Corporate Tax Cuts and Economic Growth

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Abstract

Empirical evidence on the effect of corporate income tax on economic growth is mixed. This paper explores the ambiguous mechanism of corporate income tax by using a Schumpeterian growth model with heterogeneous innovators and endogenous market structure. Our main findings are as follows: (i) Corporate tax cuts do not necessarily enhance innovation. (ii) Corporate tax cuts are likely to have a positive growth effect when the research and development (R&D) productivity across firms is heterogeneous. (iii) R&D tax deduction increases the growth rate. (iv) Based on our calibration, the corporate tax cut in 2018 had a negative effect on economic growth and welfare in the U.S. economy.

Keywords: Corporate income tax, R&D tax deduction, Innovation, Heterogeneity, Endogenous entry, Market competition

JEL-Classification: H21, H25, O31

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1 Introduction

In recent decades, almost all OECD countries have decreased corporate tax rates (see Table 1). In a recent example, the U.S. cut the corporate tax rate from 35% to 21% in 2018. The main purpose of the corporate tax cuts is to expand rewards for business activities such as investments. The policy seems to be a good plan from the viewpoint of the Schumpeterian growth model, because it theoretically raises post-innovation profit and enhances innovation-driven growth. The Schumpeterian view predicts a negative relationship between corporate tax rate and economic growth rate.

Year	U.S.	Japan	Germany	U.K.	France	Italy	Canada
2000	35.0	30.0	42.20	30.0	37.76	37.0	29.12
2005	35.0	30.0	26.38	30.0	34.93	33.0	22.12
2010	35.0	30.0	15.83	28.0	34.43	27.5	18.00
2015	35.0	23.9	15.83	20.0	38.00	27.5	15.00
2018	21.0	23.2	15.83	19.0	34.43	24.0	15.00

Year	Korea	Spain	Australia	Netherlands	Turkey	Sweden
2000	28.0	35.0	34.0	35.0	33.0	28.0
2005	25.0	35.0	30.0	31.5	30.0	28.0
2010	22.0	30.0	30.0	25.5	20.0	26.3
2015	22.0	28.0	30.0	25.0	20.0	22.0
2018	25.0	25.0	30.0	25.0	22.0	22.0

Table 1: The corporate tax rate in some OECD countries. *Source: OECD.Stat (Statutory Corporate Income Tax Rates)*

However, empirical evidence on the effect of corporate taxes on macroeconomic growth is mixed. On the one hand, Mertens and Ravn (2013) show that corporate tax is harmful for growth. In particular, they estimate that a 1% decrease in the corporate income tax rate raises real GDP per capita by 0.4% by stimulating private sector investment. Lee and Gordon (2005) and Shevlin et al. (2019) also find a negative relationship between the corporate income tax rate and future economic growth. On the other hand, Angelopolous et al. (2007) find that the corporate tax rate is weakly positively related with growth. Widmalm (2001) also reports a similar positive relation between corporate tax revenues (as share of total tax revenues) and growth. Furthermore, some studies find that the growth effect of taxation is negligible. Mendoza et al. (1997) provide evidence that supports the conjecture of Harberger (1964) that the growth rate is neutral in relation to tax rates. Ojede and Yamarik (2012) also find that the state-level corporate income tax has no short- or long-term impact on state-level growth.

To reconcile the mixed evidence, this paper theoretically shows the unclear relationship between the corporate income tax and economic growth. We introduce corporate income tax into a Schumpeterian growth model where innovators are heterogeneous and the number of firms is endogenously determined. In this model, we show that the growth effect of a corporate income tax cut can be either positive or negative depending on the current tax rate, the level of patent protection, and the degree of heterogeneity across firms. In particular, when firms are heterogeneous in R&D productivity, there is an inverted-U relationship between corporate tax rate and growth rate. We also incorporate R&D tax deduction into the model and show that a higher tax deduction rate increases growth rate and amplifies the growth effect of corporate income tax cuts both positively and negatively. Furthermore, by calibrating the U.S. economy, we evaluate the growth effect of the 2018 corporate tax cut. Our simulation result shows that the policy had a negative effect on economic growth, with a growth-maximizing corporate tax rate around 50%.

The corporate income tax cut has an ambiguous growth effect in our model, with one positive effect and two negative effects on economic growth. First, the corporate income tax cut stimulates R&D investment by increasing the (after-tax) post-innovation profit (*the Schumpeter effect*). The increase in post-innovation profit in our endogenous market structure model, however, is partially weakened by a negative effect; the corporate tax cut induces the entry of firms because the pre-innovation profit also rises. As the number of firms increases, the market becomes more competitive. This inhibits the increase in post-innovation profit (*the competition-enhancing effect*). Finally, corporate income tax cuts discourage R&D investment by increasing R&D cost. This policy expands the number of firms and raises the labor demand for production. Because this raises the wage rate in the labor market equilibrium, it negatively affects innovation (*the cost-increasing effect*). Consequently, corporate income tax cuts may work to reallocate economic resources from R&D activities to production.

The competition-enhancing effect seems to be consistent with some empirical studies. For example, Papke (1991) finds that a high tax rate reduces the number of manufacturing firm start-ups. Further, in the literature of international tax competition, tax-cutting reforms significantly affect multinational firms' choice of location. The wage-increasing effect is also empirically supported; studies show a negative relationship between corporate income tax and wages. For example, using data on 55,082 companies in nine European countries, Arulampalam et al. (2012) estimate that a $1 raise in taxes reduces wages by 49 cents.

Related literature

Aghion et al. (2016) also demonstrate an inverted-U relationship between corporate income tax and growth. To generate non-monotonicity, they assume that tax revenue is used to invest in public infrastructure that helps R&D activity. While corporate tax cuts increase rewards from successful R&D, they also have a negative effect on growth by impeding the accumulation of public infrastructure. This implies, conversely, that the inverted-U relationship in Aghion et al. (2016) depends crucially on public infrastructure. In contrast, we show that even without public infrastructure, the relationship between corporate income tax and growth can be an inverted-U.

Peretto (2007) shows that corporate income tax has two opposite effects on growth, with corporate income tax enhancing growth when the R&D tax credit rate is 100% because the negative effect disappears. Beyond that, however, the author does not analyze anything about the growth effect; in contrast, we explicitly show that the relationship between corporate income tax and growth can be an inverted-U shape when the R&D productivity across firms is heterogeneous. Moreover, our numerical analyses evaluate the U.S. tax reform in 2018 under plausible parameters. Therefore, although the results of Peretto (2007) partially overlap with ours, there are notable differences between his contributions and our own.

Iwaisako (2016) considers the effects of reducing the corporate tax rate accompanied by an increase in the consumption tax rate. The author incorporates the several taxes into a standard Schumpeterian growth model and shows that the growth-maximizing tax policy is zero corporate income tax and a high consumption tax rate. Because the author assumes that the government must balance the budget constraint, a high consumption tax rate enables the government to decrease corporate income tax that enhances innovation through the Schumpeterian effect. In other words, corporate income tax is harmful for economic growth in the model of Iwaisako (2016). In contrast, our model shows that the growth effect of corporate income tax can be either positive or negative; the evidence is mixed.

