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Kizuku Takao†

Abstract

Tax changes are often announced before the implementations and are not permanent but only temporary. R&D firms will optimally adjust their investment decision to a tax schedule accordingly. This paper analyzes how anticipated and temporary tax changes dynamically affect the innovation activities. For the purpose, we consider adjustment costs for the investment process and allow firms to make a forward looking investment decision in the framework of an R&D-based endogenous growth model. Calibrating the model with U.S. data, we obtain new insights on how to design the corporate taxation policy. A dividend tax cut is not an effective policy instrument irrespective of how it is implemented. On the other hand, a capital gains tax cut and a rise of the R&D tax credit rate are an effective policy instrument irrespective of how they are implemented. However, the implementation lags of these tax changes worsen the effectiveness of them.

Keywords: Fiscal policy, R&D, Economic growth

JEL classification: E62, O32, O41

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1 Introduction

Technological progress through commercial R&D activities is a major source of economic growth. Firms make an R&D investment decision, considering the cost and the benefit of R&D. Those values are affected by different taxation policies. As Hall and Van Reenen (2000) surveys, fiscal incentives for R&D investments differ across countries and change over time. The purpose of this paper is to provide the clear policy implications of tax changes by using an R&D-based endogenous growth model. In our model economy, technological progress is driven from in-house R&D performed by long-lived value-maximizing firms. The novel feature of our study is that we consider how firms make a forward-looking investment decision of in-house R&D in reaction to future or temporary tax changes. In the real world, tax changes are usually announced before the implementations and are not permanent but only temporary. In these situations, firms and households have an opportunity to adjust their intertemporal behavior to a tax schedule. For better understanding of taxation policy, it is important to consider what differences of the policy effects of tax changes arise depending on how the tax changes are implemented.

Calibrating the model with U.S. data, we obtain the following main findings. First, we show that an anticipated dividend tax cut stimulates in-house R&D and aggregate growth during the announcement phase. After the implementation, the tax cut is detrimental to in-house R&D and aggregate growth. The welfare effect of the tax cut are negative irrespective of how it is implemented. However, the implementation lags diminish the welfare looses. It allow firms to adjust the timing of dividend payments to the tax schedule. The future dividend tax cut increases the future cost of in-house R&D. Hence firms have an incentive to increase their current in-house R&D investments in order to raise the subsequent dividend payments. Besides, households can adjust more smoothly to the tax schedule. Second, we show that an anticipated capital gains tax cut and a rise of the R&D tax credit rate have a negative impact on in-house R&D and aggregate growth during the announcement phase. After the implementation, these tax changes stimulate in-house R&D and aggregate growth. The welfare effect of these tax changes is both positive irrespective of how they are implemented. However, the implementation lags reduce the welfare gains. Future these tax changes reduce the future cost of in-house R&D. Hence firms have an incentive to reduce their current in-house R&D investments and raises their current dividend payments. The negative announcement effect on growth exceeds the positive effect derived from more smooth path of the consumption and the leisure time of households.

To summarize our results, we suggest the following policy implications. A dividend tax cut is not effective policy instrument irrespective of how it is implemented. On the other hand, a capital gains tax cut and a rise of the R&D tax credit rate are an effective policy instrument irrespective of how they are implemented. However, the implementation lags of these tax changes worsen the effectiveness of them.

Our analyses are based on that of Peretto (2007, 2011). Specifically, the model of Peretto (2007, 2011) considers the economy where long-lived value-maximizing firms continuously improve the quality of their own product through in-house R&D, while at the same time new firms also enter into the market. The advantage of the model of Peretto (2007, 2011) is to eliminate the well-known undesirable scale effect property while keeping the policy effect property supported by recent growing empirical literatures.[1] Increases in the scale of the aggregate economy are perfectly fragmented by endogenous product proliferation. In-house R&D investments are only related to an average firm-level scale. As a result, the channel through the undesirable scale effect is removed. Only the channel through the financial market remains, which yields non-negligible effect of fiscal policy on the long-run growth.[2]

However, in the model of Peretto (2007, 2011), firm's investment decision of in-house

[1]The first generation R&D-based endogenous growth model (e.g. Romer(1990) and Grossman and Helpman (1991)) indicates that the equilibrium growth rate is increasing in the labor endowment. However, Jones (1995a) refutes this property by the time-series data of the post-war period. And then, the following two prominent types of model are developed. The former type is referred to as the semi-endogenous growth type (e.g. Jones (1995b) and Segerstrom (1998)). They resolves the undesirable scale effect property by assuming the diminishing returns in R&D production technologies. This specification yields that the steady state growth rate is only pinned down to population growth rate. By contrast, the latter type is referred as the fully-endogenous type (e.g. Peretto (1998), Howitt (1999) and Futagami and Ohkusa (2003)). They assumes that both of vertical innovation and horizontal innovation occur. This specification yields that the steady state growth rate is also dependent of the other parameters and policy variables. Recent growing empirical literatures (e.g. Laincz and Peretto (2006), Ha and Howitt (2007), and Ang and Madsen (2011)) report that the latter type performs well rather than the former type.

