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Estimating Optimum Value of Investment and Human Capital in the R&D Sector of Iran Using an Augmented Endogenous Growth Model

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Abstract

This article intends to estimate the optimal value of investment and human capital in R&D sector of Iranian economy using an augmented endogenous growth model. To do so, two issues have been studied. First, an endogenous growth model has been extended to include investment in R&D as an independent variable. In the framework of this model, in order to determine the optimal value of investment and human capital in R&D sector, we derived the optimal path. Second, using the optimal path and Iran's economic data, the optimal values of human capital and investment in Iran's R&D sector have been estimated. The results show that in order to be in a steady state with 8% economic growth, it's necessary to allocate 0.7% of total human capital and 8% of national income to R&D sector. However, at present, less than 0.3% of human capital and less than 0.5% of national income is allocated to R&D sector in the Iranian economy.

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1. Introduction

There exists an extensive literature dealing with the role of technology in economic growth. Although these studies employ a wide variety of analytical structures, they reach a common conclusion. The consensus of opinions emerged in these studies is that technology is one of important factors that determines economic growth. In spite of this fact, opinions on the interpretation of the quantity and the quality of the role of technology are crucially dependent on the way this variable is applied in model and the way its relation with other factors is organized. This has made it necessary for researchers to be more careful when introducing technology into their growth model.

The primary neoclassical models were developed by Solow, emphasizing the role of technology in economic growth. In Solow's model technology is an exogenous factor. Up to early 1980s other growth models that extended the Solow's model, emphasized the considered technology to be an exogenous factor.

Although the theorists of Neoclassical growth had understood the inefficiency of these types of growth models, they offered the explanation that, through innovation and invention of new technologies which will allow more production with the existing resources, countries have in effect supported the idea that technology is exogenous as well.

In the mid-1980s there appeared new growth theories under the title "endogenous growth theory", whose difference from previous theories was their emphasize on endogenous technological progress. In endogenous growth models the technology factor, which is formed in a monopoly structure in the initial stages of its appearance, is influenced by these conditions and plays its role in clarification of economic growth as an endogenous factor. Locus and Paul Romer were the first people who presented these models; they have dealt with this subject by emphasizing the issue of human capital (Locus 1984). In endogenous growth models, unlike the physical capital, human capital has an increasing return to scale, and as a result, by allocating more human capital to R&D sector, the ability to create new ideas will be enhanced; these new ideas will lead to an increase in the efficiency of human force in R&D sector. The endogenous growth models, which have introduced an independent sector for R&D, have paid a greater attention to the relationship between knowledge growth rate and the labor in R&D.

Within this framework less attention has been paid to the level of investment required for reaching a specified degree of knowledge progress, and securing the targeted economic growth rate; on the basis of the endogenous growth models, this study considers the investment in R&D sector as an independent variable, and solves the model once again. Then, by determining the optimal path, and using the data of Iranian economy, it is going to estimate the optimum level of investment and the required human capital in R&D sector in order to reach a steady state with a 6% economic growth rate.

2. Augmented endogenous growth model

In this study, as in other similar studies on endogenous growth, we will have a rather mechanical vision of technology production and consider the technological production in the same way as the production of goods and services.

Moreover, in order to realize the objectives, two kinds of simplification are carried out for solving the model and optimization; first, we assume that the function of goods production and the function of technology production are augmented functions of Cobb Douglas, in which returns to scale is not necessarily constant. Secondly we assume that the share of labor force and the share of production that is used in R&D sectors, to be exogenous. These assumptions will not make any change in the implication of the model. This model includes six variables:

1. Labor force (L)
2. Physical capital accumulation (K)
3. Technology (A)
4. Production (Y)
5. Consumption (C)
6. The capital in R&D sector (R)

This model resembles R&D model of P. Romer (1990), Brossman and Helpman (1991), and Aghion & Hewitt (1992). The difference here is that in the previous studies, investment in R&D sector was not regarded as a separate variable; while in this study investment in R&D is placed in the model as a separate variable.

For simplicity and solving the model we assumed that investment in R&D sector is considered as a percentage of production. ($R = \varepsilon Y$ that $0 < \varepsilon < 1$)

The model includes a continuous time, and the economy is two sectors. There are also two subsections under the production sector, goods and services subsection, and the other subsection namely R&D sectors, in which the additional stock of knowledge is produced. a_L is the proportion of human capital in R&D sector, and $(1\text{-}a_L)$ is proportion of human capital in goods production sector. K is the physical capital accumulation, and R is the accumulation of investment in R&D sector.