Roadmap

The remainder of the paper is structured as follows. Section 2 builds our model and Section 3 solves the steady state. Section 4 investigates the effect of the corporate tax cut on the growth rate. Section 5 conducts a simulation by calibrating the U.S. economy and evaluates the growth effect of 2018 tax reform. Finally, section 6 concludes the paper.

2 The model

To develop our model, we incorporated endogenous market structure and heterogeneity into the Grossman and Helpman (1991, Ch.4) model. Specifically, while the original model assumes Bertrand competition, we assume that all firms engage in Cournot competition. Out setup allows us to consider policy effect on the number of firms; in the original model market, the only firm is monopolist. We also assume that each firm's R&D productivity is heterogeneous; in our model, R&D firms and non-R&D firms coexist in the market. In reality, of course, not all existing firms invest in R&D. Our model enables us to consider the effect of policy on the ratio of innovative firms.

2.1 Households

Our household setup is exactly the same as in Grossman and Helpman (1991, Ch.4). Our model economy consists of identical and infinitely living households. Time is continuous and there is no population growth. The population size of each household is given by $L > 0$. Each household supplies a unit of labor inelastically and earns a wage in every period. A representative household has the following intertemporal utility function:

$$U_t = \int_0^\infty \exp(-\rho t) \ln C_t dt, \tag{1}$$

where ρ is the subjective discount rate and C_t is an index of consumption at time t. The economy has a continuum of industries indexed by $i \in [0, 1]$ and the households consume final goods across all industries. The period utility is given by

$$\ln C_t = \int_0^1 \ln \left(\sum_{k=0}^{\tilde{k}(i)} \lambda^k X_{kt}(i) \right) di, \tag{2}$$

where $X_{kt}(i)$ is the consumption of a good whose quality is λ^k in industry i at time t, and $\tilde{k}(i)$ means that innovation has occurred $\tilde{k}(i) + 1$ times in industry i. In the industry, there are $\tilde{k}(i) + 1$ generations of goods ($k = 0, 1, ..., \tilde{k}(i)$), and according to the additive specification in the abovementioned period utility, they are perfect substitutes for households. The quality of each good is represented as an integer k power of $\lambda > 1$, which means that the quality of the new good is λ times higher than the previous one.

The budget constraint of each household is

$$\dot{A}_t = r_t A_t + w_t + T_t - C_t. \tag{3}$$

A_t is the real value of assets (equities), r_t is the real interest rate, and w_t is the wage rate. T_t is a lump-sum transfer from the government. We assume that the government distributes all tax revenue to each household equally in every period.

The expenditure is given by

$$E_t = \int_0^1 \ln \left(\sum_{k=0}^{\tilde{k}(i)} p_{kt}(i) X_{kt}(i) \right) di, \tag{4}$$

where p_{kt} is the price of the good whose quality is λ^k. Hereafter, the notations often omit i and t for simplicity when there is no room for confusion.

We solve the utility maximization problem in two steps: static problem and dynamic problem. First, given instantaneous expenditure level E_t, we maximize the period utility function $\ln C_t$. Under the logarithmic utility function, households spend their budget equally across the product line $i \in [0, 1]$. Moreover, for each line, they choose the latest good that has the lowest quality-adjusted price. Therefore, the individual demand in industry i is $X_{\tilde{k}}(i) = E/p_{\tilde{k}}(i)$ for $k = \tilde{k}$ and $X_k(i) = 0$ for $k = 0, 1, ..., \tilde{k} - 1$.

Second, we solve the dynamic maximization problem. Each household decides the expenditure E_t in each period so as to maximize intertemporal utility function, U_t, subject to the intertemporal budget constraint. Their indirect period utility function is given by $\ln C_t = \ln E_t - \ln P_t$, where P_t is the ideal price index associated with the consumption index C_t, which is defined as

$$\ln P_t = \int_0^1 \ln\left(\frac{p_{\tilde{k}t}(i)}{\lambda^{\tilde{k}(i)}}\right) di. \tag{5}$$

Given the aggregate price index, households spend to maximize their intertemporal utility. From the maximization result, the household's optimal time path for spending is represented by $\dot{E}_t/E_t = r_t - \rho$. Following Grossman and Helpman (1991, Ch.4) and subsequent studies, we treat the expenditure as the *numéraire* by normalizing the price index in each period so that $E_t = 1$. This means that the price index falls over time at the growth rate of the consumption index. Then, we obtain $r_t = \rho$.

2.2 Industries

Consider an industry in which there is a leader and some followers who imitate the leader's good. Let F denote the total number of followers in the industry.

In the model, there are two types of followers: "innovative followers" and "non-innovative followers." The non-innovative follower only produces the imitated good. The innovative follower not only produces the imitated good but also conducts R&D investment for further innovation. Let $f_R \in [0, 1]$ denote the ratio of innovative followers to all followers.

We consider a two-stage game variant of Mankiw and Whinston (1986). In the first stage, each potential firm decides whether to enter the industry as a follower. In the second stage, the leader and F followers engage in Cournot competition. They earn the Cournot profit in each period until a certain innovative follower succeeds in her R&D. The successful innovative follower can then replace the current industry leader. Other firms will instantaneously try to re-enter the industry by imitating the new leader's good, and a new two-stage game starts again. Fig.1 briefly illustrates the structure of this model.

Note that, as in Grossman and Helpman (1991, Ch.4) and other subsequent studies, because of *Arrow's replacement effect*, the leader in each industry does not perform R&D. Even if the current leader succeeds in performing R&D, their firm ' s value does not increase because the latest good is instantaneously imitated by the followers. Empirically, even though it has the ability to innovate, the leader ' s firm tends to lack the incentive to do so. [1]

[1] For example, Igami (2017) shows that successful incumbents in the hard disk drive industry are reluctant to innovate even though they have a substantial cost advantage.

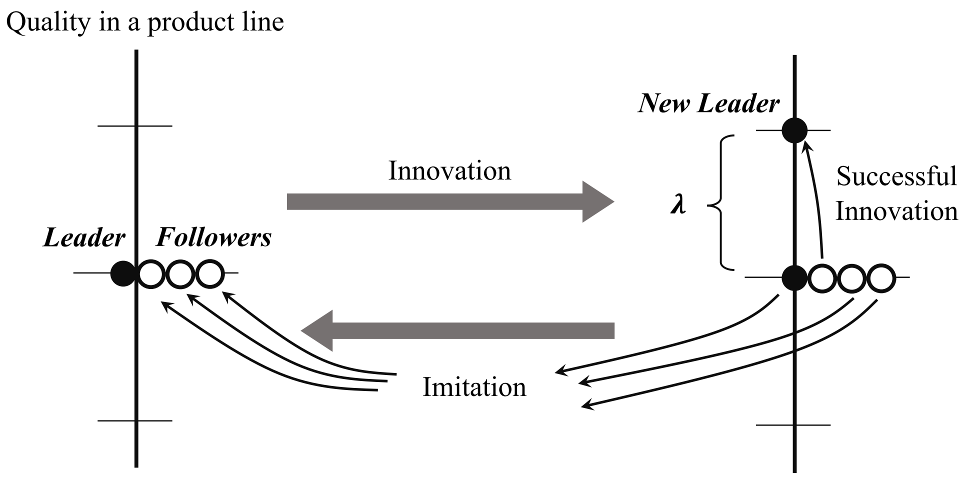

Figure 1: Model structure. The quality-ladder on the left-hand side shows each follower entering an industry by imitating the leader's good. After one follower succeeds in performing R&D, that follower becomes the new leader and obtains a patent on the latest good whose quality is λ times higher than that of the previous one, as shown on the right-hand side. Then, in a new two-stage game, the old leader and old followers re-enter the industry by imitating the new leader's good. Note that this figure does not imply that the model has two different states, as the imitation occurs instantaneously.

