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## Article

# Does the distribution of R&D incentive among production factors matter? A dynamic general equilibrium model for Türkiye

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# Does the distribution of R&D incentive among production factors matter? A dynamic general equilibrium model for Türkiye

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## Abstract

**Purpose** – This study aims to explain the effect of research and development (R&D) incentives on economic growth, focusing on the case of Türkiye. A one-sector endogenous growth model has been constructed. The model includes three actors: firm, consumer and government. The consumer derives utility from consumption, supplies human capital and engages in saving. The representative firm invests in R&D to maximize the current value of profit flows by choosing how much input it will use and how much R&D it will undertake. The public sector provides incentives for labor and capital used in R&D production. R&D has been defined as a function that endogenously increases total factor productivity (TFP).

**Design/methodology/approach** – In line with the stated purpose, this study presents a dynamic general equilibrium model. Then, this study calibrates the model parameters with Türkiye's data.

**Findings** – The results imply that incentives for R&D personnel instead of physical capital have a stronger impact on economic growth.

**Practical implications** – The findings of this study point to an important conclusion on how to distribute R&D incentives across the two main factors in R&D production, labor and capital. Incentives given to R&D personnel are more effective in Türkiye.

**Originality/value** – This study shows that the R&D incentives provided by the public sector can be important in emerging countries where many firms have just started their R&D activities. In this study, the authors worked on Türkiye as an emerging country. This study discusses policies on how the R&D incentives will be more effective on economic growth in Türkiye. This study considers that these policies may apply to all emerging countries, due to similar R&D activities in countries that cannot export technology and mostly import technology.

**Keywords** One-sector growth model, Research and development, Technological change, Government policy, Dynamic general equilibrium

**Paper type** Research paper

## 1. Introduction

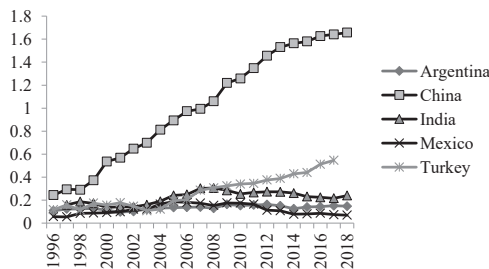
A productive innovation ecosystem is needed to engage in R&D activities, improve innovation performance and make them sustainable. The innovation ecosystem gets stronger



with skilled labor and technology investments. Therefore, it is not a coincidence that innovation performance is higher in developed countries. The effects of R&D expenditures in developing countries do not always yield positive results. The reason for this is that the already limited innovation capacity of developing economies cannot reach the necessary support in terms of relevant institutions and resources (Kleiner-Schäfer and Liefner, 2021; Wan *et al.*, 2022). According to Aubert (2005), R&D and innovation initiatives in emerging economies get negatively affected by the low level of education and ineffective information infrastructures in those economies. Aubert (2005) claims that this prevents the formation of a powerful private sector, especially in emerging economies while weakening the innovation ecosystem.

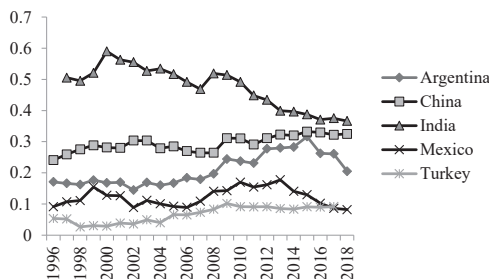
Most R&D activities in emerging economies are carried out by the private sector in recent years. The share of Gross Domestic Expenditure on R&D (GERD) in the gross domestic product (GDP) data for selected emerging economies are shown in Figures 1 and 2. These figures support the claim that the private sector leads to R&D expenditures in developing countries.

In emerging economies, where most of the R&D activities are conducted by a weak private sector, an important part of the technology need is met by foreign direct investments (FDI). The impact of imported technology on the innovative performance of emerging countries has been discussed widely in the literature. Most of the studies indicate that technology import made through the FDI channel positively affects innovation performance (Coe and Helpman, 1995; Kokko, 1996; Coe *et al.*, 1997; Liu and Wang, 2003; Sinani and Meyer, 2004; Salomon and Shaver, 2005; Zhang, 2017). Regarding the effect of technology import on technology production in developing economies, Wang and Kafouros (2009) emphasize that FDIs do not



**Source(s):** UNESCO (Science, technology, and innovation)

**Figure 1.**  
GERD performed by  
the business enterprise  
as a percentage of GDP



**Source(s):** UNESCO (Science, technology, and innovation)

**Figure 2.**  
GERD performed by  
the government as a  
percentage of GDP

reduce the need for R&D in these countries. Therefore, technology import acts as an input to produce new technologies in developing countries. In other words, the technology export of these countries is based on technology import.

In this study, a growth model for a closed economy, that is, a growth model without technology imports is constructed. The aim is to identify how the public sector should support R&D in an economy that grows with its R&D activities and is not dependent on FDI for growth. For this purpose, an R&D production function has been stated and a growth model in which this production function affects economic growth endogenously has been constructed. In the R&D production function, apart from the final production function, the efficiency of the R&D personnel and R&D capital in technology and innovation production has been determined. The determination of the effectiveness of R&D production factors is important to produce a policy for regulating the distribution of R&D incentives between R&D personnel and R&D capital.