ε is a percentage of production that is dedicated to research and development. ε and a_L are exogenous and constant parameters. Applying knowledge in a single production sector does not mean that it will be left unused in the other sector; both sectors use the entire stock of knowledge. (both goods and services sector, and knowledge production sector). But the human capital and physical capital, however, are not in the same condition in this way.

The production function in time (t) will be as follows:

$$Y(t) = \left[K(t)\right]^{\alpha} \left[A(t)(1 - a_L)L(t)\right]^{1-\alpha} \tag{1}$$

In production function (equation 1), $(1-a_L)L(t)$ is the share of labor employed in production goods. α is the production elasticity with respect to physical capital ($0 < \alpha < 1$). This production function has assumed a constant return to scale.

Production of new knowledge depends on the amount of physical capital accumulation and the labor that is utilized in R&D sector, and also the level of technology. $a_L L(t)$ is the share of labor in research and development. Also R(t) is the capital accumulation in R&D sector. By assuming the augmented Cobb-Douglass function we can assume the function below for production of technology:

$$\dot{A}(t) = B\left[R(t)\right]^{\beta}\left[\alpha_L L(t)\right]^{\gamma}\left[A(t)\right]^{\theta} \tag{2}$$

That $\gamma \geq 0$ ، $B \geq 0$ ، $\beta > 0$ and B is shift parameter.

In equation (2) the parameter θ shows the effect of the current stock of knowledge in development of R&D. This effect takes place in two ways; on the one hand, past innovation might provide the instruments for smoothing the future innovation. In this way θ will be positive. On the other hand, the simplest innovation could take place before the other ones. In this situation, a greater stock of knowledge means that making a new innovation will be more difficult so θ will be negative. Because of these contradictory effects we don't assume limitations for θ in equation (2). In this study as in Solow and Ramsey model, we consider the growth rate of labor to be exogenous. However, the growth rate of labor can be assumed logistically[1]. If we assume that growth rate of labor is constant and equal to population growth rate, we will then have:

$$\dot{L}(t) = nL(t) \tag{3}$$

(n) is the growth rate of labor force, and its value is assumed to be positive.

Supposing that there is balance in goods and services market, we will have:

$$Y(t) = I(t) + C(t) + \delta K(t) + R(t) \tag{4}$$

Equation (4) indicates that production or income[2] is used in four parts:

1. Private investment in goods and services sector.
2. Private consumption.
3. Capital depreciation.
4. Capital that is used in R&D sector.

By displacing the variable in equation (4) we can rewrite equation (4) as equation (5):

$$I(t) = \dot{K}(t)$$
$$\dot{K}(t) = Y(t) - C(t) - \delta K(t) - R(t) \qquad (5)$$

In this study the changes in the physical capital accumulation are reflected in equation (5) and in comparison with similar studies, the capital that is used in R&D has been reduced from the physical capital, and defined in terms of independent variable (R(t)).

With given production, the choice between consumption and saving choices[3] is made by households with infinite life time to maximize their utility. Thus, considering the total consumption, the utility function for all household can be noted in equation (6).

$$U = \int_{t=0}^{\infty} e^{-\rho t} \frac{C(t)^{1-1/\sigma}}{1-1/\sigma} dt \qquad (6)$$

In equation (6), C is the total consumption of private sector in economy, ρ is discount rate ($\rho > 0$) and σ is relative coefficient of avoiding risks, ($\sigma > 0$).

As in Ramsey's model, it has been assumed that households consider the initial wealth, interest and wage path as already determined and choose a consumption path for maximizing the utility function (U).

3. Calculating the level of model's variables in steady state

In this section we only deal with solving the problem of optimization, with the aim of calculating growth rates, and also the optimum level of the model's variables in steady state. The maximization should be solved by considering the social welfare function and the limitations of equations (7).

$$U = \int_{t=0}^{\infty} e^{-\rho t} \frac{C(t)^{1-1/\sigma}}{1-1/\sigma} dt$$

S.t:

$$\dot{K}(t) = Y(t) - C(t) - \delta K(t) - R(t)$$

$$\dot{A}(t) = B\left[R(t)\right]^{\beta}\left[\alpha_L L(t)\right]^{\gamma}\left[A(t)\right]^{\theta} \tag{7}$$

$$Y(t) = \left[K(t)\right]^{\alpha}\left[A(t)(1 - a_L)L(t)\right]^{1-\alpha}$$

$$\dot{L}(t) = nL(t)$$

3.1. Calculating the optimum level of growth rate of variables in steady state

In order to solve the model we must optimize the Hamiltonian function in equation (8):

$$H = e^{-\rho t}\,\frac{C^{1-1/\sigma}}{1-\frac{1}{\sigma}} + \lambda_1\left[Y - C - \delta K - R\right] + \lambda_2\left[B R^{\beta}(\alpha_L L)^{\gamma} A^{\theta}\right] \tag{8}$$

λ_1 And λ_2 are the shadow price for physical capital accumulation and accumulation of knowledge. In solving the optimization problem consumption (C) is the control variable and accumulation of physical capital (K) and knowledge (A) are state variables.

