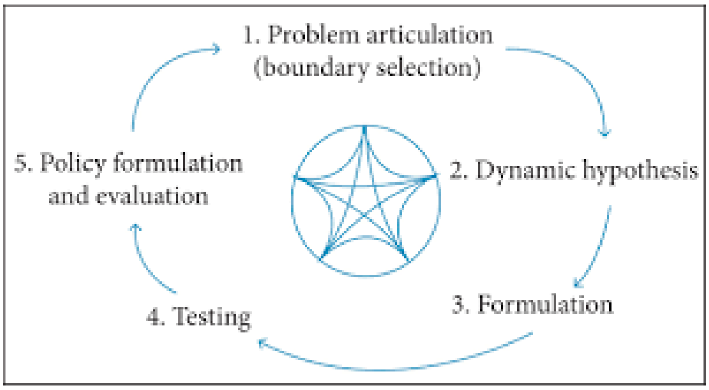

Figure 1. Modeling process in system dynamics (Sterman, 2000)

Table 1 shows study variables and the source of relationships and data extraction. It should note that the model start time is 2012, and the earthquake occurrence in 2020 is simulated. Therefore, the data related to economic growth relate to 2012.

Table 1. Introducing model variables

Symbol	Variable name	Kind of variable	Variable unit	Formula , amount	source
dA	growth of knowledge level	flow	Billion Rials/year	$(\dot{A}(t)/year) = (B_1 A(t)[(1-\eta_1-\eta_2)K(t)]^{\alpha_1}[(1-\theta_1-\theta_2)H(t)]^{\alpha_2})/year)$	Hadian and Ostadzad (2016)
At1	Knowledge inventory	Stock	Billion Rials	$A(t) = A(t-1) + \dot{A}(t)$ *2144*	Hadian and Ostadzad (2016)
A	Initial knowledge inventory	Covariate	Billion Rials	lookup	Hadian and Ostadzad (2016)
α1	Elasticity of knowledge growth to capital	Covariate	-	0.042	Hadian and Ostadzad (2016)
α2	Elasticity of knowledge growth to workforce	Covariate	-	0.049	Hadian and Ostadzad (2016)
B1	Coefficient of knowledge function	Covariate	-	0.0197	Hadian and Ostadzad (2016)
B2	Coefficient of produce function	Covariate	-	0.731	Hadian and Ostadzad (2016)
β1	power of capital on produce function	Covariate	-	0.301	Hadian and Ostadzad (2016)
β2	power of workforce on produce function	Covariate	-	0.246	Hadian and Ostadzad (2016)