## 2. Literature review

In the Romer model, which is regarded as the pioneer in the literature of R&D-based growth models, R&D is embedded in an industry that creates a patent and sells it to the intermediate goods sector. This patent, produced by the R&D sector, is used in the production of final goods with human and physical capital (Romer, 1990). In other words, there is a horizontal interaction between the sectors in the Romer model. Following Romer's model, Aghion and Howitt (1990) and Grossman and Helpman (1993) proposed R&D-based growth models. These three models have asserted that the increase in the labor force that will work in the R&D sector will positively affect growth in the long term. R&D has been addressed as a sector producing innovation and patents in the three models. There are similar and opposing perspectives in the literature. For instance, R&D has been modeled as a firm's expenditure to provide resources for innovation and productivity instead of a sector producing innovation and patent (Wakelin, 2001; Coad and Rao, 2010; Ngai and Samaniego, 2011; Coe and Helpman, 1995; Audretsch and Feldman, 1996).

The relationship between R&D expenditures and growth and the effects of R&D incentives at the firm and sector levels have been examined in the literature. We will first summarize the studies on the relationship between R&D expenditures and growth. We will then review the literature on the effects of R&D incentives on firms and the sector, specifically in the third section of the study. Many studies have revealed that R&D expenditures are effective on economic growth. Sample literature showing such studies is presented in Table 1.

Many studies conclude that R&D expenditures generate an increase in TFP and thus economic growth. Hence to ensure economic growth, the R&D activities of the firms are increased. Such activities increase the costs of the firms. To cover costs, public support policies have been developed where a part of the R&D expenditures of the firms are matched by the public. The number of studies modeling the effect of public support policies on economic growth with a theoretical approach is low. In these studies, R&D incentives are generally divided into two categories as direct and indirect incentives, and the effectiveness of these incentives on economic growth is investigated. In the study by Ghosh (2007), a dynamic general equilibrium model with a multi-sectoral endogenous growth model was built to measure the effect of alternative R&D policies, and the model was calibrated with the data of Canada. The results obtained from the study showed that R&D incentives had a positive effect on the increase in productivity in the Canadian economy. Bye *et al.* (2009) calibrated a small open economy general equilibrium model calibrated with Norwegian data. It was found that R&D incentives for the formation of capital provided low R&D intensity, but they resulted in growth and an increase in welfare compared to direct R&D incentives. Segerstrom (1991) built a dynamic general equilibrium model with a different approach and

				Distribution of R&D incentives
Author/ Authors	Sample	Method	Results	
Mansfield (1972)	USA	Descriptive analysis	Positive effect on economic growth	<b>589</b>
Freire-Seren (2001)	21 OECD Countries	Panel Regression	Positive effect on economic growth	
Zachariadis (2004)	13 OECD Countries	Panel System Estimation	Positive effect on TFP	
Cameron <i>et al.</i> (2005)	14 Manufacture Industry from the UK	Equilibrium Correction Model (ECM) and Autodistributed Lag (ADL)	Positive effect on TFP	
Křístková (2012)	Czechia	Computable General Equilibrium	Positive effect on economic growth	
Inekwe (2015)	66 Countries with different income levels	Generalized Method of Moments (GMM)	It has no impact in low-income countries but is positive in middle-high-income countries	<b>Table 1.</b> R&D expenditure-growth relationship: sample literature
<b>Source(s):</b> Authors' compilation				

divided the firms that carry out R&D activities as innovative firms and firms following these firms as forger firms. It was found in the model that incentives for innovation have a positive effect on growth.

Cheng and Tao (1999) have calibrated a small open economy general equilibrium model by Segerstrom (1991) with Slovenian data. In this study, where R&D has been modeled as an endogenous growth element, two different results emerged in the case of R&D function being linear and convex. In the model with a linear R&D function, the effects of R&D incentives were unclear while in the case of a convex function, the R&D incentives were found to promote production. Bor *et al.* (2010) have calibrated the dynamic general equilibrium model they constructed for Taiwan and found that public R&D incentives will provide resources for economic growth via technological development and human capital impacts. In this study, it has been investigated which of these incentives is more effective on economic growth in a situation where public R&D incentives are given to R&D personnel and R&D capital in a closed economy.

### 3. The model

The model has three agents. These are sector-representative firms, consumers and the government. The functional relationships between these three actors in the economic model can be listed as follows:

- (1) The consumer maximizes their utility and obtains wages by supplying labor to the firm. A part of this wage is paid for the goods and services provided by the firm. Saving finances capital accumulation and capital income is obtained from the firms in this way. Additionally, income tax is paid to the government, which is the third agent of this model.
- (2) The firm maximizes profit. The supply labor by the consumer is equal to the demand of labor by the firm. The firm pays the wage arising from this equilibrium to the consumer. The same situation is valid for capital supply (savings) and the capital demand of the firm. The firm pays the interest rate arising from capital market equilibrium to the consumer as a price for renting. In addition to these payments, a certain percentage of the profit obtained is paid to the public sector as corporate tax. The revenue of the firm is

the goods and services purchased by the consumer and the public sector. Another source of income for the firm is the incentives provided by the public sector.

- (3) The government funds the incentives and public expenditures with the income tax obtained from the consumer and the corporate tax levied on the profit of the producer.
- (4) All supplies and demands are equal for the producer and the consumer in the model. A balanced budget has been ensured with collected taxes, provided incentives and public expenditures.