With regard to first order condition we have:

$$\frac{\partial H}{\partial C} = 0 \Rightarrow C^{-1/\sigma} e^{-\rho t} - \lambda_1 = 0 \Rightarrow \lambda_1 = c^{-1/\sigma} e^{-\rho t} \tag{9}$$

By taking logarithm and then differential of equation (9) we will have:

$$\frac{\dot{\lambda}_1}{\lambda_1} = -\frac{1}{\sigma}\frac{\dot{C}}{C} - \rho \tag{10}$$

Other conditions for maximization will be as follows:

$$\frac{\partial H}{\partial K} = -\dot{\lambda}_1 \Rightarrow -\dot{\lambda}_1 = \lambda_1[\frac{\alpha Y}{K} - \delta] \Rightarrow \frac{\dot{\lambda}_1}{\lambda_1} = \delta - \frac{\alpha Y}{K} \tag{11}$$

In equation (11) we have used from derivatives of production function (equation 1) with respect to physical capital ($\frac{\partial Y}{\partial K} = \alpha\frac{Y}{K}$).

By making the equation (10) and (11) equal, we will have:

$$\delta - \frac{\alpha Y}{K} = -\frac{1}{\sigma}\frac{\dot{C}}{C} - \rho \Rightarrow \frac{\dot{C}}{C} = -[\rho + \delta - \alpha \frac{Y}{K}] \tag{12}$$

If we suppose that $\frac{\dot{C}}{C}$ is equal to g_c, from equation (12) we will have:

$$\frac{Y}{K} = \frac{\frac{1}{\sigma} g_c + \rho + \delta}{\alpha} \tag{13}$$

Steady state is a point where growth rates of variables are constant. Therefore at the steady state we should have $\dot{g}_c = 0$.[4] Considering the equation (13) we will have:

$$Ln\left(\frac{Y}{K}\right) = Ln\left[\frac{\frac{1}{\sigma} g_c + \rho + \delta}{\alpha}\right] = \text{constant}$$

By taking derivative from the above equation in steady state we have[5]:

$$g_Y^* = g_K^* \tag{14}$$

Equation (14) shows that in steady state, physical capital accumulation growth rate and production growth rate are equal.

By taking the logarithm of equation (10) we have:

$$\ln(Y) = \alpha LnK + (1-\alpha)\left[LnA + Ln(1-a_L) + LnL\right]$$

By taking derivative from above equation respect to time and also by using equations (11) and (14) we have:

$$g_Y = \alpha g_k + (1-\alpha)(g_A + n)$$

$$g_Y^* = a g_Y^* + (1-\alpha)[g_A^* + n] \Rightarrow g_Y^* = g_A^* + n \Rightarrow g_A^* = g_Y^* - n \tag{15}$$

Equation (15) demonstrates that the growth rate of knowledge in steady state is the equated difference between the growth rates of production and labor force growth rate.

By dividing equation (5) by K we have:

$$\frac{\dot{K}}{K} = \frac{Y}{K} - \frac{C}{K} - \delta - \frac{R}{K} \tag{16}$$

According to the assumption of model, investment in R&D sector is a fraction of production. Thus we have:

$$R(t) = \varepsilon Y(t) \tag{17}$$

By replacing equation (13) and (17) in equation (16) and a few simplifications we will come to:

$$\frac{C}{K} = [-g_k + \frac{(1-\varepsilon)}{\alpha}[\frac{1}{\sigma} g_c + \rho + \delta] - \delta] \tag{18}$$

Equation (18) shows that with a constant coefficient, consumption should change with respect to physical capital accumulation, or the proportion ratio of consumption to capital accumulation remains at a constant level.

Given that, in steady state, the value of g_c and g_k are constant, the right side of the equation (18) is constant as well. By taking logarithm and after that taking derivative with respect to time we will have:

$$g_c^* = g_k^* \tag{19}$$

The summary of equations and the results of solving the model can now be summarized as follows:

$$\begin{aligned} & g_c^* = g_k^* = g_Y^* = g_R^* = g^* \\ & g_A^* = g^* - n \end{aligned} \tag{20}$$

Equation (20) indicates that, in a steady state, consumption growth rate g_c^*, production growth rate (g_Y^*), physical capital accumulation growth rate (g_k^*) and growth rate of investment in R&D must be equal.