Symbol	Variable name	Kind of variable	Variable unit	Formula , amount	source
β3	power of knowledge on produce function	Covariate	-	0.221	Hadian and Ostadzad (2016)
β4	power of energy on produce function	Covariate	-	0.123	Hadian and Ostadzad (2016)
dY	Growth of total production	flow	Billion Rials/year	$\frac{(\frac{Y(t)}{rial^2})}{year} = B_2[(\eta_1)K(t)]^{\beta_1}[(\theta_1)H(t)]^{\beta_2}[E(t)]^{\beta_3}[A(t)]^{\beta_4} / (\frac{rial^2}{year})$	---
Y	Gross domestic production	Stock	Billion Rials	1605453	Central Bank of Iran
dE	Energy production changing	flow	Billion Rials/ye	$(\frac{E(t)}{rial^2}) = (B_3[(\eta_2)K(t)]^{\Upsilon_1}[(\theta_2)H(t)]^{\Upsilon_2}[A(t)]^{\Upsilon_3}[IES(t)]^{\Upsilon_4}$ /rial^2)	---
E	Energy production	Stock	Billion Rials	550984	Iran Energy Balance Sheet
B3	other variables on energy production function	Covariate	-	0.300	Hadian and Ostadzad (2016)
E1	Primary energy supply	Covariate	Billion Rials	289467	Iran Energy Balance Sheet
ϒ1	Elasticity of energy production to capital	Covariate	-	0.223	Hadian and Ostadzad (2016)
ϒ2	Elasticity of energy production to workforce	Covariate	-	0.037	Hadian and Ostadzad (2016)
ϒ3	Elasticity of energy production to knowledge level	Covariate	-	0.0247	Hadian and Ostadzad (2016)
ϒ4	Elasticity of energy production to ESTI	Covariate	-	0.8589	Hadian and Ostadzad (2016)
irate	Investment rate	Covariate	-	0.25	World bank data
I	investment	flow	Billion Rials/ye	I(t)= irate*Y(t)	---
K	Physical capital	Stock	Billion Rials	PULSE(0, 8)*(I+nonlife loss+zi-est)+PULSE(8, 1)*(I+nonlife loss+zi-est-destruction1-destruction2)+PULSE(9, 32)*(I+nonlife loss+zi-est(7770050	Amini and Neshat (2005)
est	Depreciation	flow	Billion Rials/ye	Estrate*k	Amini and Neshat (2005)
estrate	Depreciation rate	Covariate	-	0.05	Amini and Neshat (2005)
pop	population	Covariate	Thousand people	U15+(15-65)+m65	---
b	birth	flow	Thousand people/year	br*pop	---
br	Birth rate	Covariate	-	0.016	World bank data
d	death	flow	Thousand people/year	dr*pop	---
dr	Death rate	Covariate	-	0.005	World bank data
hh	Workforce	Covariate	1	H*15-65*hhh	Central Bank of Iran
h	Active population ratio to 15-64	Covariate	-	lookup	Central Bank of Iran
U15	Population under 15	Stock	Thousand people	PULSE(0, 8)*(b-d1-mian)+PULSE(8, 1)*(b-d1-mian-casualties1-casualties2-casualties3)+PULSE(9, 32)*(b-d1-mian) 17561000	Statistical Center of Iran
15-65	Population 15 -64	Stock	Thousand people	PULSE(0, 8)*(mian-d2-salm)+PULSE(8, 1)*(mian-d2-salm-casualt1-casualt2-casualt3)+PULSE(9, 32)*(mian-d2-salm) 53244000	Statistical Center of Iran
M65	Population more than 65 years old	Stock	Thousand people	PULSE(0, 8)*(salm-d3)+PULSE(8, 1)*(salm-d3-casual1-casual2-casual3)+PULSE(9, 32)*(salm-d3) 4343000	Statistical Center of Iran
salm	Elder rate	flow	Thousand people/year	(15-65/64)/year	---
mian	Middle-aged rate	flow	Thousand people/year	(U15/15)/year	---
year	year	Covariate	year	1	---
rial	rial	Covariate	Billion Rials	1	---
C	consumption	Covariate	Billion Rials	0.45*Y	Statistical Center of Iran