Numerical solutions of the model have been performed in Dynare (Juillard *et al.*, 1996) run under Octave (Eaton *et al.*, 2012). This software combination offers a numerical solution to dynamic general equilibrium models by including the necessary equation systems after introducing the model's parameters, endogenous variables and exogenous variables to the system. The distinction between endogenous and exogenous variables is quite important in the analysis of the model, for the concepts of endogeneity and exogeneity can directly affect the outcome of the model simulation.

### 3.1 Firm

The firm aims to increase TFP by making R&D expenditures while maximizing the current value of all profits achieved during its existence. R&D is an endogenous process aiming to increase the productivity of the production in the firm and is defined as follows:

$$RD_t = Q_t^\theta N_t^{1-\theta} \quad (1)$$

$RD_t$  is R&D production at time  $t$ ;  $Q_t$  represents the physical capital stock used in R&D;  $N_t$  represents the number of labor used in R&D production, and  $\theta$  is the capital share in R&D production. In the model, the final good production function is in the form of a Cobb–Douglas production function.

$$Y_t = A_t K_t^\alpha L_t^{1-\alpha} \quad (2)$$

$Y_t$  represents the final good production amount of the firm, and  $K_t$  and  $L_t$  represent the physical capital and labor force used in the production of final goods, respectively.  $\alpha$  is a parameter indicating the share of capital used in the production of final goods.

It is assumed that the R&D expenditures,  $RD_t$ , directly translate to TFP, represented via  $A_t$ , as follows:

$$A_t = RD_t = Q_t^\theta N_t^{1-\theta} \quad (3)$$

As in equation 1,  $Q_t$  represents the stock of physical capital,  $N_t$  represents the number of labor and  $\theta$  represents the share of capital in R&D production. We have notationally replaced  $RD_t$  and  $A_t$ . Making this substitution in the production function:

$$Y_t = RD_t^\psi K_t^\alpha L_t^{1-\alpha} \quad (4)$$

where we introduce  $\psi < 1$  as a parameter that indicates that the R&D has diminishing impact on the production of final output. Given these specifications, the firm's nominal profit function at time  $t$ , is as follows:

$$\pi_t = [Y_t - (w_{1,t}L_t + (1 - \tau_{s,t})w_{2,t}N_t) - (r_{1,t}K_t + (1 - \tau_{q,t})r_{2,t}Q_t)](1 - \tau_{p,t}) \quad (5)$$

$\pi_t$  represents profit at time  $t$ ;  $r_{1,t}$  represents the interest rate to be paid on the capital used in the production of final goods;  $r_{2,t}$  represents the interest rate to be paid on the capital used in R&D production;  $w_{1,t}$  represents the wage paid to the labor used in the production of final

goods; and  $w_{2,t}$  represents the wage paid to the labor used in R&D production. In the model, labor used in the R&D production function is denoted by  $N_t$ , and capital used in the R&D production function is denoted by  $Q_t$ . The public sector provides firms with R&D incentives as much as  $\tau_{s,t}$  for qualified labor  $N_t$  and  $\tau_{Q,t}$  for capital  $Q_t$  used in R&D production.  $\tau_{p,t}$  represents the corporate tax collected on the profit of the firm.

### 3.2 Consumer

The intertemporal utility function of the consumer is based on a constant relative risk aversion form as follows:

$$\sum_{t=0}^{\infty} \beta^t \frac{c_t^{(1-\varphi)} - 1}{1 - \varphi} \quad (6)$$

where  $c_t$  represents the consumption demand,  $\beta$  is the utility discount parameter and  $\varphi$  represents intertemporal substitution. The consumer faces a budget constraint, defined as follows:

$$c_t + s_t \leq [w_{1,t}L_t + w_{2,t}N_t](1 - \tau_m) + (1 + r_t)s_{t-1} + \pi_t \quad (7)$$

The labor supplied by the consumer to the firm,  $LS_b$ , is exogenous. The labor supply of the consumer is met by the firm's demand and the available labor is employed in two different ways. The firm uses a part of this labor supply in the R&D production ( $N_t$ ) and the other part in the final good production ( $L_t$ ). Therefore, the firm makes two different wage payments to the consumer identified through  $w_{1,t}$  and  $w_{2,t}$ . The consumer pays an income tax,  $\tau_m$ , to the public sector over these wages. The consumer buys services with some of its remaining wage ( $c_t$ ) and saves the remaining part ( $s_t$ ).  $s_{t-1}$  on the income side of [equation 7](#) shows the previous period savings of the consumer. The savings made by the consumer in period  $t-1$  were covered as income in the consumer's budget in period  $t-1$ . Also on the income side of the consumer budget,  $\pi_t$  is the residual net profit received from the firm.

### 3.3 Government

The government finances expenditures, including the incentives it provides to firms, with the taxes it collects. Also, there is no public borrowing and the government budget is balanced. Tax revenues consist of production tax collected from firms and income taxes collected from consumers. The public provides R&D incentives ( $T_{D,t}$ ) to firms with these tax revenues. The government provides incentives for R&D only. Therefore, the public R&D incentive expenditure equation is as follows:

$$T_{D,t} = \tau_{s,t}(w_{2,t}N_t) + \tau_{q,t}(r_{1,t}Q_t) \quad (8)$$

Income tax collected out of wage income is:

$$T_{m,t} = [w_{1,t}L_t + w_{2,t}N_t]\tau_m \quad (9)$$

Out of the profits made, tax collection is done as:

$$T_{p,t} = \tau_{p,t}\pi_t \quad (10)$$

### 3.4 Closure of the model

The model has a balanced government budget:

$$T_{D,t} + G_t = T_{m,t} + T_{p,t} \quad (11)$$

Regarding the asset market equilibrium, savings done by the consumer finance the physical capital used in the production of final goods and the capital used in R&D activities. That is;

$$S_t = K_t + Q_t \tag{12}$$

Labor market equilibrium is such that the labor demand by the firm for final output production and R&D activities are met by the consumer's supply of labor. Labor demand is equal to the sum of demand for final output production and R&D activities, i.e.  $LD_t = L_t + N_t$ . With no demographic dynamics and inelastic labour supply, this demand is equal to an exogenous labor supply,  $LS_t$ . Hence;

$$LD_t = LS_t \tag{13}$$

4. Calibration and scenario analysis

The model has been calibrated with the data collected from Türkiye. Model parameters have been calculated by giving hypothetical values to some parameters depending on the data of Türkiye. Data from 2015 were used due to the year being a relatively recent year devoid of economic tribulations. Hence year 2015 is a good candidate for a representative point on a steady state. The basic data of Türkiye for 2015 are shown in Table 2.

Given model calibration, three scenarios are investigated through the numerical solution of the model's steady state. The first scenario considers increasing the R&D capital incentives,  $\tau_{q,t}$ . The second scenario focuses on increases in R&D labor incentives,  $\tau_{s,t}$ . The third scenario considers simultaneous increases. For each case, the model is solved for different values of the parameter investigated. That is, under Scenario 1, the model's steady state is solved for different values of  $\tau_{s,t}$ . By examining numerical solutions for different variables of the model, the impact of these two policy alternatives is investigated. It should be emphasized that the numerical solutions refer to steady states. That is, transitional dynamics between steady states are not discussed.

Table 2.  
Calibration data  
(Türkiye, 2015)

Symbol	Database	Definition	Amount
C	TURKSTAT (National Accounts)	Household Consumption Data	1,412 (billion TL)
G	TURKSTAT (National Accounts)	Public Expenditure	325 (billion TL)
K	International Monetary Fund (IMF)	Capital Stock	3,707 (billion TL)
r <sub>1</sub>	Central Bank of the Republic of Türkiye	Interest rate (average, annual)	0.094 (rate)
Q	TURKSTAT (R&D Accounts)	R&D CapitalStock (Calculated by authors using R&D investment)	193 (billion TL)
L	TURKSTAT (EmploymentDataset)	Employment	26,621 (thousand, count)
w <sub>1</sub>	TURKSTAT	The average wage (annual)	36,159 TL
N	TURKSTAT (R&D Accounts)	R&D personnel (full time equivalent)	122,288 (count)
T <sub>D</sub>	TURKSTAT (R&D Accounts)	R&D Incentives (total)	8,036 million TL
T <sub>P</sub>	General Directorate of Budget and Financial Control	Corporation tax (total)	33,388 million TL
Source(s): Authors' compilation			



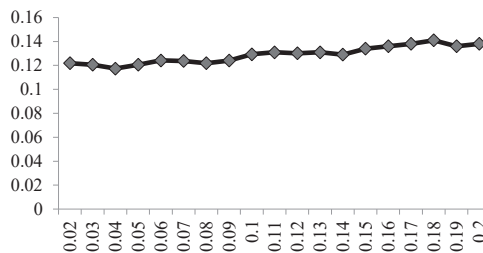
#### 4.1 Scenario 1: Increasing R&D capital incentives while R&D personnel incentives are fixed

Increasing public incentives for the physical capital used in R&D ( $Q_t$ ) reduces the costs incurred by the company while reaching the technologies needed. This can create two different behaviors in the firm, as pointed out by Lach (2002). In his study, Lach (2002) calculated a ratio called the R&D incentives effect for the R&D expenditures that a company can make without R&D incentives and the R&D expenditures made by receiving R&D incentives. According to this ratio, it has been concluded that while R&D incentives increase R&D expenditures in small firms, it creates a negative but statistically insignificant effect on large firms. Hence, there are two possibilities. The R&D incentives will either increase the firm's R&D expenditures or create a crowding-out effect that reduces R&D expenditures (Lach, 2002). Accordingly, in case of an increase in R&D capital incentives, the first variable to be examined in the model is the interest rate that determines the rental price of the capital. The incentive initially impacts the cost of capital to the firm and thus would change the use of capital in R&D.

Figure 3 shows the steady-state values of  $r_2$  for each unit increase of  $\tau_{q,t}$ , i.e. R&D capital incentives. According to Figure 1, as  $\tau_{q,t}$  increases, an upward trend is observed in interest rates. This implies that as incentives increase, the cost of capital used in R&D increases. This is most likely due to higher capital usage. Figure 4 shows that there is indeed a slight increase in capital usage. The increase in incentives increases the demand for capital, causing a capital cost increase that may even offset the incentives.