We will next try to get the growth rate (g^*) in steady state[6]. Considering equation (9), we will have:

$$\frac{\dot{A}}{A} = g_A = B\,R^{\beta}\ [a_L L]^{\gamma}\ A^{\theta\text{-}1} \tag{21}$$

By taking logarithm and derivative with respect to time and provided that the long term growth rate is constant[7], we will have:

$$g^* = \frac{n(\theta - 1 - \gamma)}{\beta + \theta + 1} \tag{22}$$

Equation (22) shows the long run growth rate in a steady state. Given the equation (20) and (22), the long run knowledge growth rate will be equal to:

$$g_A^* = \frac{-n(\gamma + \beta)}{\beta + \theta - 1} \tag{23}$$

Equation (23) shows the long run knowledge growth rate.

3.2. Calculating the level of model's variables in steady state

Considering the equation (18) we will have:

$$\frac{C}{K} = [g^*(\frac{1-\varepsilon}{\alpha\sigma} - 1) + \frac{(1-\varepsilon)(\rho+\delta)}{\alpha} - \delta] \tag{24}$$

With the use of simplification for solving the model and calculating the level of variables in steady state (C^*, K^*, Y^*), we assume that technology is labor-augmenting. According to production function (equation 9) we have $\theta = \gamma$. Based on this assumption in steady state, the long run economy growth rate will be equal to:

$$g^* = \frac{n}{1-(\beta+\theta)} \tag{25}$$

By doing a few mathematical calculation and simplification we will have the level of production in a steady state equal to:

$$Y^* = [(1-a_L)^{\alpha-1}\ \varepsilon^{\frac{\beta(1-\alpha)}{\theta}}\ \ \tau_1^{\frac{1-\alpha}{\alpha}}\ \ \ \tau_2^{\alpha}]^{\omega} \tag{26}$$

In equation (26), Y^* is level of production at a steady state point. In equation (26) the values of τ_1, τ_2 and ω are defined in equations (27) to (29):

$$\tau_1 = (\frac{Ba_L^{\gamma}}{g^* - n}) \tag{27}$$

$$\tau_2 = (\frac{\frac{1}{\sigma}g^* + \rho + \delta}{\alpha}) \tag{28}$$

$$\omega = \frac{\theta}{\alpha\theta - \beta(1-\alpha) - 1} \tag{29}$$

Taking the equation (13) and (26) into consideration we will have:

$$K^* = \frac{\alpha}{\frac{1}{\sigma}g^* + \rho + \delta} Y^* \tag{30}$$

In equation (30), K^* is the level of physical capital accumulation in steady state.

According to equation (24) we come to:

$$C^* = [\frac{(1-\varepsilon)}{\alpha}\left[\frac{1}{\sigma}g^* + \rho + \delta\right] - \delta - g^*]\ K^* \tag{31}$$

In equation (31) level of K^* is calculated from equation (30). Equation (31) shows optimum level of consumption in steady state.

3.3. Calculating the optimum level of saving rate in steady state

Since the model is bisectional, the household income is either consumption or saved. So we can insert the equation (32), which shows that saving is equal to household consumption subtracted from gross domestic production (Household income).

$$Y = S + C \Rightarrow S = Y - C \tag{32}$$

Consumption (C^*) is taken from equation (31) and income (Y^*) is taken from equation (30) in equation (32).

$$S = Y - C = K\left(\frac{\frac{1}{\sigma}g + \rho + \delta}{\alpha}\right) - \left[\frac{(1-\varepsilon)(\frac{1}{\sigma}g + \rho + \delta)}{\alpha} - \delta - g\right] K \qquad (33)$$

By simplification and according to equation (30), equation (34) will be achieved in a steady state.

$$S = \frac{\alpha}{\frac{1}{\sigma}g + \rho + \delta}\left(\frac{\varepsilon(\frac{1}{\sigma}g + \rho + \delta)}{\alpha} + \delta + g\right)Y \qquad (34)$$

Considering the equation (34), after simplification, the saving rate in steady state calculated according to equation (35) is

$$s^* = \varepsilon^* + \frac{(\delta + g^*)\alpha}{\frac{1}{\sigma}g^* + \rho + \delta} \qquad (35)$$

Based on equation (35), since the model is an endogenous growth model, saving rate is not a constant value; it is the function of the model's parameters.

$$s^* = s(\varepsilon^*, g^*, \delta, \alpha, \sigma, \rho) \qquad (36)$$

The optimum level of saving rate for Iran's economy has been calculated in section 4.3.