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Symbol	Variable name	Kind of variable	Variable unit	Formula , amount	source
G	government expenditure	Covariate	Billion Rials	0.11*Y	Statistical Center of Iran
cul	Percent of insurance expenditure	Covariate	--	۰/۰۲	Central insurance of IR Iran data
pre	premium	Covariate	Billion Rials	cul*(C+G)	Central insurance of IR Iran data
pr rein	Reinsurance premium	Covariate	Billion Rials	0.24*pre	Central insurance of IR Iran data
life premium	Life premium	Covariate	Billion Rials/ye	pre-pr rein))/year*(0.2	Central insurance of IR Iran data
nonlife premium	Nonlife premium	Covariate	Billion Rials/ye	pre-pr rein))/year*(0.8	Central insurance of IR Iran data
other revenue	Other revenue of insurance	Covariate	Billion Rials/ye	1821	Central insurance of IR Iran data
insurance	Insurance performance	Covariate	Billion Rials	life premium+nonlife premium+other revenue-life loss-nonlife loss-other expenditure 2112	Central insurance of IR Iran data
life loss	Life loss	Covariate	Billion Rials	((0.69* life premium)-(0.69* life premium *loss rein))	Central insurance of IR Iran data
nonlife loss	nonlife loss	Covariate	Billion Rials	((0.84*nonlife premium)-(0.84* nonlife premium *loss rein))	Central insurance of IR Iran data
other expenditure	Other insurance costs	Covariate	Billion Rials/ye	(0.24*pre)/year	Central insurance of IR Iran data
loss rein	Percentages of reinsurance losses	Covariate	--	0.25	Central insurance of IR Iran data
haghomr	aanonlife premium	Covariate	Billion Rials/ye	0.12*life premium	Central insurance of IR Iran data
lossomr	nonlife loss	Covariate	Billion Rials/ye	0.11*life loss	Central insurance of IR Iran data
zakhire riazi	Mathematical reserves	Covariate	Billion Rials	haghomr-lossomr 1800	Central insurance of IR Iran data
zi	Mathematical reserveson year	Covariate	Billion Rials/ye	zakhire riazi/year	---
destruction1	earthquake destruction	flow	Billion Rials/ye	1833440	JICA (2000)
Destruction2	fire destruction after earthquake	flow	Billion Rials/ye	(em2(rescue teams))/(year)	Sadeghian et al. (2016)
Casual1	Casualties1(more than 65 year)	flow	Thousand people/year	(emd*(0.15*m65))/(people*year)	JICA (2000) Sadeghian et al. (2016)
Casual2	Injured Casualties (more than 65 years)	flow	Thousand people/year	t2*((people*aaa*(0.15*m65))+(emd1*(0.15*)(m65))))/(2*year*people^2	Amini et al. (2012)
Casual3	Patient Casualties (more than 65 years)	flow	Thousand people/year	((t33*(tal3))/(year*people)	Ramezankhani and Najafiyazdi (2007)
Tal3	Number of patients (more than 65)	Covariate	Thousand people	0.45*0.11*0.15*m65	Ramezankhani and Najafiyazdi (2007)
casualt1	Casualties1(15 -64)	flow	Thousand people/year	(emd*(0.17*"15-64"))/(people*year)	JICA (2000) Sadeghian et al. (2016)
casualt2	Injured Casualties(15-64)	flow	Thousand people/year	t2*((people*aaa*(0.17*"15-)64"))+(emd1*(0.17*"15-(64"))))/(2*year*people^2	Amini et al. (2012)
casualt3	Patient Casualties(15-64)	flow	Thousand people/year	(t33*tal2)/(people*year)	Ramezankhani and Najafiyazdi (2007)
Tal2	Number of patients (15-64)	Covariate	Thousand people	0.45*0.11*0.17*" 15-64"	Ramezankhani and Najafiyazdi (2007)
casualties1	Casualties1(under15)	flow	Thousand people/year	(emd*(0.12*u15))/(people*year)	JICA (2000) Sadeghian et al. (2016)
casualties2	Injured Casualties(under15)	flow	Thousand people/year	t2*((aaa*(0.12*u15)*people)+(emd1*(0.12*u)(15))))/(2*year*people^2	Amini et al. (2012)
casualties3	Patient Casualties (under 15)	flow	Thousand people/year	(tal1*t33)/(year*people)	Ramezankhani and Najafiyazdi (2007)
Tal1	Number of patients (under15)	Covariate	Thousand people	0.45*0.11*0.12*" u14"	Ramezankhani and Najafiyazdi (2007)

4. Results and discussion

In order to simulate Romer's endogenous economic growth model, the first causal loop diagram was drawn (Figure 2), and based on that, the Stock and flow diagrams were drawn (Figure 3). In this model, the damages caused by the earthquake are shown in the form of the destruction of physical assets and secondary damages due to fires after the earthquake. Part of the deaths caused by the earthquake is due to the death due to debris, another part is the death of the injured, and the next part is the death due to infectious diseases after the earthquake, which is drawn separately for each age group. Then, simulation was done using relevant data and information. The parameters are extracted from previous studies or data from Central Bank, World Bank, Iran Statistics Center, and Energy Balance Sheet.