In the following subsections, we solve the two-stage problem with backward induction.

2.3 Cournot competition

Consider an industry that consists of a leader and F followers. We assume that they all engage in Cournot competition where their unit production costs are asymmetric. While the leader can produce one state-of-the-art good by using one unit of labor, followers must devote $\chi > 1$ units of labor to produce one unit of the same quality good, where $\chi \in (1, \lambda)$ is the parameter of cost-disadvantage for followers. For example, if $\chi = 1$, followers can imitate the production technology of the new innovator perfectly. Thus, χ captures the degree of difficulty of imitation for followers (e.g., the level of patent breadth).

As we derived in Section 2.1, the inverse demand function for goods in an industry is $p = 1/X$. Given the inverse demand function and the wage rate of one unit of labor, w, producer j maximizes their after-tax profit, π_j. Accordingly, the profit maximization problem is

$$\max_{y_j} \pi_j = (1-\tau)\frac{1}{X} \cdot y_j - \gamma_j^P w \cdot y_j, \tag{6}$$

where τ is the corporate income tax rate, y_j is the output level, and γ_j^P is the unit cost of production. Note that $\gamma_j^P = 1$ when producer j is the leader and $\gamma_j^P = \chi$ when they are a follower. By solving (6), we obtain the output of producer j as follows:

$$\begin{aligned}\frac{\partial \pi_j}{\partial y_j} = 0 \quad &\Leftrightarrow \quad (1-\tau)\frac{1}{X} - (1-\tau)\frac{1}{X^2}y_j - \gamma_j^P \cdot w = 0 \\ &\Leftrightarrow \quad y_j = X - \frac{\gamma_j^P w \cdot X^2}{1-\tau}. \end{aligned} \tag{7}$$

In market equilibrium, the aggregate demand X equals the aggregate output in the industry. We assume that all followers are symmetric. Then, the market clearing condition is

$$X = y_L + F \cdot y_F \equiv Y, \tag{8}$$

where y_L is the leader's output, y_F is the output of each follower, and Y is the aggregate industry output. Using (7) and (8), we can derive the industry's aggregate output in the Cournot equilibrium as follows:

$$\begin{aligned} Y \quad &= \quad Y - \frac{wY^2}{1-\tau} + F \cdot \left(Y - \frac{\chi w Y^2}{1-\tau} \right) \\ &\Leftrightarrow \quad Y = \left(\frac{F}{1+\chi F} \right) \left(\frac{1-\tau}{w} \right). \end{aligned} \tag{9}$$

Then, the Cournot equilibrium price is

$$p = \left(\frac{1+F\chi}{F} \right) \left(\frac{w}{1-\tau} \right). \tag{10}$$

Using (7) and (9), we obtain the equilibrium output of each producer as follows:

$$y_F \quad = \quad \frac{F}{(1+\chi F)^2} \left(\frac{1-\tau}{w} \right), \tag{11}$$

$$y_L \quad = \quad \frac{F[1+(\chi-1)F]}{(1+\chi F)^2} \left(\frac{1-\tau}{w} \right). \tag{12}$$

Then, the followers' and leader's after-tax profits are

$$\pi_F(F) \quad = (1-\tau) \left(\frac{1}{1+\chi F} \right)^2, \tag{13}$$

$$\pi_L(F) \quad = (1-\tau) \left(1 - \frac{F}{1+\chi F} \right)^2. \tag{14}$$

The after-tax profits decrease in τ and F. Therefore, as potential followers enter, the profits of existing firms shrink.

2.4 Entry

We assume that all followers must incur a fixed operating cost c_F in each period for late arrival.[2] In reality, leader firms have a certain first-mover advantage and by abusing their monopolistic position may be able to prevent potential firms from entering the industry. In addition, each leader can secure influential trademarks, less expensive land, visibility through advertisements, and a specific relationship with retailers earlier than the late entrants. These activities will work to generate some fixed operating costs for follower firms.[3] We assume that the fixed operating cost is paid by devoting labor. More formally, we assume that $c_F = wL_F$, where L_F is the amount of labor devoted to incur the fixed cost.

After each follower earns the after-tax Cournot profit π_F, they must pay the fixed operational cost c_F. They cannot survive if π_F is strictly smaller than c_F. This implies, conversely, that a potential firm can enter the market as long as the Cournot profit is greater than the fixed cost. Then, the free-entry condition for production is given by

$$\pi_F \leq c_F, \tag{15}$$

where the equality holds when $F > 0$.

2.5 R&D

All followers who paid c_F choose whether to perform R&D activities that may succeed in creating a high-quality good. We assume that R&D activities are performed only by existing firms that produce goods for the market, an assumption justified by considering that the research productivity of existing firms is higher than that of potential firms, because manufacturing experience gives the producer essential clues about further innovations. This assumption is in contrast to Grossman and Helpman (1991, Ch.4) and other subsequent studies, because they assume that only potential firms engage in R&D activities. In their model, no existing firm has an incentive to innovate because every existing firm is already a monopolist. (This is Arrow ' s replacement effect.) However, in reality, we often observe R&D investment by existing firms. Recent empirical studies have found that existing firms' own-product improvement, rather than creative destruction by market entrants, is a major source of economic growth, (e.g., Bartelsman and Doms (2000); Garcia-Macia et al. (2019)). In particular, Garcia-Macia et al. (2019) report that 80.2% of TFP growth for 2003-2013 in the U.S. is attributed to innovation by existing firms. We believe that, in the quality-improvement innovation model, existing firms' R&D activities rather than potential firms' R&D activities should be highlighted.

The success of R&D investment follows a Poisson process. A follower j can draw a

[2] Suzuki (2019a) regards this cost as the patent licensing fee paid by followers and examines the optimal licensing strategy of patent holders.

[3] In reality, leaders are often prohibited by antitrust laws from performing such activities. Therefore, the fixed cost can also be considered a governmental policy variable. Suzuki (2019b) investigates the effect of the fixed cost on average innovation to explore the competition-innovation relationship.

lottery that may succeed in performing R&D, with a small probability of $a_j \in [a_{\min}, a_{\max}]$, by employing one worker. We assume that followers are heterogeneous in their R&D efficiency ($a_{\min} < a_{\max}$). When each follower enters the market, it realizes that its own a_j. For simplicity, we assume that a_j is uniformly distributed in $[a_{\min}, a_{\max}]$.

We assume that there is a R&D tax deduction in this economy. If firm j is an innovative follower, it can deduct a part of the R&D cost (the wage paid to a researcher) from the corporate income. Let the taxable corporate income be $py_j - \zeta w$ where $\zeta \in [0, 1]$ is the R&D tax deduction rate. We assume that that $\tau\zeta w$ is refunded to innovative followers when they perform R&D.