4. Estimating the optimum level of variables for Iran's economy[8]

In this section, using the statistical data from Iran's economy we calculated the model's variables at the steady state. Also according to given parameters, the optimum level of human and physical capital allocated to R&D sector in Iran's economy is analyzed.

The steady state can be analyzed in two ways:

1. Inserting the value of parameters in the model and calculating the level of those variables in the steady state. With given current economic

situation and the initial level of variables, we should analyze different policies for placing economy on saddle path and leading it towards a steady state.

2. By changing the value of policy parameters, we can shift the stability curves and, hereby shift the steady state point. We assumed that the level of current variables is at the steady state; then we found the level of various policy parameters. The magnitude of every parameter that is calculated at this point is called the optimum value of that parameter in steady state.

In this study we are going to calculate the parameters similar second way. In order to attain the optimum values of policy parameters in steady state, we have to assume that economy is in a steady state. According to values of the current economy variable, we have analyzed the optimum values of parameters. Concerning this paper, those policy parameters that we are going to find the optimum values of them are:

1. The share of optimum level of investment in R&D sector, or investment rate in R&D sector (ε^*).

2. The share of optimum labor in R&D sector (a_L^*).

3. The optimum long run saving rate (s^*).

4.1. Estimating the optimum share of investment in R&D sector

In this section, based on various levels of growth rates, the share of investment in R&D sector is calculated. Considering the equation (31) and based on the levels of variables and the value of model's parameters, the long run growth rate is definite in equation (37).

$$g^* = \left[\frac{C^*}{K^*} + \delta - \frac{(\rho + \delta)(1 - \varepsilon)}{\alpha} \right] \left(\frac{\alpha\sigma}{1 - \varepsilon - \alpha\sigma} \right) \qquad (37)$$

In equation (37), the levels of C^*, K^* are the respective levels of private sector's consumption and physical capital accumulation in a steady state. It has been assumed that economy is in a steady state and we want to calculate the optimum level of the model's parameters. So, we used the values of these variables using Table (1).

Table 1. The parameters for calculating the optimum level of $\varepsilon *$

Parameter	Values	Source
Production elasticity respect to physical capital (α)	0.3	Research calculation[9]
Relative risk aversion coefficient (σ)	0.09	Different articles[10]
Discount rate (ρ)	0.2	Assume that it is equal to interest rate[11]
Depreciation rate (δ)	0.1	It has been assumes that physical capital will depreciate within 10 years[12]
Consumption (C), (Billion Rials)	344852	Private sector's consumption in the years 2008 (central bank of Islamic Republic of Iran)
Physical capital accumulation (K), (Billion Rials)	159598	Physical capital accumulation in 2008 (central bank of Islamic Republic of Iran)[13]

The value of parameters considered in Table 1, have been substituted in equation (37). The share of investment in R&D sector from production ($\varepsilon *$) are drawn in Figure (1) according to long run growth rate (g^*).

According to Figure (1), in order to have a higher growth rate in steady state, the rate of investment in R&D sector should be higher. If we take the growth rate in steady state to be 8 percent[14], the optimum rate of investment in R&D sector should be also 8% of production.

In next section, the economy growth rate will be taken as 8% ($g^* = 0.08$) and the optimum rate of investment in R&D sector will be equal to 8% of total production ($\varepsilon^* = 0.08$).

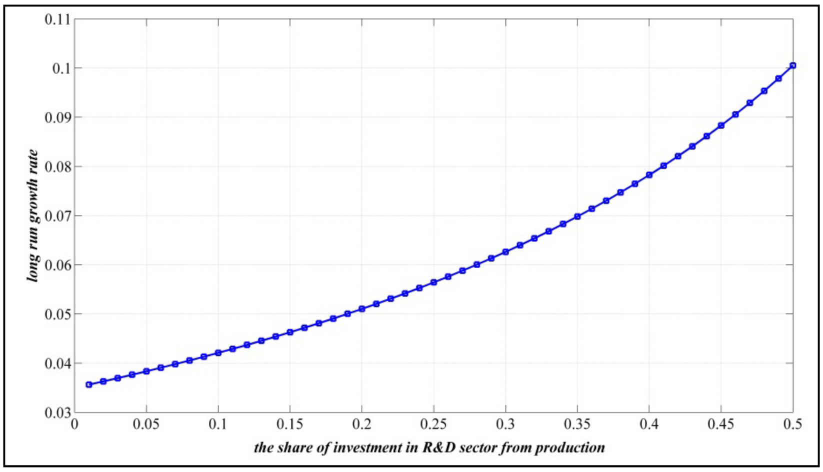

Figure 1. The share of investment in R&D sector ($\varepsilon *$) with respect to long run economy growth rate (g^*)

4.2. Estimating the optimum share of labor in R&D sector of total labor

In this section, we used the values obtained in section 4.1 and calculated the share of labor in R&D sector. In order to calculate the share of labor force in R&D sector, we should carry out an analysis and calculation of the other parameters of the model.