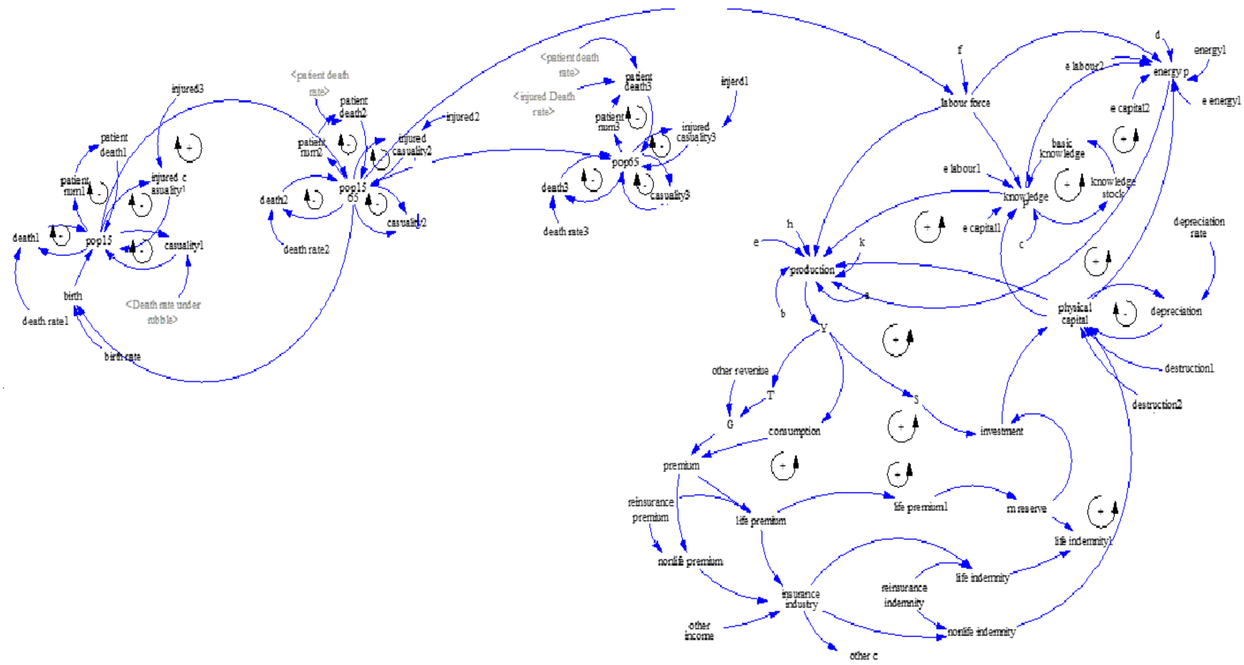

Figure 2. Causal loop diagram

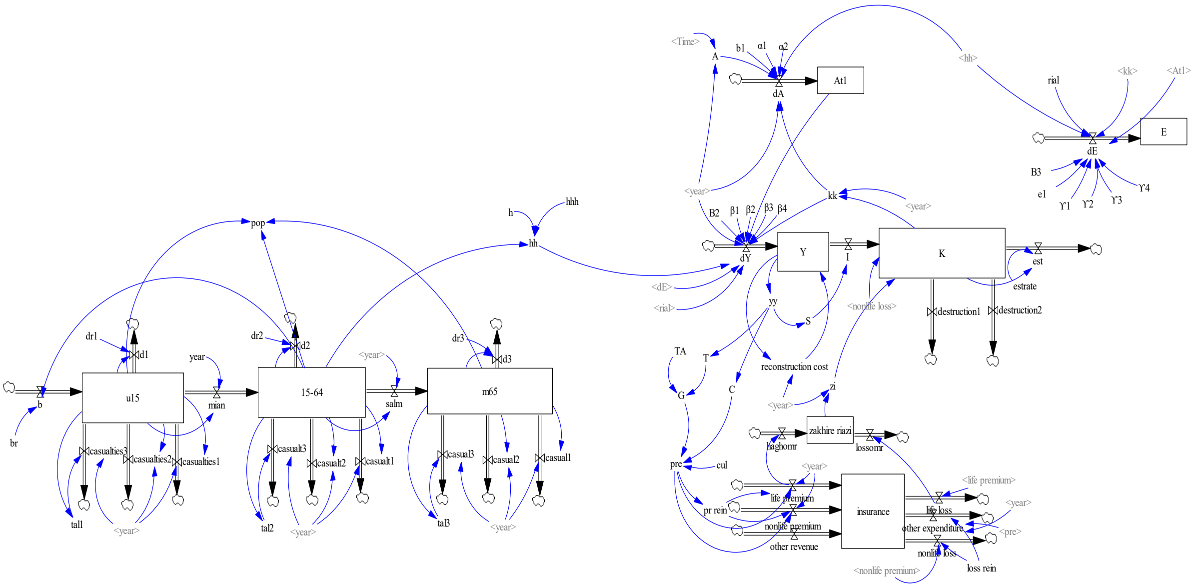

Figure 3. Stock and flow diagram

The following tests are performed to test the model validity:

a) **Behavior reproduction test:** To assess the model validity, we studied the model from 1996 to 2013 in comparison with the actual data extracted from the Central Bank of Iran and the Statistics Center of Iran. According to Figure 4, with a close approximation, we reached the results close to reality.