The R&D tax credit is a popular tax incentive system in developed countries. For example, in the Federal U.S. tax system, the R&D tax credit is equal to 20% of the excess of qualified research expenses over a calculated base amount. For simplicity, we assume that the base amount is zero.

A follower conducts R&D investment if the net benefit of R&D is positive, or else they become a non-innovative follower. Then, the condition for performing R&D is given as

$$a_j V_t \geq (1 - \tau\zeta) w_t, \tag{16}$$

where V_t is the value of innovation.

2.6 Equilibrium

To make the analysis meaningful, we consider a parameter range where the number of followers is strictly positive. Then, as free-entry condition (15) holds with equality, F is determined as follows:

$$F^* = \frac{1}{\chi}\left(\sqrt{\frac{1-\tau}{c_F}} - 1\right). \tag{17}$$

This equation suggests that the corporate tax rate has an upper bound $\tilde{\tau} = 1 - c_F$.

We focus on a realistic situation in which research firms and imitators coexist ($0 < f_R < 1$). In reality, not all existing firms invest in R&D. In particular, many small and medium-sized enterprises do not engage in any research (see Chambers et al. (2002) and Ho et al. (2005)).

There is a marginal follower who is indifferent to performing R&D. As her net benefit from performing R&D is zero, we have

$$\bar{a} V = (1 - \tau\zeta) w, \tag{18}$$

where $\bar{a}$ is the cutoff value of R&D efficiency. This implies that a fortunate follower who draws $a_j \in [\bar{a}, a_{\max}]$ becomes an innovative follower. Then, the fraction of innovative follower is given by

$$f_R = \frac{a_{\max} - \bar{a}}{a_{\max} - a_{\min}}. \tag{19}$$

In the economy, the labor is allocated to production, paying operating fixed cost, and R&D investments. At labor market equilibrium, the aggregate labor demand must be equal to labor supply L. The condition of labor market equilibrium (LME) is

$$y_L + F \cdot \chi y_F + F\left(\frac{c_F}{w}\right) + F f_R = L. \tag{20}$$

Consider the returns from holding a particular leader's stock. The leader earns π_L in every period, and it is perfectly distributed to the stockholders. However, the leader's stock loses its value when a certain innovative follower is successful in innovating. We assume that there is a perfectly risk-free asset market and the interest rate on the safe assets is equal to r_t. Therefore, the following equation holds as a no-arbitrage condition (NAC) in the asset market.

$$rV_t = \pi_L(F) + \dot{V}_t - \Omega(F, f_R)V_t, \tag{21}$$

where $\Omega(F, f_R)$ is the aggregate innovation rate, given by (for the calculation, see also panel (a) in Fig.4),

$$\begin{aligned} \Omega(F, f_R) &= \int_{(1-f_R)F}^{F} \left(a_{\min} + \frac{a_{\max} - a_{\min}}{F}x\right) dx \\ &= \underbrace{\frac{1}{2}\left[2a_{\max} - (a_{\max} - a_{\min})f_R\right]}_{\text{Average probability}} \cdot \underbrace{Ff_R}_{\text{Number of innovators}}, \end{aligned} \tag{22}$$

which is increasing in F and $f_R \in (0, 1)$. The first part in (22) is the average R&D success probability of innovative followers. If all followers are innovative ($f_R = 1$), the average probability is $(a_{\max} + a_{\min})/2$. Also, the average probability is $(a_{\max}$ when $f_R = 0$. This is a case in which only a follower who has $a_{\max}$ is innovative (note that the measure is zero). In the homogeneous case ($a_{\max} = a_{\min} = a$), the average probability is always a.

3 The steady state

In the following, we derive two important equations that characterize the steady state in the economy. First, using (14),(17), (24) and $\dot{V} = 0$, and rearranging, we obtain

$$V = \frac{\left(\sqrt{c_F}/\chi + (1 - 1/\chi)\sqrt{1-\tau}\right)^2}{\rho + \Omega(F, f_R)}. \tag{23}$$

This is decreasing in f_R and is illustrated as the downward sloping curve "NAC" in Fig.2. Second, by substituting (11), (12), and (17)-(19) into (20) and rearranging, we obtain

$$V = \frac{(1 - \tau\zeta)\hat{L}_Y}{[a_{\max} - (a_{\max} - a_{\min})f_R](L - Ff_R)}, \tag{24}$$

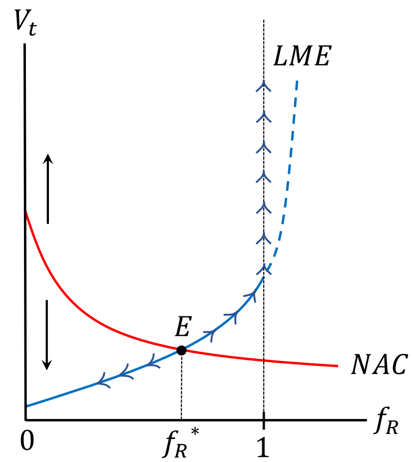

Figure 2: Phase diagram in the case of $0 < f_R^* < 1$.

where $\hat{L}_Y$ is a constant defined as

$$\hat{L}_Y \equiv \frac{c_F}{\chi}\left(\sqrt{\frac{1-\tau}{c_F}} - 1\right)\left[\left(2 - \frac{1}{\chi}\right)\sqrt{\frac{1-\tau}{c_F}} + \frac{1}{\chi}\right]. \tag{25}$$

Equation (24) is represented by the upward sloping curve "LME" in Fig.2. The intersection of the two curves is the steady state of the economy. The steady state is unique and unstable. As there are only jumpable variables in the dynamics, there are no transitional dynamics in the model, and the economy immediately jumps to the steady state at $t = 0$. This feature guarantees that the comparative statics between different steady states are applicable in the evaluation of policy effects.

We evaluate welfare by assuming that the economy starts in the steady state from $t = 0$. Using (2) and (8), we can decompose the period utility as follows:

$$\ln C_t = g_t \cdot t + \ln Y_t, \tag{26}$$

where g_t is the economic growth rate. The steady-state value of g and Y are calculated as follows:

$$g = \Omega \ln \lambda, \tag{27}$$

and,

$$Y = \frac{1}{\chi}\left(1 - \sqrt{\frac{c_F}{1-\tau}}\right)\left(\frac{1-\tau}{w}\right). \tag{28}$$

In other words, the growth rate is determined by the rate of new innovation arrivals and the size of innovation. The steady-state wage rate in Y is determined by (18), (19), and V^*.

By integrating the lifetime utility function with respect to time, we obtain the representative household's welfare as follows:

$$W = \frac{1}{\rho}\left[\underbrace{\frac{\ln\lambda}{\rho}\Omega}_{Innovation} + \underbrace{\ln Y}_{Consumption}\right]. \tag{29}$$

This tells us that the welfare can be decomposed into two parts: the speed of quality-upgrading innovation and the quantity of consumption.

4 The relationship between corporate tax and growth

4.1 The corporate tax cut and two curves in Fig.2

We examine the effect of corporate tax cut ($\tau \downarrow$) on the growth rate. Since $\ln\lambda$ in (27) is constant, we only have to check the effect on Ω. From (22), it can be decomposed to the effect through F and the effect through f_R. The former effect is obviously positive from (17), because the corporate tax cut increases the number of innovative followers if f_R is constant. The latter effect is unclear, because f_R is determined by the intersection of two curves in Fig.2. In the following, we investigate the direction of shifts of NAC curve and LME curve.