By replacing the variable, and a few simplifications, equation (29) can be rewrite as equation (38)

$$\beta+\theta=\frac{g^*-n}{g^*} \tag{38}$$

In view of the fact that population growth rate in Iran is approximately constant and is almost equal to 1.5 percent ($n=0/015$)[15], and also considering the 8% growth rate in steady state and relation (38), we will have: $\beta+\theta=.75$

According to equation (9) and given that $\gamma=\theta$, then $\beta+\theta$ will give us returns of knowledge ($\dot{A}(t)$) respect to effective labor force in R&D sector ($\alpha_L L(t)A(t)$), and investment in R&D ($R(t)$). Considering the assumption of this study we have a decreasing return to scale in knowledge production. ($\beta + \theta = .75$)

The value of current knowledge elasticity of knowledge stock (θ) and current knowledge elasticity of investment in R&D (β) should be specified in a way that total values of them been 0.75.

Following that a_L^* [16] has been calculated, two scenarios have been defined for that calculation. The value of these scenarios' parameters have been summarized in Table (2). In the first scenario β [17] is considered to be less than θ [18]. In the second scenario, however, β is larger than θ.[19]

In the case of Iran, it can be assumed that the labor in production of technology is more important with respect to investment. Therefore, we go for scenario 1 and calculate the share of optimum labor in R&D sector in steady state.

Table (2): parameters for calculating the share of optimum labor in R&D

Parameter	**Value**	
	Scenario 1	Scenario 2
Knowledge elasticity of investment in R&D (β)	0.25	0.5
Current knowledge elasticity of stock of knowledge (θ)	0.5	0.25
Long run growth rate (g^*)	0.08	0.08
Share of investment in R&D sector of total production (ε^*)	0.08	0.08
Production elasticity of physical capital (α)	0.3	0.3
Risk aversion coefficient (σ)	0.09	0.09
Discount rate (ρ)	0.2	0.2
Depreciation rate (δ)	0.1	0.1

Given the two scenarios, we substitute the value of parameters from Table (2) into equation (26). Based on the share of labor in R&D (a_L^*), the different levels of production in steady state (Y^*) (for both scenarios) are drawn in Figure (2).

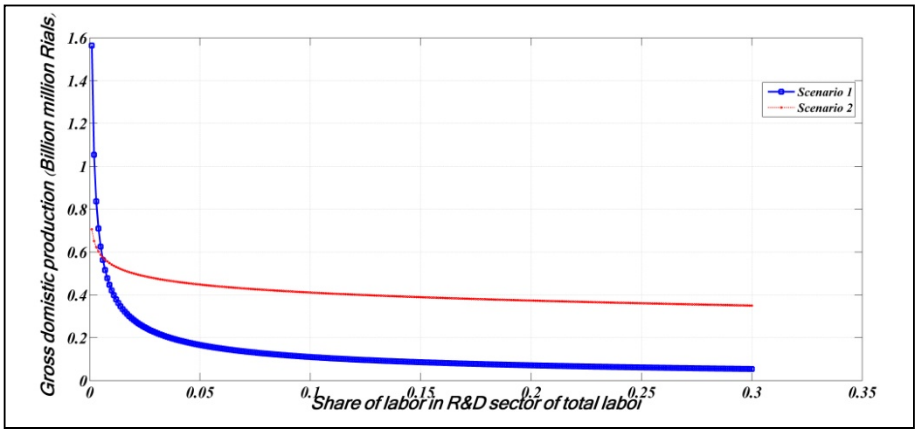

Figure 2. The relationship between the share of labor force in R&D sector (a_L^*) and production in steady state (Y^*)

This graph is descending; it means that economies with low production or developing countries should have a greater share of labor in R&D, than developed countries.