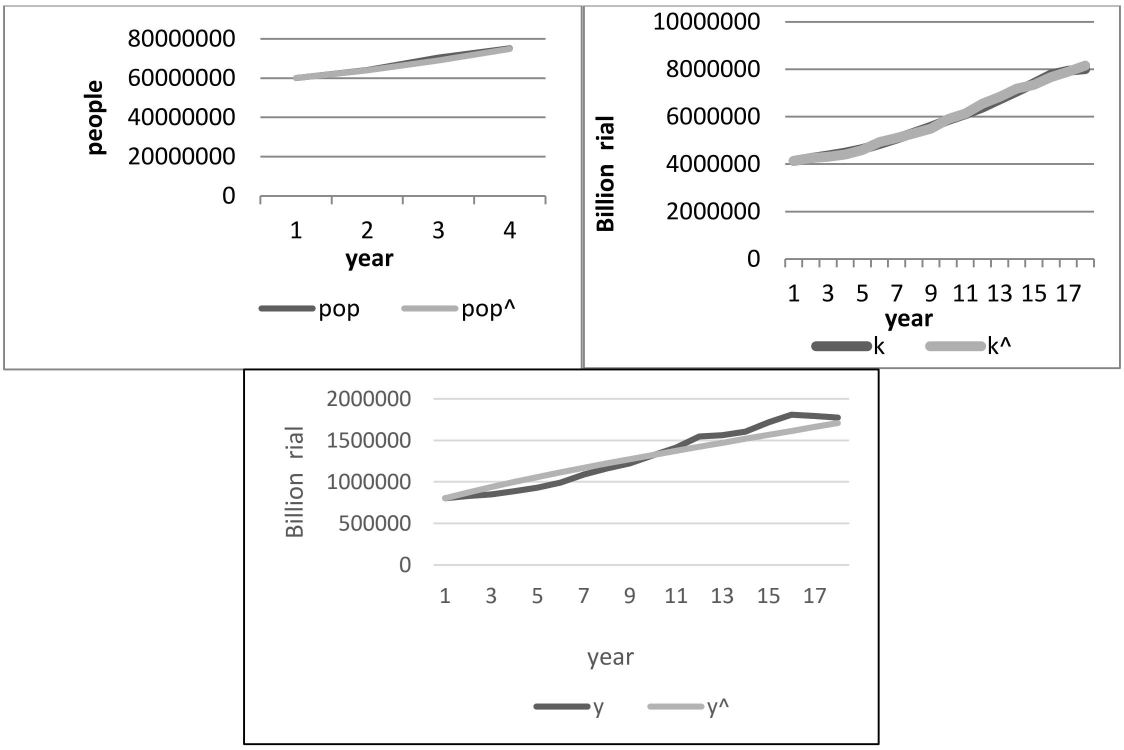

Figure 4. Comparison of the values calculated by the model (y^) with real values (y)

b) **Boundary-adequacy test:** We formulated all the variables needed to examine endogenous economic growth according to theoretical principles and existing literature, including physical and human capital and the knowledge production function. The values assigned to the variables are determined based on their real values. They can provide a proper approximation of the behavior of the gross domestic product (GDP) and economic growth of Iran.

c) **Structure verification test:** A review of model matching with reality in the decision-making process shows that the behavior of defined variables and their impact on model behavior in the critical stages is perfectly in accordance with reality. This is confirmed due to the model's behavior in this situation and by the survey of experts.

d) **Dimensional test:** This test is performed to determine the unit of variables and coordinate them with the reality that is performed on the model's variables, which indicates that the unit of variables is in accordance with reality.

e) **Extreme policy test:** In this section, the behavior of variables has been investigated in a limit state. Non-negativity of the state variables and the direction of the movement of information and materials based on model assumptions are among the issues discussed in this section, and the behavior of variables confirms this situation. Also, in order to prevent irrational behavior of variables in the limit state, infinite capacities are defined for variables of state and rate. For example, the behavior of the variable in the production of goods and capital is shown in Figures 5 and 6 in the event of an increase in depreciation rates of up to 90%. The lower curve represents changes in capital and production in the case of an increase in the rate of depreciation, in which the capital variable is close to zero over the next two years, and the production of goods will fall sharply after two years, too. Figures 7 and 8 show the behavior of the production variable and the population in the case of declining birth rates up to 0.001. The lower curves indicate the behavior of variables in the case of declining birth rates. As it is seen, the population under 15 years of age is rapidly decreasing, and after a while, this decline is transferred to the population aged 15-64. Following a decline in the population aged 15-64, labor and, consequently, the output will be reduced.