The corporate tax cut has an ambiguous effect on NAC curve because there are two opposite effects. The first is a negative effect. Because the corporate tax cut increases the number of followers F^*, given as f_R, it increases Ω in the denominator of (23). This implies that the leader's expected survival time becomes shorter, and it negatively affects the incentive to innovate. The second is a positive effect. From (14), this policy naturally increases the leader's after-tax profit, and it stimulates the followers' incentive to innovate (*the Schumpeterian effect*). This effect is captured by the increase in the numerator of (23). But the Schumpeterian effect is mitigated by the increase in the number of followers, because a stronger market competition shrinks the Cournot profit (*the competition-enhancing effect*). This result implies that the corporate tax cut does not dramatically increase the after-tax profit.

In contrast, the effect on the LME curve is clear. From (24), the corporate tax cut necessarily shifts up the LME curve and thus generates a movement along the NAC curve that produces slower growth. This is *the cost-increasing effect* through the labor market. A rise in the number of followers increases the labor demand for production. Then, the equilibrium wage (=R&D cost) rises, which discourages followers' incentive to innovate.

As a result, the total effect on the growth rate is ambiguous because the direction of shift of the NAC curve is unclear. However, we can show the following statement analytically.

Proposition 1. *Suppose that the corporate tax rate is at the upper bound ($\tau = \tilde{\tau}$). Then, (i) $f_R = 1$, (ii) $g = 0$, and (iii) $dg/d\tau < 0$ hold.*

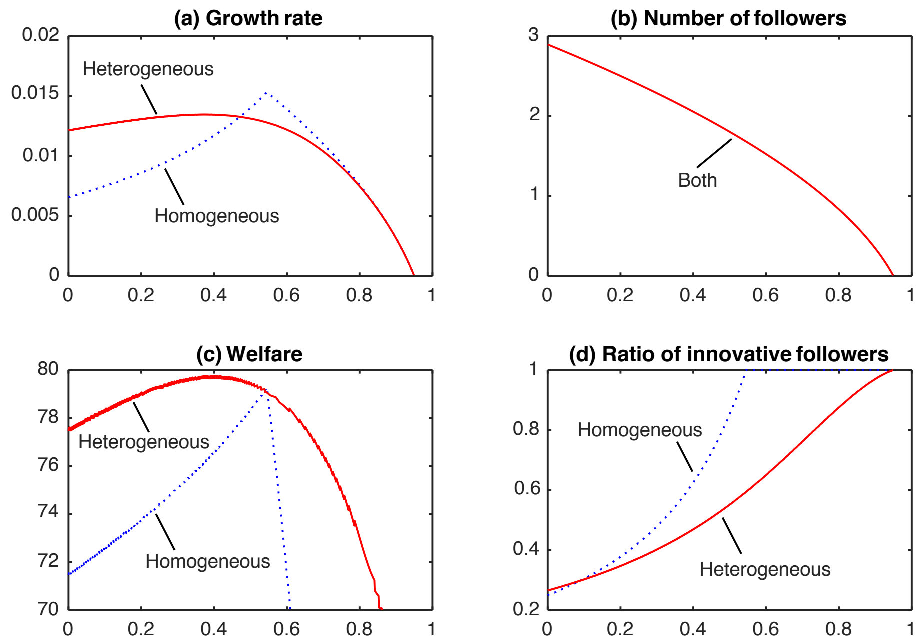

Figure 3: The effects of the corporate tax change in a heterogeneous economy and a homogeneous economy. Parameters are $L = 10, \lambda = 1.2, \chi = 1.2, \rho = 0.03, (a_{\max}, a_{\min}) = (0.05, 0.05)$ and $(0.1, 0), c_F = 0.05$, and $\zeta = 0.2$. The solid lines show the heterogeneous case and the dotted lines show the homogeneous case.

Proof. See Appendix. □

Property (iii) in proposition 1 states that the corporate tax cut from the upper bound $\tilde{\tau}$ necessarily increases the growth rate. This also implies that the relationship between the corporate tax rate and the growth rate at least cannot be globally positive. Therefore, the relationship between them is either globally negative or non-monotone (e.g., inverted-U shape).

4.2 The relationship with heterogeneity

We investigate how the degree of heterogeneity in R&D efficiency affects the policy effect. To highlight the role of heterogeneity, we consider a homogeneous case in which $a_{\max} = a_{\min} = a$ holds as a benchmark economy.

Proposition 2. *In the homogeneous case ($a_{\max} = a_{\min} = a$), the corporate tax cut decreases the growth rate when $f_R < 1$ and increases the growth rate when $f_R = 1$.*

Proof. In the case of $f_R = 1$, this result is obvious from (17) and (22). See Appendix for the case of $f_R < 1$. □

Proposition 2 states that, in the homogeneous case, the relationship between the corporate income tax rate and the growth rate is globally non-monotone (see also Panel (a) in Fig.3). However, because a corner solution situation $f_R = 1$ is unrealistic and we focus on the case of $f_R < 1$, we should note that the corporate income tax cut always decreases the growth rate in the homogeneous case. The clear relationship is inconsistent with the empirical findings. Hence, the homogeneous case fails to show an unclear relationship between τ and g.

However, a numerical example of the (mean-preserving) heterogeneous case in Panel (a) in Fig.3 shows that, within a realistic range $f_R \in [0, 1)$, there is an inverted-U relationship between corporate tax and growth. In this case, the corporate tax cut has a positive effect on the growth rate to the right of the peak. Therefore, it should be emphasized that heterogeneity produces an ambiguous relationship between corporate tax rate and growth that is consistent with empirical findings.

Corporate tax cuts can have a positive effect on the growth rate in heterogeneous cases. As mentioned above, corporate tax cuts increase the number of followers who draw the lottery of R&D productivity, and this has a positive effect on growth. However, as shown in Panel (d) in Fig.3, corporate tax cuts decrease the ratio of innovative followers f_R, and this has a negative effect on growth.[4] Therefore, as shown in Fig.4, the total effect is ambiguous. But Panel (d) in Fig.3 also shows that the negative effect on f_R is relatively mild in the heterogeneous case. There is a following *selection mechanism*. The corporate tax cut induces only inefficient followers (low a_j) to give up their R&D activities while efficient followers (high a_j) can keep conducting them. Conversely, in the homogeneous case, the corporate tax cut induces many identical followers to stop their R&D investment. Furthermore, the selection mechanism mitigates the effect of the decrease in f_R on Ω by increasing the average R&D success probability in (22). However, (22) also tells us that this selection mechanism disappears when $a_{\max} = a_{\min}$. This is also a reason why corporate tax cuts cannot have a positive growth effect in homogeneous cases.

Intuitively, in the homogeneous case, the corporate tax cut just reallocates labor from the R&D sector to the production sector. However, in the heterogeneous case, the corporate tax cut also reallocates labor from inefficient followers to efficient followers.

4.3 The relationship with patent protection

We investigate how the strength of patent protection affects the tax policy effect.

