Do RD subsidies necessarily stimulate economic growth?

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Abstract

This paper analyzes the growth effect of subsidy policies in a modified R&D-based growth model of Romer (1990), in which both innovation and capital accumulation are engines of long-run economic growth. We show that, under certain conditions, subsidizing the R&D sector may be growth-impeding.

1. Introduction

R&D subsidy policies are now commonly adopted in developing and developed countries the world over. Popular views are that R&D subsidies direct resources to innovative activities, and thus can stimulate economic growth. This view has been testified within the framework of classic innovation-led endogenous growth models (Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992). These and numerous subsequent studies basically support that R&D subsidies have in general positive effects on long-run growth. Empirical evidences, on the other hand, are less clear about the positive effects of these policies on productivity growth (see, e.g., Beason and Weinstein, 1996; Westmore, 2013).

In this paper, we analyze the effects of subsidy policies on long-run growth in an expanding-variety R&D-based growth model, developed by Romer (1990), with both innovation and capital accumulation being the engines of long-run economic growth (e.g., Chu et al., 2012; Iwaisako and Futagami, 2013). The subsidy policies under consideration include a subsidy for the costs (of the employment of workers) in three sectors: the final-good sector, the R&D sector, and the capital-producing sector.[1] Our analysis shows that subsidizing the final-good sector is growth-impeding. However, subsidizing the other two sectors has uncertain effects on long-run growth. This finding implies that the typical view that a subsidy for R&D leads to faster growth does not necessarily hold. Intuitively, the R&D sector and the capital-producing sector are both contributive to economic growth. Given the fact that the two sectors compete over labor, when an R&D subsidy is implemented, an increased R&D investment in the form of an expansion in R&D workers tends to crowd out available inputs for the capital-producing sector. This leads to two conflicting effects on growth, and the overall effect then should hinge upon the relative importance of the two sectors. As will be shown below, if the productivity of the capital-producing sector is dominant, subsidizing R&D may depress long-run growth.

Our study is related to the literature on the effects of R&D subsidy policies in R&D-based growth models. Davidson and Segerstrom (1998) consider two types of

[1] Subsidizing production costs of R&D is an approach that have been most commonly adopted in the literature (e.g., Zeng and Zhang, 2007; Grossmann and Steger, 2013; Grossmann et al., 2013; Chu et al., 2015). As for the subsidy to the final-good sector, we consider a subsidy to the hiring of final-good workers, simply for the purpose of easy comparison. Our main result will not change if we consider other types of subsidies for final goods production.

R&D (innovative R&D and imitative R&D), and find that subsidies on different types of R&D result in different growth effects. Segerstrom (2000) employs the Howitt's (1999) model without scale effects, and shows that R&D subsidies can have ambiguous effects on growth. Zeng and Zhang (2007) and Gómez and Sequeira (2014) provide quantitative evaluation for the effects of R&D subsidies on both growth and welfare. By adopting a semi-endogenous growth model of Jones (1995), Grossmann and Steger (2013) and Grossmann et al. (2013) explore the optimal R&D subsidization, but their studies are absent from the long-run growth effects due to the nature of a semi-endogenous growth model. The present study contributes to this strand of literature by considering both R&D and capital accumulation as engines of long-run growth, and by showing that the growth effects of an R&D subsidy depend on the relative productivity between these two sectors.

2. The model

We modify the basic model of Chu et al. (2012) by (i) introducing subsidies, (ii) removing money, and (iii) assuming inelastic labor supply. We now briefly describe the model structure.

2.1. Households

There is a unit continuum of households. The population is stationary. The lifetime utility is

$$U = \int_0^\infty e^{-\rho t} u_t \, dt, \tag{1}$$

where $u_t = \ln C_t$, C_t is the consumption of final goods, and ρ>0 is the subjective discount rate. The total labor supply of each household is fixed and normalized to unity.[2] Thus, the household's budget constraint is $\dot{a}_t = r_t a_t + w_t - C_t - T_t$, where a_t