[2]There is no consensus about whether the long-run growth responds to taxation policy or not. However, recent empirical studies (e.g. Romer and Romer (2010) and Mountford and Uhilg (2009)) support that the macroeconomic effects of tax changes are much higher than the conventional thoughts.

R&D turns out to be static problem. The reason is that the model assumes that the production function of in-house R&D is linear. This assumption implies that current in-house R&D investments are only dependent of the current market condition and tax rates. As a result, if we consider anticipated and temporary tax changes in the setting, we fail to capture how firm's investment decision of in-house R&D dynamically reacts to anticipated and temporary tax changes. To examine the macroeconomic impacts of such tax shocks, we also incorporate the framework of adjustment costs of investment used in the literatures of investment theory.[3] More specifically, we assume that firms confront on the convex adjustment costs associated with in-house R&D investments. This specification is indeed more realistic. Some empirical literature points out the existence of high adjustment costs for R&D investments (e.g. Nadiri (1989), Himmelberg and Petersen (1994) and Brown and Petersen (2011)). In the presence of the adjustment cost, firm's investment decision of in-house R&D alters to a forward-looking setting. Therefore, the dynamic system of the economy is characterized also by the (tax-adjusted) shadow value of in-house R&D, which determines the level of in-house R&D investments.[4] The shadow value summarizes all informations relevant to the investment decision of in-house R&D. The flexibility of the shadow value is very useful to analyze how the investment decision of in-house R&D dynamically reacts to anticipated and temporary tax changes.

Peretto (2007, 2011) have already examined effects of various tax changes related to corporate activities. In particular, Peretto (2007, 2011) mainly focus on effects of a dividend tax cut like that conducted in the Jobs Growth and Taxpayer Relief Reconciliation Act of 2003 (JGTRRA) in the U.S..[5] To be more detail, Peretto (2007) analyzes the revenue-neutral tax changes in the environment where the rate of the dividend tax is endogenously determined to finance the tax changes and balance the budget constraint of the government. The analyses suggest that policy makers should conduct the other taxation policy (such as

[3] See, for example, Hayashi (1982), Abel (1982), and Abel and Blanchard (1983)

[4] In Peretto (2007), the dynamic system of the economy is characterized by only one state variable (the number of firms per capita). In Peretto (2011), it is characterized by one state variable (the number of firms per capita) and one jump variable (the consumption ratio). On the other hand, the dynamic system of the model in our analysis is characterized by not only the number of firms per capita and the consumption ratio but also one additional jump variable (the shadow value of the innovation).

[5] To be precise, this tax reform substantially reduced the rate of the dividend tax with the moderate cut of capital gains tax.

a capital gains tax cut and a rise of the R&D tax credits) rather than a dividend tax cut. Peretto (2011) extends to the case where the government finances tax changes with debt. Calibrating the model with U.S. data, Peretto (2011) quantitatively shows that a dividend tax cut produces the slowdown of aggregate growth and considerable welfare losses.

The differences between our paper and Peretto (2007, 2011) are as follows. Peretto (2007, 2011) only focus on the macroeconomic impacts of unanticipated and permanent tax changes. On the other hand, we consider effects of anticipated and temporary tax changes in the environment where firms dynamically determine the level of their R&D investments. Besides, we examine the effectiveness of the alternative policy instruments rather than that of a divided tax cut in the environment where the government finances the tax changes with debt just like Peretto (2011). As Peretto (2011) claims, such a financing scheme is more appropriate to consider policy experiments of the taxation policy.

Our paper is also related to the following previous studies. Zeng and Zhang (2002) and Peretto (2003) also study effects of tax changes on the basis of non-scale R&D-based growth model. However, both of the paper analyze only unanticipated and permanent tax changes and do not consider transitional dynamics and welfare implications. Summers (1981) and Abel (1982) analyze how anticipated and temporary tax changes affect a forward-looking investment decision of firms by using the framework of the adjustment costs for investments. However, their analysis are based on the partial equilibrium approach. As a result, their analysis can not consider effects on aggregate growth and welfare. Strulik and Trimborn (2010) studies effects of anticipated and temporary tax changes in the general equilibrium setting. Their model is based on the neoclassical growth model with endogenous corporate finance and then the steady state growth rate is exogenous in this setting.