Proposition 3. *Suppose that the patent protection is the weakest ($\chi = 1$). Then, the corporate tax cut necessarily decreases the ratio of innovative followers (f_R).*

Proof. Assume that $\chi = 1$ holds. Then, the Schumpeter effect disappears (see the numerator in (23)). Therefore, the tax cut shifts the NAC curve downward and the LME curve upward. □

[4]This means that the Schumpeterian effect is dominated by the cost-increasing effect in both cases.

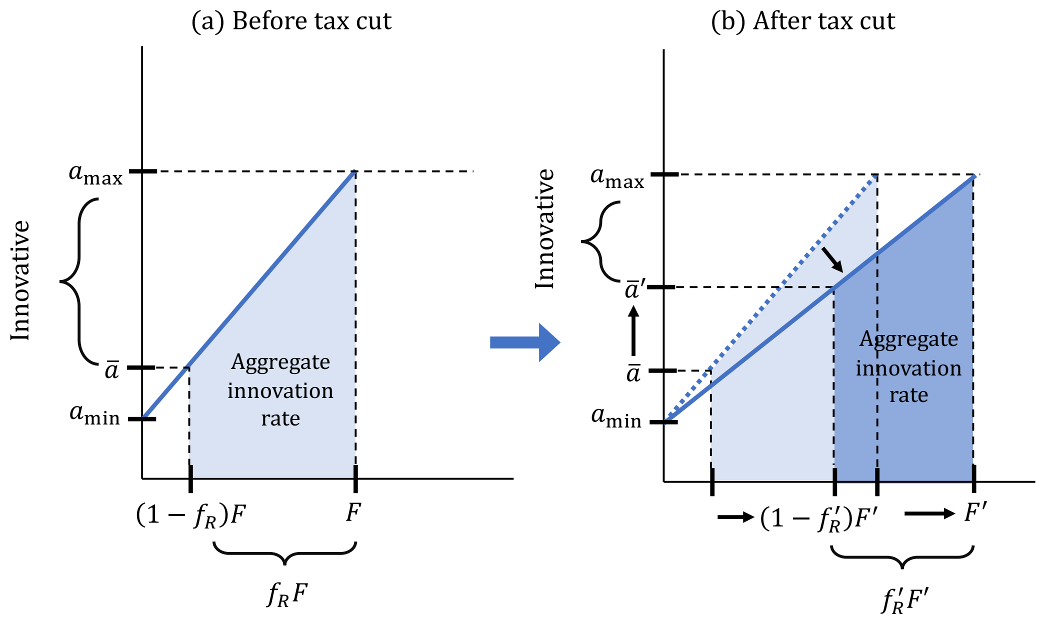

Figure 4: The effects of corporate tax cut on the threshold, the number of innovative followers, and the ratio of innovative followers in a heterogeneous economy. The policy raises the threshold of R&D productivity. In other words, the policy discourages inefficient followers from conducting R&D (*negative effect*). However, the policy also raises the number of followers who draw the lottery of R&D productivity. Therefore, it increases the number of relatively efficient followers (*positive effect*).

This proposition suggests that the corporation tax cut is likely to have a negative effect on economic growth under a weak patent protection. A numerical analysis in panel (a) of Fig.5 shows that the conjecture is partially correct. The range of downward sloping becomes broader when patent protection is weak. Therefore, corporation tax cuts are likely to reduce growth rate.

Fig.5 also shows that when the patent protection is stronger, the growth-maximizing corporate tax rate is smaller. Weak patent protection decreases the leader's profit, because many followers enter the market through imitation. Furthermore, R&D cost increases, because many followers demand labor to produce the imitated goods. Therefore, to enhance innovation, the government should exclude followers by setting the corporate tax at a higher rate. Conversely, when patent protection is strong, the follower has sufficient incentive to innovate through the Schumpeterian effect. In this case, the government does not need to exclude the followers by increasing the corporate tax. Consequently, growth-maximizing corporate tax rate is smaller as patent protection is stronger.

Panel (c) of Fig.5 shows that there is a parameter range where the welfare-maximizing corporate tax rate is smaller as the patent protection is stronger. Our result is in contrast to the finding of Iwaisako (2016) that, from the perspective of welfare, the corporate income

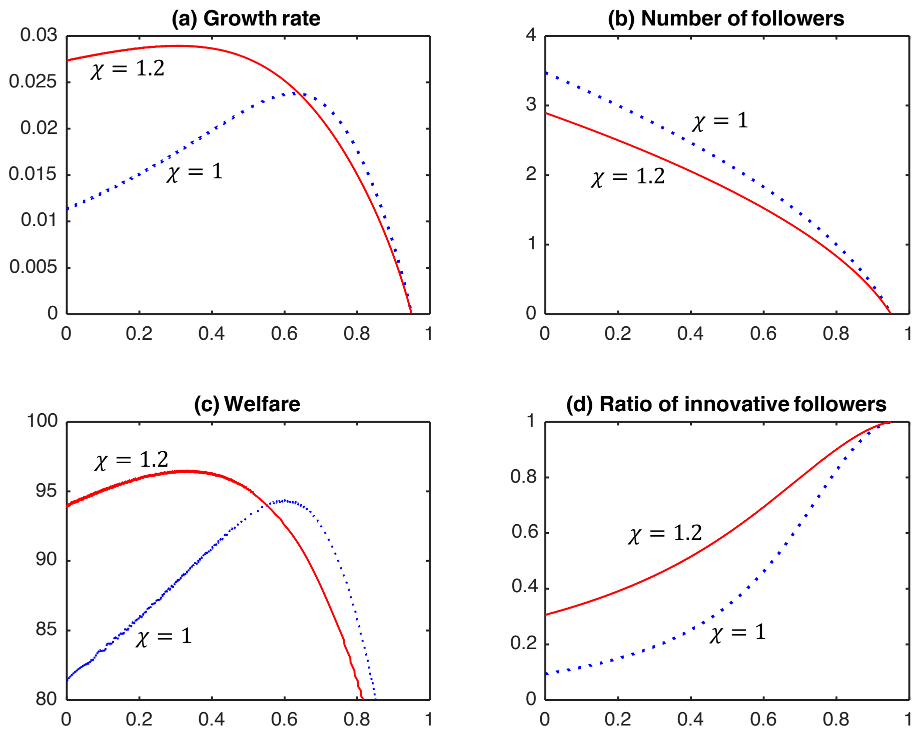

Figure 5: Patent protection and the effects of the corporate tax change. Parameters are $L = 10, \lambda = 1.2, \chi = 1$ and $1.2, \rho = 0.03, a_{\max} = 0.2, a_{\min} = 0, c_F = 0.05$, and $\zeta = 0.2$.

tax rate should be higher as patent protection becomes stronger. The difference in results comes from our endogenous market structure. In both models, under a strong patent protection, labor may be excessively devoted to R&D from the perspective of welfare. In our model, to reallocate labor from R&D to production, the corporate tax rate should be smaller, because it encourages the entry of followers who produce imitated goods. In other words, corporate tax cut crowds out R&D investment in our model. However, in the Bertrand competition model of Iwaisako (2016) in which there is no actual entry of potential firms to reallocate labor from R&D to production, the corporate tax rate should be larger because it discourages potential firms' incentive to innovate.