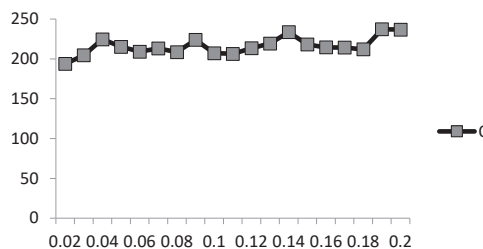
#### 4.2 Scenario 2: increasing R&D personnel incentives while R&D capital incentives are fixed

In this scenario, R&D personnel incentives are increased while capital incentives are held constant. Such an action would change the relative prices of labor used in R&D and labor used in final output production. For,



Source(s): Authors' calculations

**Figure 3.**  
 $r_2$  in case of an increase  
in R&D capital  
incentives ( $\tau_{q,t}$ )



Source(s): Authors' calculations

**Figure 4.**  
R&D capital stock in  
case of increase in R&D  
capital incentives

$$\frac{w_{2,t}}{w_{1,t}} = \frac{\psi(1-\theta)L_t}{(1-\tau_{s,t})(1-\alpha)N_t} \quad (14)$$

This is consistent with the findings of Wallsten (2000). Firms that want to benefit from the support provided by the government increase the price of this production factor by increasing their demand for R&D personnel (Wallsten, 2000). Hence an increased use of labor is likely.

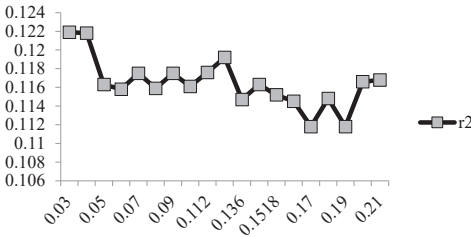
What is the effect of wage increases on capital prices? Factors of production are substitutes, at least to a certain degree. Thus, in addition to a reallocation of labor between alternative uses, capital and labor would be substituted in R&D as well. Figure 5 shows the steady-state values of the R&D capital interest rate in each unit increased by  $\tau_s$ .

As can be seen in Figure 5, increasing R&D personnel incentives decreased capital prices. This is a cross effect and it might imply factor substitution. While the wage level increased in the factor market, capital prices have been decreasing.

Incentives for the R&D production factors have different effects on total output. Figure 6 shows the effects of incentives for R&D production factors on total output. Figure 6 shows that the increase in the R&D personnel incentives ( $\tau_s$ ) creates a higher total output level compared to the increase in R&D capital incentives ( $\tau_Q$ ). Therefore, it can be said that R&D incentives increase the productivity of production factors with labor-focused incentives having an edge.

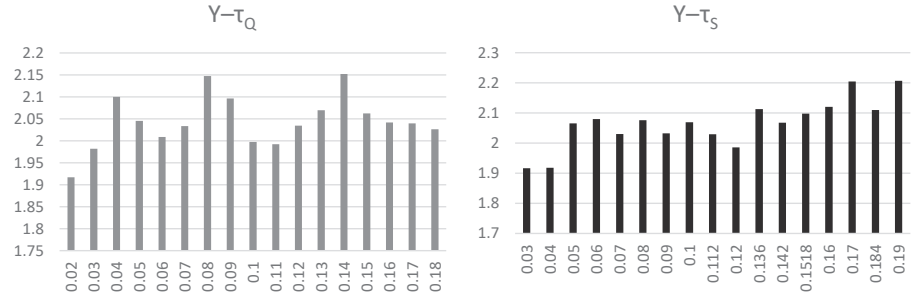
The government offers R&D incentives and collects taxes to finance these incentives. One of these taxes is the income tax. Increasing expenditures such as R&D incentives should lead to an increase in income tax rates. Figure 5 shows the effect of increases in incentives, i.e.  $\tau_Q$  and  $\tau_s$ , on income tax ( $\tau_m$ ) rates.

**Figure 5.**  
 $r^2$  in case of an increase  
in R&D personnel  
incentives ( $\tau_s$ )



Source(s): Authors' calculations

**Figure 6.**  
Comparison of the  
effects of  $Q$  and  $S$   
increases on total  
output



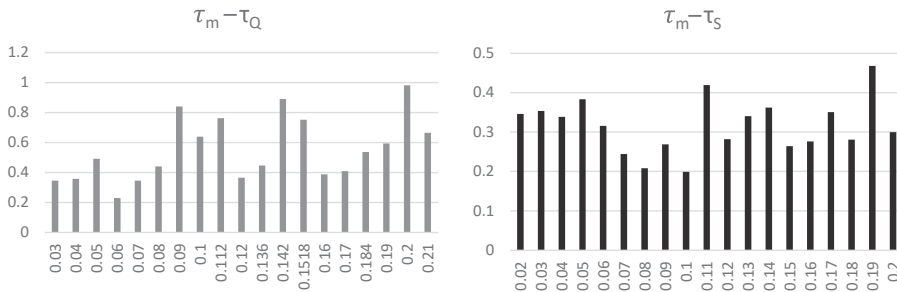
Source(s): Authors' calculations

According to Figure 7, the increase in capital incentive rates ( $\tau_Q$ ) necessitates a higher income tax than the increases in labor incentive rate ( $\tau_S$ ). This indirectly shows that R&D capital incentives are more costly than R&D personnel incentives. Of the increases in capital and labor incentives, the capital incentive is causing higher costs and also negatively affects social welfare. Because the high rate of income tax will cause a decrease in the goods and services that the consumer will buy. Therefore, of these two scenarios, it can be said that the optimum results in terms of both social welfare and TFP increase are achieved with labor-focused incentives.