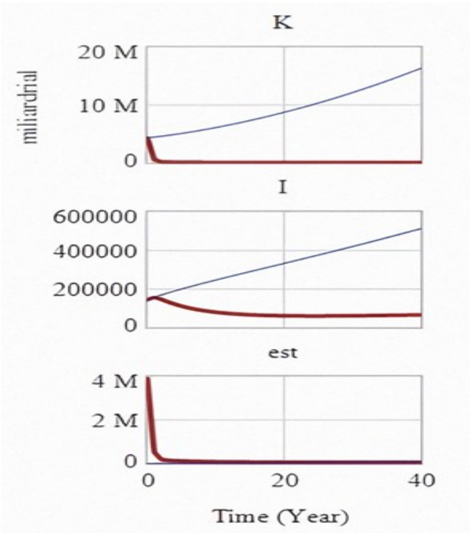

Figure 5. The behavior of the capital variable

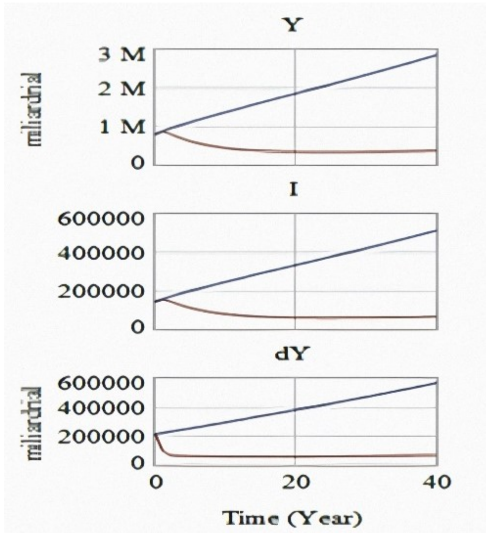

Figure 6. The behavior of the production variable

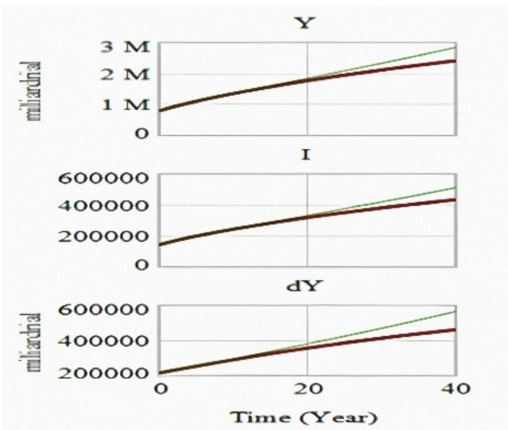

Figure 7. The behavior of the production variable

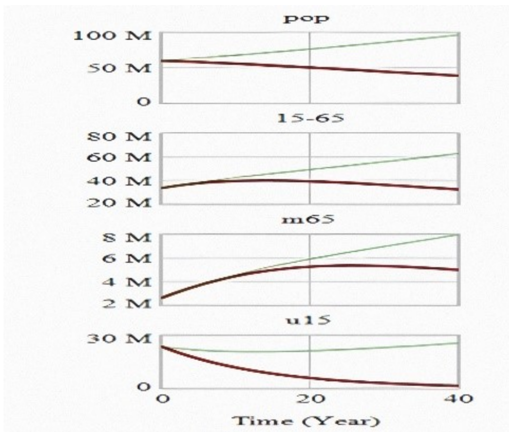

Figure 8. The behavior of the population variable

In the following, three hypotheses are examined:

Hypothesis 1: In case of an earthquake in Tehran, due to the dead, disabled and injured, part of the country's human resources will be lost and will lead to a decrease in the production of goods and the economic growth of Iran.

Hypothesis 2: In the event of an earthquake, residential houses, commercial, industrial and administrative units will be destroyed, and machines and commercial capital, and infrastructures of the region will be damaged. Therefore, reducing physical capital will lead to a decrease in economic growth, and physical capital will decrease again.

Hypothesis 3: In the event of an earthquake, savings are diverted from productive investments to damage reconstruction. Therefore, reconstruction costs will have a negative effect on economic growth.

We analyze rescue operations' impact on reducing the Tehran earthquake's devastating effects on Iran's economic growth with the origin of 2012 and assume that the earthquake happened in 2020. Required information on the severity, mortality rate, and possible damage of earthquakes in each case are derived from JICA (2001). It should note that in all scenarios, causalities were considered about the number of causalities at night. Information on possible earthquakes is shown in Table 2.

Table 2. Rey fault information (JICA, 2001)

		Ray Fault model
Length (km)		26
Width (km)		16
Moment Magnitude (Mw)		3.5
Origin	N (degrees)	35.8255
	E (degrees)	51.7392
Azimuth (Clockwise from North) (degrees)		263
Dip angle (degrees)		75
Depth of upper edge (km)		5

In the event of an earthquake in the Rey fault, the number of causalities under the debris, deaths due to injury and disease, and fires after the earthquake are shown separately in each age group, as shown in the Figures (9) to (12). The amount of labor and physical capital of the country will decrease, which will lead to a decrease in the gross domestic product. Curve 1 shows the state of Iran's gross domestic product without the occurrence of an earthquake until 2051. Curve 2 shows the effect of the reduction of labor, and curve 3 shows the effect of the destruction of physical capital due to an earthquake. Curve 4 simultaneously shows the effect of the reduction of human resources and physical capital and the reduction of production due to the cost of post-earthquake reconstructions.