[2] To keep the analysis simple, we assume that the total labor supply is inelastic, but our results are

is the household's asset, r_t is the interest rate, w_t is the wage rate,[3] and T_t is the lump-sum tax. The usual Keynes-Ramsey rule is:

$$\frac{\dot{C}_t}{C_t} = r_t - \rho \,. \tag{2}$$

2.2. Final goods

Final goods Y_t (the *numeraire*) are produced by competitive firms using labor and a continuum of intermediate goods:

$$Y_t = L_{Y,t}^{1-\alpha} \int_0^{A_t} x_t^{\alpha}(i)\, di \,, \tag{3}$$

where $L_{Y,t}$ is labor in final goods production, $x_t(i)$ is the intermediate good of type i ($i \in [0, A_t]$), and A_t is the number of varieties of intermediate goods. Denoting $p_t(i)$ as the price of $x_t(i)$ relative to final goods, the profit function of the final goods firm is

$$\pi_{Y,t} = Y_t - (1 - s_Y) w_t L_{Y,t} - \int_0^{A_t} p_t(i) x_t(i) di \,, \tag{4}$$

where s_Y is the subsidy on the employment of final-goods labor. The conditional demand functions are:

$$L_{Y,t} = \frac{(1-\alpha)Y_t}{(1-s_Y)w_t} \,, \tag{5}$$

$$x_t(i) = L_{Y,t} \left(\frac{\alpha}{p_t(i)} \right)^{\frac{1}{1-\alpha}} . \tag{6}$$

2.3. Intermediate goods

There is a continuum of differentiated intermediate goods $x_t(i)$, $i \in [0, A_t]$. Each intermediate firm is owned by a monopolist who uses one unit of capital k_t to

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qualitatively robust to a more general utility function $u_t = \ln C_t + \eta \ln(1 - L_t)$ where L_t denotes the endogenous labor supply. Deviations are available from the authors upon request.

[3] We assume that labor is perfectly mobile across sectors, which implies a unified wage rate.

produce one unit of intermediate good, i.e., $x_t(i) = k_t(i)$. Thus, the monopolistic profit is $\pi_{x,t}(i) = p_t(i)x_t(i) - q_t k_t(i)$, where q_t is the capital rental price. Profit maximization yields the familiar pricing rule $p_t(i) = q_t / \alpha$, which implies that the intermediate firms are symmetric. Therefore, we can drop notation i for variables $\{x_t, p_t, k_t, \pi_{x,t}\}$. The profit then can be simplified to:

$$\pi_{x,t} = (\frac{1-\alpha}{\alpha})q_t k_t . \tag{7}$$

The market-clearing condition for capital goods is $\int_0^{A_t} x_t(i)di = A_t x_t = K_t$, where K_t is aggregate capital. For future use, it is also helpful to derive the conditions from (6) and (7) that $q_t K_t = \alpha^2 Y_t$ and $A_t \pi_{x,t} = (1-\alpha)\alpha Y_t$.

2.4. R&D

In the competitive R&D sector, the value of a variety, denoted as $v_{A,t}$, follows the no-arbitrage condition:

$$r_t v_{A,t} = \pi_{x,t} + \dot{v}_{A,t} , \tag{8}$$

which states that the return of investment in R&D will be equal to the monopolistic profit $\pi_{x,t}$ plus the capital gain $\dot{v}_{A,t}$. The R&D firm employs labor to produce new varieties with the technology $\dot{A}_t = \varphi A_t L_{A,t}$, where the parameter φ determines the R&D productivity and $L_{A,t}$ is labor used in R&D. The government may provide subsidies s_A for the employment of R&D workers. The profit of R&D is:

$$\pi_{A,t} = v_{A,t}\dot{A}_t - (1-s_A)w_t L_{A,t} . \tag{9}$$

The zero-profit condition implies:

$$v_{A,t}\varphi A_t = (1-s_A)w_t . \tag{10}$$

2.5. Capital production

Let us denote the value of one unit of capital as $v_{K,t}$. The no-arbitrage condition for $v_{K,t}$ is:

$$r_t v_{K,t} = q_t + \dot{v}_{K,t}, \tag{11}$$

which states that the return of investment in capital production is equal to its rental price q_t plus the capital gains $\dot{v}_{K,t}$. Capital goods are produced by a unit of continuum competitive firms that employ labor $L_{K,t}$. The corresponding production technology is $\dot{K}_t = \delta K_t L_{K,t}$, where δ is a parameter reflecting the productivity in the capital-producing sector.[4] The government may provide subsidies s_K for the capital-producing firms to hire labor. The profit of a capital-producing firm is:

$$\pi_{K,t} = v_{K,t}\dot{K}_t - (1-s_K)w_t L_{K,t}. \tag{12}$$

The zero-profit condition implies:

$$v_{K,t}\delta K_t = (1-s_K)w_t. \tag{13}$$

2.6. The government, market clearing, and aggregation

The government levies a lump-sum tax on the households to finance its subsidy policies:

$$T_t = s_Y w_t L_{Y,t} + s_A w_t L_{A,t} + s_K w_t L_{K,t}. \tag{14}$$

The market-clearing conditions for capital goods and the labor market are:

$$K_t = \int_0^{A_t} x_t(i)di = A_t x_t, \tag{15}$$

$$L_{Y,t} + L_{A,t} + L_{K,t} = 1. \tag{16}$$

The household's asset a_t contains the investment in R&D and in capital production, i.e., $a_t = v_{A,t}A_t + v_{K,t}K_t$. Accordingly, the resource constraint for final goods can be calculated as $Y_t = C_t$.

3. Long-run growth effects of subsidy policies

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[4] Chu et al. (2012) specify that $\dot{K}_t = \delta \Omega_t L_{K,t}$, where Ω_t reflects the technology level. To permit sustained growth, they further assume $\Omega_t = K_t$ to capture the capital externality in the AK model.

On the balanced growth path, the allocations of labor are stationary, which can be derived as (a tilde denotes the steady-state value):

$$\tilde{L}_Y = \frac{1+\xi}{1+\Phi}, \tag{17a}$$

$$\tilde{L}_A = \frac{(1-s_Y)\alpha}{(1-s_A)}\frac{1+\xi}{1+\Phi} - \frac{\rho}{\varphi}, \tag{17b}$$

$$\tilde{L}_K = \frac{(1-s_Y)\alpha^2}{(1-s_K)(1-\alpha)}\frac{1+\xi}{1+\Phi} - \frac{\rho}{\delta}, \tag{17c}$$

where

$$\xi \equiv \left(\frac{1}{\delta} + \frac{1}{\varphi}\right)\rho \quad \text{and} \quad \Phi \equiv (1-s_Y)\alpha\left(\frac{1}{1-s_A} + \frac{\alpha}{(1-\alpha)(1-s_K)}\right)$$

are composite parameters. To ensure that $\tilde{L}_A$ and $\tilde{L}_K$ are non-negative, we impose the following restrictions on the two productivity parameters:

Condition 1. $\varphi \geq \hat{\varphi} = \dfrac{\rho(1-s_A)(1+\Phi)}{\alpha(1-s_Y)(1+\xi)}$ and $\delta \geq \hat{\delta} = \dfrac{\rho(1-\alpha)(1-s_K)\left(1+\Phi\right)}{\alpha^2(1-s_Y)\left(1+\xi\right)}$.

The first inequality of Condition 1 ensures that $\tilde{L}_A \geq 0$ and the second ensures that $\tilde{L}_K \geq 0$. From (17a)-(17c), the following lemma holds:

Lemma 1. *The effects of subsidies on equilibrium labor allocations are:*

$$\frac{\partial \tilde{L}_A}{\partial s_A} > 0;\ \frac{\partial \tilde{L}_Y}{\partial s_A} < 0;\ \frac{\partial \tilde{L}_K}{\partial s_A} < 0, \tag{18a}$$

$$\frac{\partial \tilde{L}_K}{\partial s_K} > 0;\ \frac{\partial \tilde{L}_Y}{\partial s_K} < 0;\ \frac{\partial \tilde{L}_A}{\partial s_K} < 0, \tag{18b}$$

$$\frac{\partial \tilde{L}_Y}{\partial s_Y} > 0;\ \frac{\partial \tilde{L}_A}{\partial s_Y} < 0;\ \frac{\partial \tilde{L}_K}{\partial s_Y} < 0. \tag{18c}$$

Proof. Straightforward from differentiating (17a)-(17c) with respect to s_Y, s_A, and s_K. ■

Lemma 1 shows that, when an R&D subsidy is implemented, an increased R&D investment in the form of an expansion in R&D workers tends to crowd out available inputs for the capital-producing and final goods sectors. The same results applies to both s_K and s_Y.