#### 4.3 Scenario 3: increasing both R&D capital and R&D personnel incentives

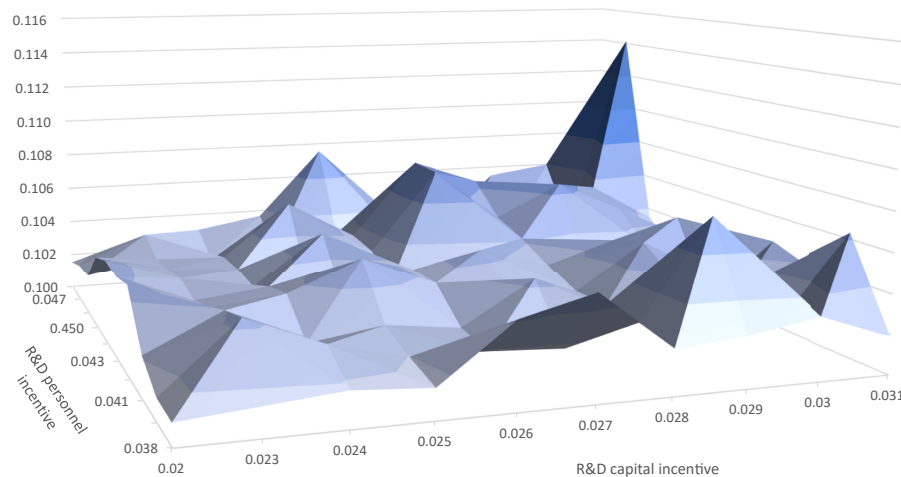
Determining the effects of simultaneously increasing incentive rates on capital accumulation and productivity increase are important for the incentive policies to be implemented.

Figure 8 shows in three dimensions the share of R&D capital  $Q$  in total output  $Y$  in case of increasing capital and labor R&D incentive ratios together. The figure shows the R&D



**Figure 7.**  
Effects of labor and  
capital incentive  
increase on the income  
tax rate

Source(s): Authors' calculations



Source(s): Authors' calculations

**Figure 8.**  
R&D capital per output  
with simultaneous  
changes in labor and  
capital incentives

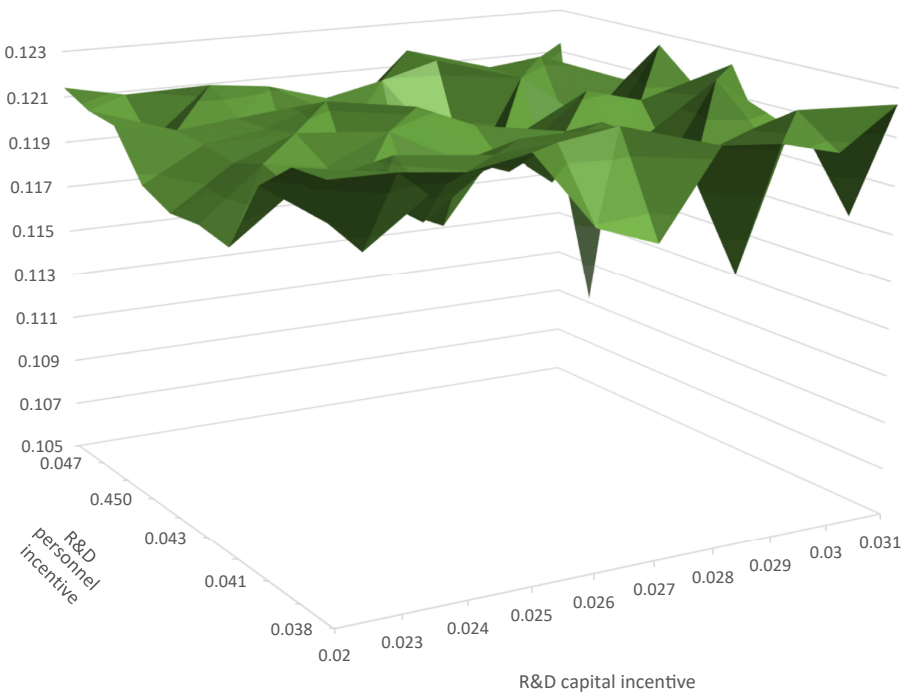
personnel incentive rates on the right vertical axis and the physical capital incentive rates involved in R&D production on the horizontal axis. In Figure 8, the increasing trend of R&D capital is parallel to both incentive rate increases. In other words, with the increase of both incentive rates together, the share of R&D capital in  $Y$  has increased.

Figure 9 shows the steady-state values of  $r_2$  when  $\tau_Q$  and  $\tau_S$  incentive rates are increased simultaneously. In the figure, R&D personnel incentive rates are shown on the left horizontal plane, while the right side of the horizontal plane shows R&D physical capital incentives.  $r_2$  fluctuations in Figures 1 and 3 are seen to be smoother in Figure 9 and do not contain any trends. Hence, the impact on capital price is in a sense well-balanced. The net effect of the policy on R&D capital is an increase in R&D capital, which is shown in Figure 8.

Increases in R&D capital impact R&D production. In Figure 10, the left vertical line shows the incentive rates for the R&D personnel, and the horizontal line shows the incentive rates for the R&D physical capital.