4.4 R&D tax deduction

Proposition 4. *Suppose that $0 < \tau < \tilde{\tau}$. Then, a higher R&D tax deduction rate ζ increases the ratio of innovative followers and the economic growth rate.*

Proof. Suppose that ζ is increased while other parameters are unchanged. Then, the LME curve shifts downward unless $\tau = 0$, and it increases f_R. Because ζ does not affect F, this tax deduction ($\zeta \uparrow$) increases the aggregate innovation rate Ω. □

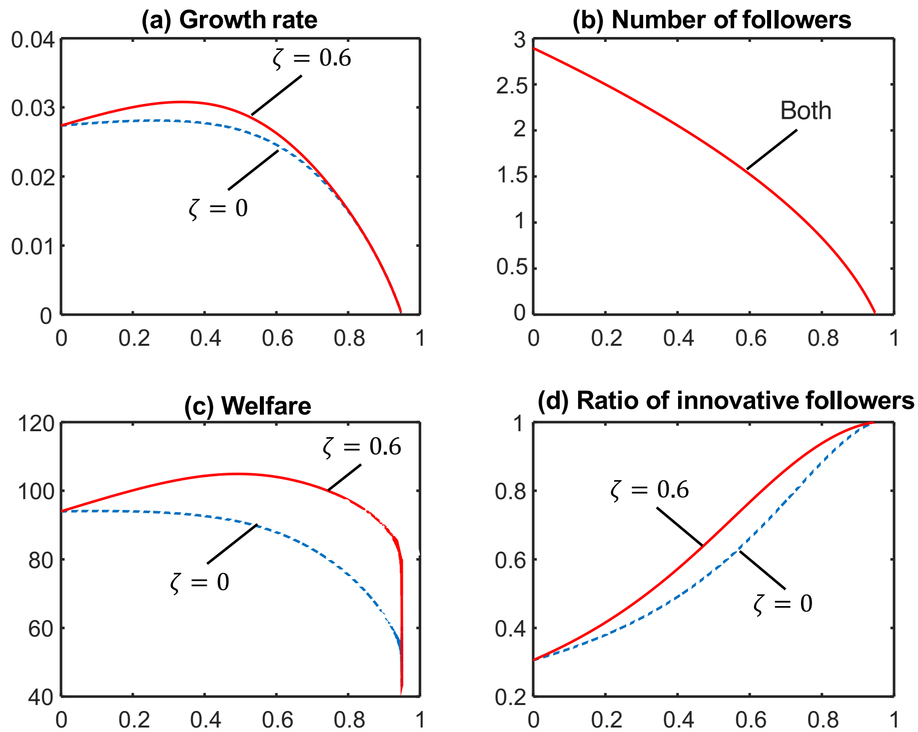

Figure 6: R&D tax deduction and the effects of the corporate tax change. Parameters are $L = 10, \lambda = 1.2, \chi = 1.2, \rho = 0.03, a_{\max} = 0.2, a_{\min} = 0, c_F = 0.05$, and $\zeta = 0$ and 0.6.

As there is a broad agreement that tax incentives stimulate R&D, proposition 4 is consistent with many empirical studies (e.g., Mamuneas and Nadiri (1996); Hall and van Reenen (2000); Bloom et al. (2002); Minniti and Venturini (2017)).

Fig.6 is our numerical example. The statement in proposition 4 is represented as in Panels (a) and (d) of Fig.6. By proposition 1, g and f_R are independent from ζ when $\tau = 0$ and $\tau = \tilde{\tau}$. This simply captures the fact that the R&D tax deduction becomes meaningless as the corporate tax rate approaches zero. As ζ rises, the curve in Panel (a) expands upward while each end point is unchanged. This implies that the corporate tax cut is likely to have a negative growth effect when the R&D tax deduction rate is high and the corporate tax rate is already low. Therefore, we obtain a policy implication that the growth-maximizing corporate tax rate depends on the level of tax incentive.

5 Quantitative analyses

This section provides a numerical example under plausible parameter values to evaluate the growth effect of the U.S. tax reform in 2018.

5.1 Calibration of the U.S. economy

Let us calibrate the structural parameters (L, λ, χ, ρ, $a_{\max}$, $a_{\min}$, c_F). We calibrate the parameters by targeting the scenario in which innovation drives an average economic growth rate of 2% in the U.S. under the corporate tax rate until 2017, $\tau = 0.35$, and the regular R&D credit $\zeta = 0.2$.

According to Hashmi (2013), the average of 1−Lerner in the U.S. is 0.76. In our model, 1−Lerner is $F/(1+F)$. This means that $F \simeq 3.17$. We set the average markup of price over marginal cost to 1.33. This is in the plausible range (see Basu (1996) and Jones and Williams (2000)). In our model, the average markup, ψ, in an industry is

$$\psi = \frac{1/3.17 + \chi + 3.17 + 1/\chi}{4.17}. \tag{30}$$

By solving this, we obtain $\chi \simeq 1.06$. We assume that the patent protection in the U.S. is almost perfect and adopt $\lambda = \chi = 1.06$. This corresponds to Park (2008) and shows that the patent right index in the U.S. is 4.88 (the maximum is 5), the biggest in the world. This value is also very close to the 1.05 adopted in Acemoglu and Akcigit (2002). Using (17) and $F \simeq 3.17$, we set $c_F = 0.0349$. Chambers et al. (2002) shows that the average number of non-R&D firms is 2,679 while the average number of R&D firms is 1,792. Therefore, the rest of parameters must be determined to satisfy $f_R \simeq 0.4$. We set the discount rate ρ to a conventional value of 0.03 and assume that $a_{\min} = 0$. Then, by using $a_{\max}$ and L as free parameters, we numerically find that $a_{\max} = 0.335$ and $L = 23$ satisfy $f_R \simeq 0.4$ and $g \simeq 0.02$.

5.2 Results

Fig.7 shows our numerical results. Panel (b) and (d) display the effect of the corporate tax on the number of followers and the ratio of innovative followers, respectively. From (22), combining these two effects yields the relationship between the corporate tax rate and the growth rate in panel (a).

Panel (a) shows that there is an inverted-U relationship between the corporate tax and economic growth. The growth-maximizing tax rate is around 50%, and the corporate tax cut has a negative impact on growth to the left of the peak. Therefore, our numerical result implies that the corporate tax cut in the U.S. in 2018 (35% $\to$ 21%) has a negative growth effect. Quantitatively, the policy decreases the growth rate around 0.11%. Our result suggests that the corporate tax rate should be a higher, not lower. This result seems to be consistent to the result in Aghion et al. (2016) that finds that the growth-maximizing corporate tax rate ($\simeq$ 42.47%) is higher than the actual rate. Panel (d) shows that the welfare will be improved by raising the corporate tax rate. Therefore, our result suggests that the corporate tax rate should be higher from the perspective of welfare, not only growth.