Concerning Figure (2), in order to acquire (a_L^*) we should first calculate the levels of Y^* in steady state. Given equation (30), and by performing some mathematical calculation, the equation (39) will be achieved.

$$Y^* = K^* \times \frac{\frac{1}{\sigma}g^* + \rho + \delta}{\alpha} \tag{39}$$

Given the value of parameters stated in Table (3) and equation (39), the optimum level of production (Y^*) is measured. This level is equal to $Y^* = 514260$ billion Rials in steady state. Considering the Figure (2) and having the level of Y^*, we can find the amount of a_L^*. In scenario 1 the optimum amount of a_L^* is measured to be equal to 0.7 percent. In scenario 2 this value will be 2 percent. Since we have chosen the first scenario for Iran's economy, we take the value of a_L^* at 0.7 percent. It means that in steady state 0.7% of labor should be applied to R&D sector.

Table (3): parameters for estimating optimum production in steady state

Parameter	Value
Long run growth rate (g^*)	0.08
Production elasticity of physical capital (α)	0.3
Relative risk aversion coefficient (σ)	0.09
Discount rate (ρ)	0.2
Depreciation rate (δ)	0.1
Physical capital accumulation (K), (Billion Rials)	159598

4.3. Long run optimum saving rate (s^*)

In this section we calculate the optimum saving rate in steady state, using the calculated in section 3-3.

Taking equation (35) and the value of parameters in Table (3) into account, in Figure (3) we have drawn various amount of optimum long run saving rate (s^*) based on the share of investment in R&D sector (ε^*) in steady state. According to Figure (3) the greater ε^* that we have in steady state, the less consumption and greater s^* we should also have. This is economically justifiable issue. This is due to the fact that model is bisectional, and investment in R&D sector comes from the saving of private sector. In previous sections ε^* was estimated to be 0.28 in steady state. Figure (3) indicate that the optimum long run saving rate in steady state should be 0.34 or 34%.

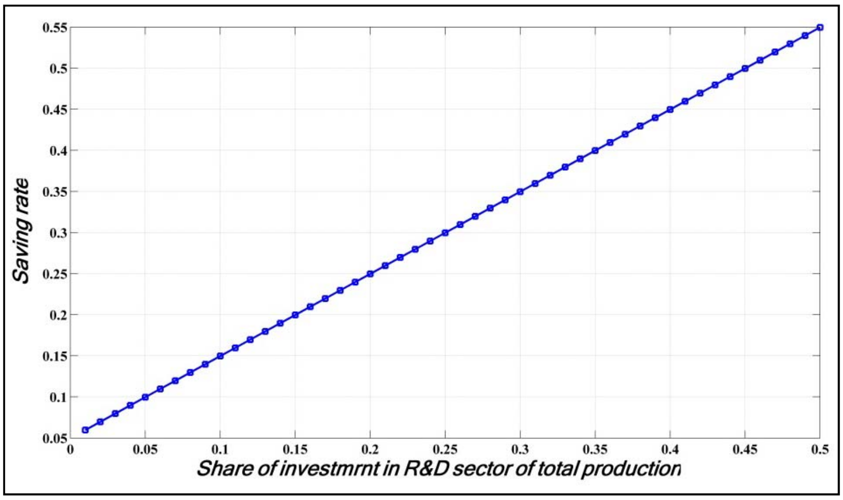

Figure 3. Long run saving rate (s^*) based on share of investment in R&D sector (ε^*)

5. Conclusion

In this study, through using an augmented endogenous growth model in which it is assumed that R&D sector is independent, we have considered the role of investment variables in that sector as separate part, and by solving that model, the optimum point in a steady state was planned. By using this optimum point and by applying the output data of Iran's economy we estimated the optimum share of investment in R&D of total production and required labor for R&D sector of Iran's economy with the aim of reaching steady state with an economic growth rate of 8 percent.

The results show that:

a) In order to reach higher economic growth rate, the level of investment in R&D sector should increase. In order to secure more investment in R&D sector, the saving rate should be increased.

b) To reach steady state, those countries that have low production (e.g. developing countries) should apply more labor in R&D sector than the developed countries.

After solving the model, we calculated the parameters at steady state. Using the data of Iran's economy. Based on these findings, if we consider the economic growth rate of Iran's economy to be 8 percent, the optimum investment in R&D should be set at 8 percent of national income (without oil export). Also, at this level of economic growth rate the labor required for R&D sector should be placed at 0.7 percent of total labor of economic. What is more important is that if we want to achieve 8 percent growth level, we have to allocate 34% of national income to saving.