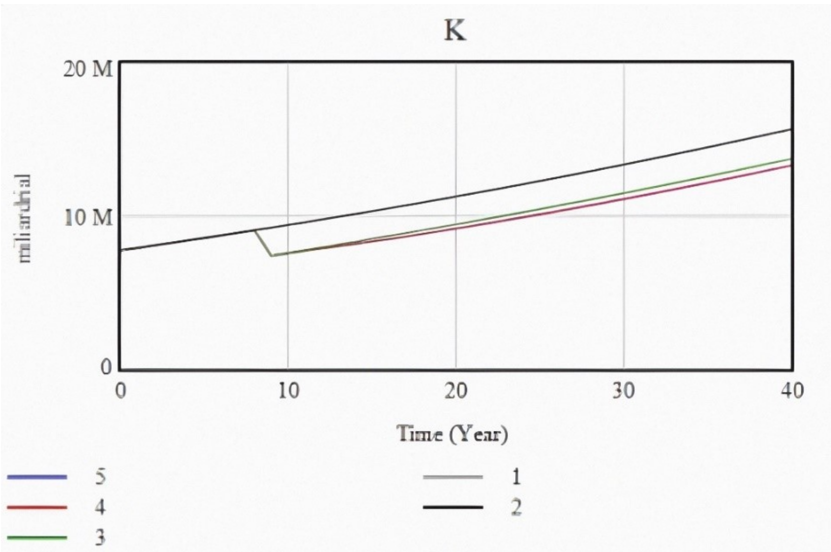

Figure 9. Behavior of physical capital in the event of rey fault earthquake

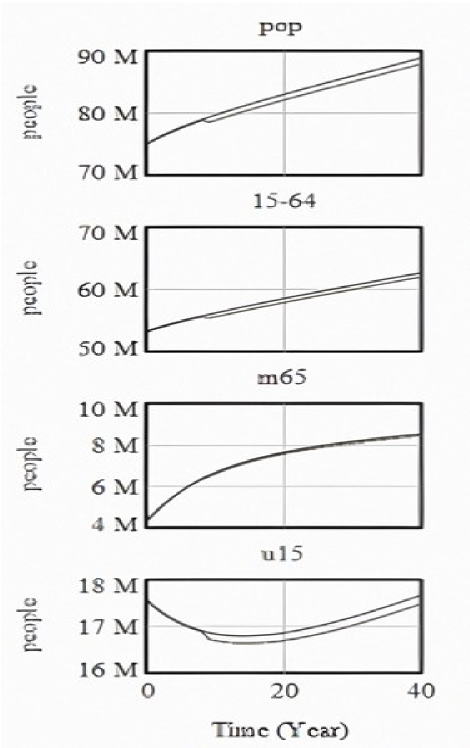

Figure 10. Behavior of the population in the event of rey fault earthquake

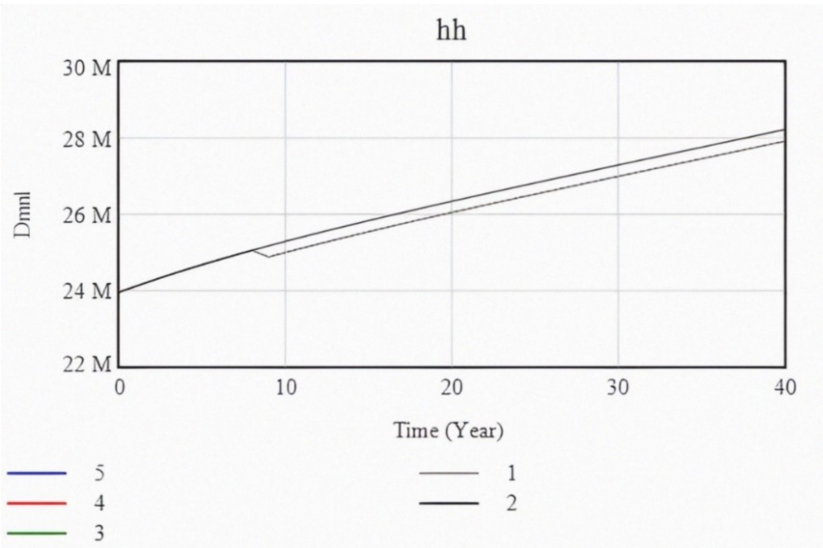

Figure 11. Behavior of labor in the event of rey fault earthquake

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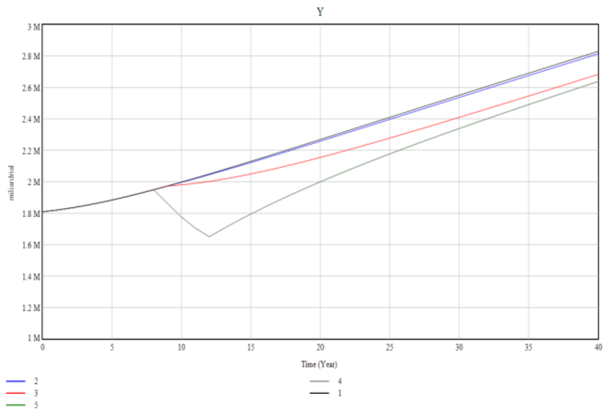

Figure 12. Behavior of economic growth in the event of rey fault earthquake

The changes made after the earthquake in physical capital, human power, population, and GDP for two scenarios are listed in the Table 3 to analyze the possible effects of the Tehran earthquake on Iran's economic growth. It should be noted that the numbers presented in the table 3 indicate the status of the variables two years after the earthquake and thirty-two years after the earthquake.

Table 3. Changes in model variables in each scenario

Variable scenario	**Population (person)**		**Labor (person)**		**physical capital (Billion Rials)**		**GDP (Billion Rials)**	
Year	2021	2051	2021	2051	2021	2051	2021	2051
No earthquake	81225300	89963800	27294200	29249500	9429480	15674400	1998240	2829450
earthquake	78972200	87991200	25699000	28601700	7573210	13274300	1775730	2625970

5. Conclusion

This study investigated the effects of a possible earthquake in Tehran's Rey fault on Iran's economic growth. The limitations of this study are assuming the stability of other conditions such as investment rate, knowledge production, birth rate, etc. Also, the Tehran earthquake's effect on the economic growth of Iran has been investigated. Therefore, the results cannot be generalized to other cities in Iran. The results show that the country's economic growth rate will decrease after the earthquake, and the negative effects of the earthquake will continue in the long term. This result is in line with research, including the study of Cavallo and Noy (2011). Due to the existence of traditional and old fabric in the south of Tehran city, the initial destruction caused by the earthquake will be severe in the Rey fault. On the other hand, rescue and relief operations will also be very difficult, so the number of causalities and damages will increase.