Now we move to the effects of subsidy policies on balanced growth. By using $x_t(i) = x_t$ and (15), the aggregate production function can be arranged as:

$$Y_t = A_t^{1-\alpha} L_{Y,t}^{1-\alpha} K_t^{\alpha} . \tag{19}$$

Taking log and differentiating with respect to time yields the balanced growth rate, denoted by $\tilde{g}(\equiv \dot{\tilde{Y}} / \tilde{Y})$, as:

$$\tilde{g} = (1-\alpha)\frac{\dot{\tilde{A}}}{\tilde{A}} + \alpha \frac{\dot{\tilde{K}}}{\tilde{K}} = (1-\alpha)\varphi \tilde{L}_A + \alpha \delta \tilde{L}_K . \tag{20}$$

The above equation clearly shows that the balanced growth rate is determined by both R&D and capital accumulation. According to Condition 1 and (20), we can infer that if $\varphi = \hat{\varphi}$, the R&D sector shuts down such that economic growth is driven only by capital accumulation, as in the AK-type endogenous growth model. In contrast, if $\delta = \hat{\delta}$, the capital production shuts show; in this case, economic growth is driven only by R&D and thus our model reduces to the standard Romer model.

To easily convey our results, we suppose that the government initially does not implement any subsidy policies. Equipped with (17b), (17c), (20) and Lemma 1, we can elaborate the growth effects of subsidy policies by the following proposition:

Proposition 1. *The effects of subsidies on balanced growth rate* $\tilde{g}$ *are as follows:*

(i) $\tilde{g}$ *is always decreasing in* s_Y *;*

(ii) $\tilde{g}$ *is increasing in* s_A *if and only if* $\varphi / \delta > \alpha^3 / (1-\alpha)(1-\alpha+\alpha^2)$;

(iii) $\tilde{g}$ *is increasing in* s_K *if and only if* $\varphi / \delta < (1+\alpha)/(1-\alpha)$.

Proof. Inserting (17b) and (17c) into (20) and differentiating with respect to s_Y, s_A, and s_K. ■

A subsidy to the final-goods sector decreases the labor in the R&D and capital-producing sectors, both of which are the engines of growth. Therefore, it always depresses growth. Whether a subsidy to R&D and capital-producing sectors is growth-enhancing or not depends on their relative productivities. When the relative productivity between the R&D and the capital-producing sectors φ/δ is relatively large, the R&D sector is more productive. Under this situation, it is better to subsidize the R&D sector. When φ/δ is relatively small, the capital-producing sector is more productive; then a subsidy to this sector is more likely to stimulate growth.

Appendix (Not for publication)

In this appendix we provide the derivation of the labor allocations on the balanced growth path (17a)-(17c). By using equations (5) and (10), we can obtain the expression $\varphi v_{A,t} A_t (1-s_Y) L_{Y,t} = (1-\alpha)(1-s_A) Y_t$. Differentiating the log of this expression with respect to time, and inserting $Y_t = C_t$ yield:

$$\frac{\dot{v}_{A,t}}{v_{A,t}} = \frac{\dot{A}_t}{A_t} + \frac{\dot{C}_t}{C_t}. \tag{A1}$$

Then, by inserting $\dot{A}_t / A_t = \varphi L_{A,t}$ and $\dot{C}_t / C_t = r_t - \rho$ into (A1), together with (8), (10) and the condition $A_t \pi_{x,t} = (1-\alpha)\alpha Y_t$, we obtain:

$$\tilde{L}_A = \frac{(1-s_Y)\alpha \tilde{L}_Y}{1-s_A} - \frac{\rho}{\varphi}, \tag{A2}$$

Following a similar algorithm, we can utilize (5), (13), and the condition $q_t K_t = \alpha^2 Y_t$ to derive:

$$\tilde{L}_K = \frac{(1-s_Y)\alpha^2 \tilde{L}_Y}{(1-s_K)(1-\alpha)} - \frac{\rho}{\delta}\,. \tag{A3}$$

Finally, equations (A2) and (A3) plus the clearing condition for labor market, (16), give us the closed-form labor allocations (17a)-(17c) in the main text.

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