Endnotes

1. Logistical labor is measured in this equation: $\dot{L}(t)=L(t)(a\text{-}bL(t))$. which means that labor can not rise infinitely, and has a maximum limit.
2. It is assumed that economy is in a balance.
3. It is assumed that household savings are equal to investment. This assumption is true for two sectors models.
4. It means that derivative of growth rate with respect to time is zero, and the growth rate is constant.
5. $g_K = \frac{\dot{K}}{K}$ and $g_Y = \frac{\dot{Y}}{Y}$
6. $g_c^* = g_k^* = g_Y^* = g_R^* = g^*$
7. Derivative with respect to time is equal to zero $(\dot{g}_A = 0)$.
8. This section is an application of the calculations done in section 3.
9. A study done by the Central Bank of Islamic Republic of Iran (Reference number 20) shows that elasticity of production is estimated to be 0.42. But we estimate this coefficient equal to 0.3. However, a sensitivity analysis is carried out in section 5 for production elasticity of 0.42.
10. Most of the articles on coefficient of risk aversion in agricultural sector had been estimated. This value is an average of the statistics by those articles.
11. The value of this parameter estimated 0.07 in the reference No. 1. In section 5 the effects of optimum values of variables have been analyzed for different rate of this parameter.

12. In section 5 of this article an analysis has been shown, which shows that the depreciation rate does not have a considerable effect on calculations.
13. It is necessary to note that the levels of consumption and physical capital accumulation are based on the statistical data of 2007. According to equation (37) the ratio of these two variables must considered here. Since the growth rates of these two variables will be equal in steady state, and the ratio will remain constant in the time.
14. The average rate of annual growth rate in the forth development plan, is considered to be 8 percent.
15. It is assumed that the growth rate of labor is equal to population growth rate.
16. Share of labor force in R&D sector of total labor.
17. Knowledge elasticity of investment in R&D.
18. Current knowledge elasticity of stock of knowledge.
19. In both scenarios there is decreasing returns to scale, and its value is $\beta+\theta=.75$. In the first scenario, the current knowledge elasticity of investment in R&D is smaller, and in the second scenario, the current knowledge elasticity of investment in R&D is larger.

References

Abdoli, G. (2010). An estimation of discount rate for Iran. *Economic Research*, 9 (3), 135-186.

Acemoglu, D. (1996). A microfoundation for social increasing returns in human capital accumulation. *Quarterly Journal of Economics*, 111, 779-804.

Aghion, P. & Howitt, P. (1998). *Endogenous growth theory*. Cambridge MA: MIT Press.

Barro, R. J. & Sala-i-Martin X. (1995). *Economic growth*, New York: McGraw-Hill.

Frantzen, D. (2000). R&D, Human capital and international technology spillovers: A cross country analysis. *Scandinavian Journal of Economics,* 102 (1), 57-75.

Iran's Center of Statistics, *Annual of Iran's Statistics*, different years.

Lucas R. E. J., Nancy L. & Stokey, F. (1984). Optimal growth with many consumers. *Journal of Economic Theory*, 32(1), 139-171.

Lucas, R. E. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, 10, 3-42.

Mankiw, N., Romer, D. & Weil, S. (1992). A contribution to the empirics of economic growth. *Quarterly Journal of Economics,* 107, 112-128.

Motevaseli, M. (1991). *Investment in human capital and economic development*. Monetary and Banking Research Institute, Tehran.

Nelson, R. & Phelps, E. S. (1966). Investment in humans, technological diffusion and economic growth. *American Economic Review*, 56 (1/2), 69-75.

Rabiee, M. (2010). The effect of innovation and human capital on economic growth in Iran. *Journal of Knowledge and Development*, 16, 26.

Romer, P. (1990). Endogenous technological change. *Journal of Political Economy*, 98(2), 71-102.

Romer, P. M. (1990). Endogenous technical change. *Journal of Political Economy*, 98, 71-102.

Romer, P. M. (1986). Increasing returns and long run growth. *Journal of Political Economy*, 94, 1002-37.

Romer, P. M. (1994). The origins of endogenous growth. *Journal of Economic Perspectives*, 8, 3-22.

Salehi, M. J. (2003). The Effect of Human Capital on Iran's Economic Growth. *Journal of Research and Planning in Higher Education*, 23 (24), 43-73.

Schumpeter, J. A. (1934). *The theory of economic development*. London: Transaction Publishers.

Sobhani, H. (2003). Efficiency of Education Investments. *Journal of Economic Research*, 45, 76-89.

The central bank of Islamic Republic of Iran, *Economic Report and Balance Sheet*, different years.

The central bank of Islamic Republic of Iran, (2006). *A collection of economic research, An analysis of productivity in Iran's economy.*