In this study, the occurrence of a possible earthquake affects economic growth in three ways. According to Figure 10, the population decreases due to death under debris, injuries, or the

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spread of infectious diseases after the earthquake. According to Figure 11, the death of the population leads to a decrease in the active human resources of the country. According to chart 6, physical assets are also reduced due to the destruction caused by the earthquake or the fires after the earthquake. Also, in the early years after the earthquake, part of the savings are diverted towards reconstruction. Therefore, economic growth decreases. According to Figure 12, curve 2 shows human causalities, which alone do not have a significant effect on the reduction of economic growth, but its effects, along with the destruction of physical capital and reconstruction costs, will be significant on the reduction of GDP, as shown by curve 5. Therefore, all three hypotheses are confirmed. The decrease in labor caused by the earthquake in the Ray's fault will reduce the GDP by 12,000 billion Rials in 2031 and 17,810 billion Rials in 2051. The reduction of physical capital caused by the earthquake in Ray's fault will reduce the GDP by 101,900 billion Rials in 2031 and by 128,680 billion Rials in 2051. The reconstruction costs caused by the earthquake in Ray's fault will reduce the GDP by 154,880 billion rials in 2031 and by 56,980 billion rials in 2051.

Therefore, it can be concluded that the occurrence of a severe earthquake in Tehran will have a negative effect on Iran's economic growth. The results show that these negative effects will continue long-term within 30 years after the earthquake. In the early years after the earthquake, the gross domestic product will decrease by about 300 thousand billion rials, and this decrease will continue in the long term, but it will be adjusted over time. For example, 30 years after the occurrence of an earthquake, the reduction of GDP will be about 100 thousand billion rials compared to the condition of no earthquake. Therefore, paying more attention to preventive measures, risk management, and crisis management is suggested.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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