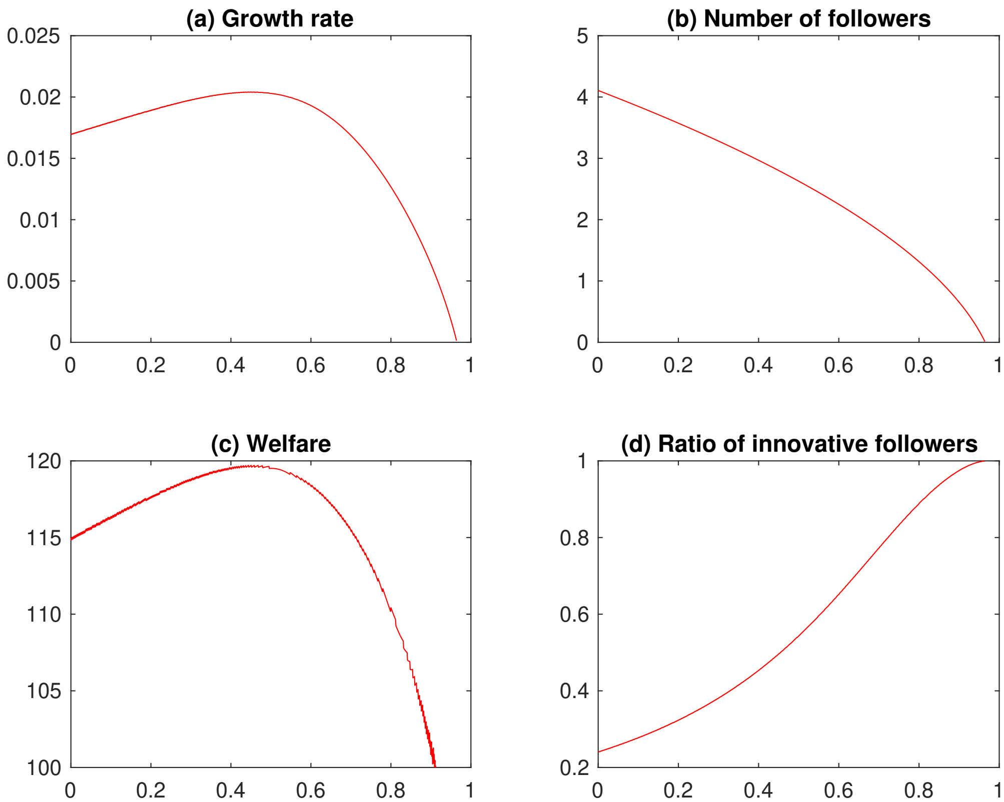

Figure 7: Simulation results of the U.S. economy.

6 Conclusion

Is corporate income taxation harmful to economic growth? The conventional answer is yes, but empirical evidence is mixed and unclear. To explore the ambiguous mechanism of corporate income taxation, this paper develops a Schumpeterian growth model with heterogeneous innovators and endogenous market structure.

First, we found that the corporate tax cut does not necessarily enhance innovation, because the market becomes more competitive and R&D cost rises. In particular, our analyses show that the relationship between the corporate tax rate and economic growth rate can be inverted-U. Second, the corporate tax cut is likely to have a positive effect when the R&D productivity across firms is heterogeneous, while the growth effect is always negative in the homogeneous case. In reality, we observe a few R&D-intensive firms but many non-R&D firms. Therefore, the result in the heterogeneous case is more plausible. Third, R&D tax deduction increases growth rate. Finally, we calibrated the U.S. economy and show that the corporate tax cut in 2018 had a negative effect on economic growth and welfare.

Appendix

Proof of proposition 1

Proof. (i) Recall that $F^* = 0$ holds when $\tau = \tilde{\tau} \equiv 1 - c_F$. Then, from (24) and (25), when $\tau \to \tilde{\tau}$, the LME curve shifts downward and approaches a horizontal line $V = 0$. In contrast, the RHS in (23) is always positive in $\tau \in [0, \tilde{\tau}]$ Therefore, at some $\tau = \hat{\tau} < \tilde{\tau}$, the NAC curve intersects the LME curve on $f_R = 1$. This means that f_R reaches the upper bound in $\tau \in [\hat{\tau}, \tilde{\tau}]$. (ii) It is obvious by substituting $F^* = 0$ into (22). (iii) The growth rate is $g = \Omega \ln \lambda$. Therefore, we only have to check the effect on Ω. By differentiating Ω with respect to τ,

$$\frac{\partial \Omega}{\partial \tau} = \underbrace{G'(f_R)}_{+} \frac{df_R}{d\tau} F^* + \underbrace{G(f_R)}_{+} \underbrace{\frac{dF^*}{d\tau}}_{-}, \tag{31}$$

where $G(f_R) \equiv (1/2)[2a_{\max} - (a_{\max} - a_{\min}) f_R] f_R$. Recall that $F^* = 0$ holds when $\tau = \tilde{\tau}$. Then, $\partial \Omega / \partial \tau < 0$. □

Proof of proposition 2

Proof. Suppose that $a_{\max} = a_{\min} = a$ and $f_R < 1$. Then, (23) and (24) becomes

$$V = \frac{\left(\sqrt{c_F}/\chi + (1 - 1/\chi)\sqrt{1-\tau}\right)^2}{\rho + aR}, \tag{32}$$

and,

$$V = \frac{(1 - \tau\zeta)\hat{L}_Y}{a(L - R)}, \tag{33}$$

where $R \equiv F f_R$ is the number of innovative followers. By solving these equations and using (22), we obtain

$$\Omega = \frac{\Gamma(\tau) a L - \rho}{\Gamma(\tau) + 1}. \tag{34}$$

where

$$\begin{aligned} \Gamma(\tau) &= \frac{\left(\sqrt{c_F}/\chi + (1 - 1/\chi)\sqrt{1-\tau}\right)^2}{(1 - \tau\zeta)\hat{L}_Y} \\ &= \frac{1}{1 - \tau\zeta} \left[\frac{(\chi - 1)^2 (1 - \tau) + 2(\chi - 1) c_F^{1/2} (1 - \tau)^{1/2} + c_F}{(2\chi - 1)(1 - \tau) - 2(\chi - 1) c_F^{1/2} (1 - \tau)^{1/2} - c_F} \right]. \end{aligned} \tag{35}$$

Because Ω increases in Γ, the proof is completed if we show that Γ is increasing in τ. Since $1/(1 - \tau\zeta)$ increases in τ, if we show that the bracket in (35) is also increasing in τ, the proof is completed.

For simplicity, we define $t \equiv 1 - \tau \in (c_F, 1]$. Using this, we express the numerator and the denominator in the bracket in (35) as follows:

$$f(t) = (\chi - 1)^2 t + 2(\chi - 1)c_F^{\frac{1}{2}} t^{\frac{1}{2}} + c_F, \tag{36}$$

and,

$$g(t) = (2\chi - 1)t - 2(\chi - 1)c_F^{\frac{1}{2}} t^{\frac{1}{2}} - c_F. \tag{37}$$

By definition, we only have to show that the sign of $f'(t)g(t) - f(t)g'(t)$ is negative in $t \in (c_F, 1]$. Computing and rearranging, we obtain

$$\begin{aligned} f'(t)g(t) - f(t)g'(t) \quad = \quad & -\left[(\chi - 1)^2 - (2\chi - 1)\right] c_F \\ & -\left[(\chi - 1)^3 + (\chi - 1)(2\chi - 1)\right] c_F^{1/2} t^{1/2}. \end{aligned} \tag{38}$$

This is decreasing in t. Therefore, if $f'(c_F)g(c_F) - f(c_F)g'(c_F) < 0$, this is always negative in $t \in (c_F, 1]$. We can observe that the condition holds as follows:

$$f'(c_F)g(c_F) - f(c_F)g'(c_F) = -\chi^3 c_F < 0. \tag{39}$$

□

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