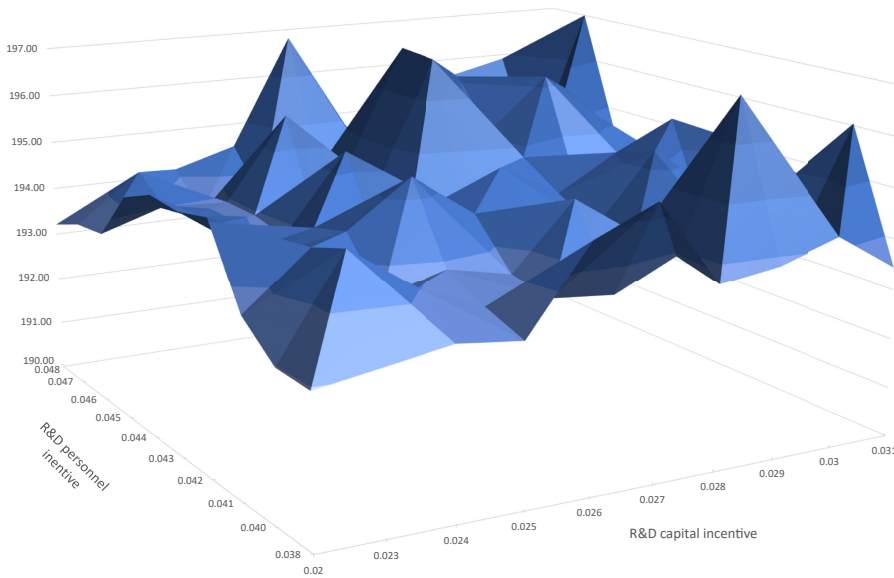
Figure 10 shows the R&D steady-state values when R&D capital and R&D labor incentives are increased together. Looking back at Figure 8, the increase in the numerical value of R&D is similar to the increase observed for R&D capital per output. The increase in the R&D capital would increase the numerical value of R&D, which had similar effects on the total output. These effects are shown in Figure 11, which shows the total output  $Y$  in three dimensions in the case of increased incentives for both R&D production factors.

In Figure 11, the vertical line involves the R&D personnel incentive rates and the horizontal line involves the R&D physical capital incentive rates. Increasing incentives for both R&D production factors generate an increase in total output  $Y$ .



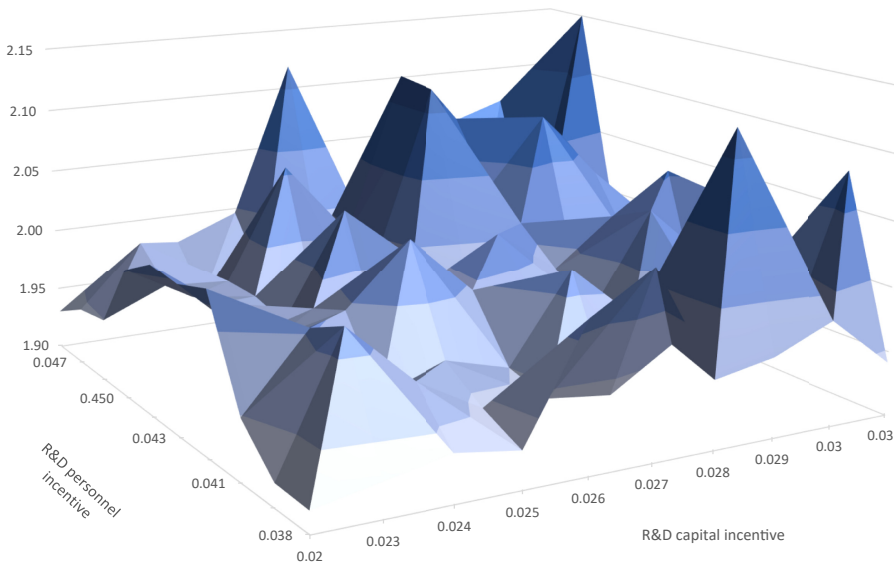
**Figure 9.**  
Impact of a  
simultaneous increase  
in labor and capital  
incentives on  $r_2$

**Source(s):** Authors' calculations



Source(s): Authors' calculations

**Figure 10.**  
Impact of a  
simultaneous increase  
in labor and capital  
incentives on R&D  
expenditures



Source(s): Authors' calculations

**Figure 11.**  
Impact of a  
simultaneous increase  
in labor and capital  
incentives on final  
output (Trillion TL)

Remember that [Figure 6](#) shows the final output obtained as a result of the increases made by keeping either capital or labor incentive rates constant in the previous two scenarios. When  $\tau_Q$  is constant, it can be seen that the total output in the case of  $\tau_S$  increase is above the total

output in Figure 11, where both incentive rates are increased. Also, if both incentive rates are increased in Scenario 3, the income tax rate imposed by the government on the consumer to ensure the government budget balance and to finance these incentives increases. This situation is shown in Figure 12.

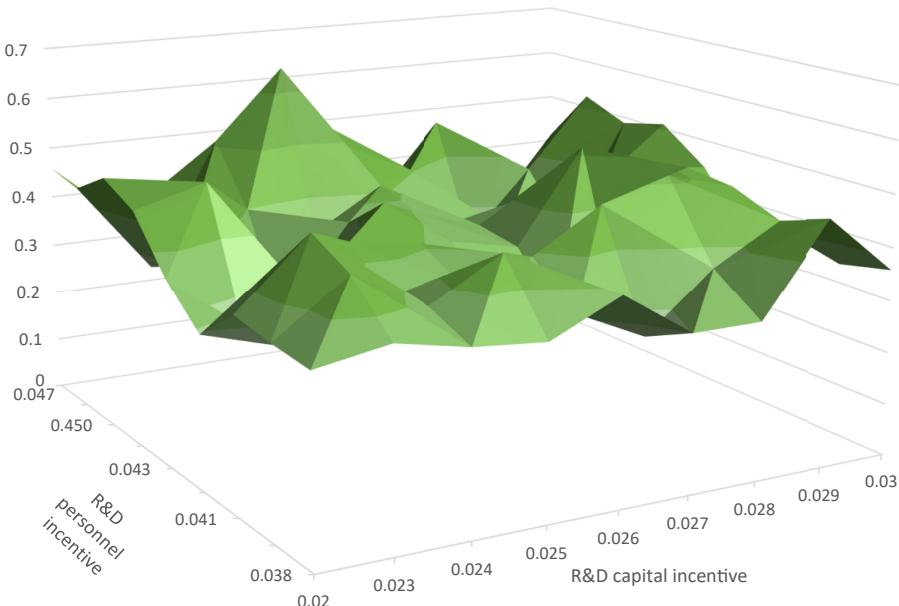
In Figure 12, the left vertical line shows the R&D personnel incentive rates and the horizontal line shows the R&D capital incentive rates. Compared to Figure 7, the income tax rate  $\tau_M$  in Figure 12 is below the income tax rate due to changes in capital incentives (the  $\tau_M - \tau_Q$  rate) and above the income tax rate due to changes in labour incentives (the  $\tau_M - \tau_S$  rate). As a result, increasing both incentive rates produces ineffective results compared to Scenario 2. Because in Scenario 2, higher total output and lower income tax rates are obtained.

5. Discussions

In the dynamic general equilibrium model we have set up, it is assumed that firms are engaged in R&D activities. Besides, R&D activities have been handled as a production function and a policy has been designed to increase the efficiency of production factors used in this production function. In the next step, the model has been calibrated with data from Türkiye. Our findings are given in Section 4.

The constructed model has been simulated for three different scenarios and the findings of each of these three scenarios showed that the increase in R&D capital and R&D personnel incentives had a positive effect on economic growth. In which scenario these positive contributions of R&D incentives are more effective is important for both social welfare and efficient use of resources. Therefore, the effects of these three scenarios on both TFP and social welfare should be carefully analyzed. Such an analysis could reveal how the incentives should be distributed between R&D capital and R&D personnel to ensure growth.

The three conducted scenarios have the following implications:



**Figure 12.**  
Impact of a  
simultaneous increase  
in labor and capital  
incentives on the  
income tax rate

Source(s): Authors' calculations

- (1) *Scenario 1:* In this scenario, the incentive rate on capital used in R&D ( $\tau_Q$ ) was increased, keeping the incentive rate on labor used in R&D ( $\tau_S$ ) constant. This exercise increased the firm's demand for R&D capital and increased capital prices. As a result, the firm's capital accumulation is suppressed. On the other hand, due to the increasing capital prices, the cost of capital incentives has also increased. The public sector financed these incentives from the consumer by increasing the income tax rate as a requirement of the fiscal balance. This has resulted in a decrease in social welfare.
- (2) *Scenario 2:* In this scenario, the incentive rate on labor used in R&D ( $\tau_S$ ) was increased by keeping the incentive rate on capital used in R&D ( $\tau_Q$ ) constant. This has caused a high substitution between factors of production and lowered interest rates. On the other hand, R&D capital formation was at a similar level to the increase in Scenario 1. But in Scenario 2, R&D capital formation is less costly. Besides, in Scenario 2 compared to Scenario 1, total output  $Y$  is higher and income tax rates are lower. This scenario is the one in which social welfare is optimal compared to other scenarios.
- (3) *Scenario 3:* In the last scenario, the incentive rate on capital used in R&D ( $\tau_Q$ ) and the incentive rate on labor used in R&D ( $\tau_S$ ) are increased simultaneously. This scenario generates a lower increase in the total output level compared to Scenario 2. However, income tax and interest rates, which increased in Scenario 1, remained lower in Scenario 3. Still, Scenario 3 has not produced as optimal results as Scenario 2.

## 6. Conclusion

The main result from the analysis of the constructed model is that in Scenario 2, the increase in R&D personnel incentives increased productivity. As a result, it has been concluded that economic growth is more prominent in Scenario 2 than in Scenarios 1 and 3. This result is an expected result, especially for Türkiye as an emerging economy. As [Aubert \(2005\)](#) stated, the shortage of skilled labor in emerging economies hinders the development of R&D activities. Model results support [Aubert \(2005\)](#). The increase in skilled labor, in other words, the increase in human capital accumulation, could accelerate economic growth.

Skilled labor is also important for the development of basic research outputs, which is the most important type of R&D in innovation production. Therefore, Türkiye needs to produce appropriate policies to achieve growth and development goals. These policies should have the potential to affect all segments of society. For example, bringing education to international standards, allocating research infrastructure to universities that are the engines of basic research, and providing necessary support are the most important policies to be followed. In addition to these policies, after providing the necessary basic research infrastructure, it is very important to establish applied research grounds where basic research can be applied. Once these steps are followed successfully, thanks to the high-value-added products produced by Türkiye will get the chance to improve its market share in international markets. In this case, creating an improvement in Türkiye's economic indicators will provide an opportunity to close the gap between developed countries and Türkiye.

Unfortunately, the results could not be compared to other studies in the literature. As far as the authors can determine, the impacts of incentives on R&D and growth are mostly studied in an empirical context supported by econometric analysis. Such studies do not consider incentives provided via factors of production. Therefore, a comparable analysis could not be identified. It could be a fruitful endeavor to conduct modelling studies similar to this one for different countries. The results from countries at different development levels may provide unique policy implications.

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