The rest of the paper is organized as follows. Section 2 describes the model. Section 3 characterizes the dynamic system and the steady state equilibrium of the market economy. Section 4 quantitatively analyzes the transitional adjustment of the aggregate economy to tax changes, calibrating the model with U.S. data. Section 5 conducts the sensitivity analysis of the numerical analysis. Finally, Section 6 discusses the policy implications and states the conclusion remarks.

2 The model

In this section, we set up the model based on Peretto (2011). Except for the presence of adjustment costs associated with in-house R&D investment for quality improving, the environment is the same as Peretto (2011). Time is continuous. The economy is closed and consists of the final goods sector, the intermediate goods sector, households, and the government. Long-lived value-maximizing firms produce their specific intermediate good and continuously improve the quality of their own product through in-house R&D, while at the same time new firms also enter into the market. All fiscal variables are treated parametrically since they change either only at discrete events or not at all. And so we omit the time index, t, on fiscal variables.

2.1 The final goods sector

The final goods, Y_t, is produced by the following production function:

$$Y_t = \int_0^{N_t} X_{it}^{\theta} \left(Z_{it}^{\alpha} \bar{Z}_t^{1-\alpha} L_{it} \right)^{1-\theta} di, \quad 0 < \alpha, \theta < 1, \tag{1}$$

where N_t, X_{it}, and L_{it} respectively represent the mass of intermediate goods, the input of intermediate good i (produced by firm i), and the input of labor who use the intermediate good i. The productivity of L_{it} depends not only on the quality of the intermediate good i, Z_{it}, but also on the average level of quality across intermediate goods, $\bar{Z}_t \equiv \int_0^{N_t} \frac{1}{N_t} Z_{jt} dj$. Final goods are consumed by households and the government and used only as one factor of all activities in the intermediate goods sector. Perfect competition prevails in the final goods sector. The price of final goods is normalized to one. Therefore, we obtain the following optimal conditions:

$$X_{it} = \left(\frac{\theta}{P_{it}} \right)^{\frac{1}{1-\theta}} \left(Z_{it}^{\alpha} \bar{Z}_t^{1-\alpha} L_{it} \right), \tag{2}$$

$$L_{it} = \left(\frac{1-\theta}{W_t} \right)^{\frac{1}{\theta}} X_{it} \left(Z_{it}^{\alpha} \bar{Z}_t^{1-\alpha} \right)^{\frac{1-\theta}{\theta}}, \tag{3}$$

where P_{it} and W_t respectively represent the price of the intermediate good i and the wage rate of labor.

2.2 The intermediate goods sector

Monopolistic competition prevails in the intermediate goods sector. There is the continuum of goods indexed by type $i \in [0, N_t]$. The firm i exclusively produces its differentiated good with its quality Z_{it}. Monopoly of each firm is permanently protected by the perfect patent protection. Producing one unit of intermediate goods requires one unit of final goods. And fixed operating costs, $\phi \bar{Z}_t$ ($\phi > 0$), are required at each point in time.

Each firm improves its product quality through in-house R&D. The law of motion of the firm-specific quality is

$$\dot{Z}_{it} = R_{it}. \tag{4}$$

In contrast to Peretto (2007, 2011), we assume that given increases of the firm-specific quality level, $R_{it} \geq 0$, involve adjustment costs associated with the innovation, following the specification of Hayashi (1982). Specifically, we assume that the total amount of R&D expenditure is given by

$$\Phi(R_{it}, Z_{it}) = R_{it} + \frac{h}{2} \frac{R_{it}^2}{Z_{it}}, \quad h > 0, \tag{5}$$

where the case of $h = 0$ corresponds to the specification of Peretto (2007, 2011).[6]

The gross cash flow of firm i is $F_{it} = X_{it}(P_{it} - 1) - \phi \bar{Z}_t$, where the first term represents revenue minus variable production costs and the second term represents fixed operating costs. Let σ be the rate of the R&D tax credit (the fraction of R&D expenditure which firms are allowed to subtract from their corporate taxable amount).[7] The total amount of corporate tax imposing on firm i is $\tau_\Pi \left[F_{it} - \sigma \Phi(R_{it}, Z_{it})\right]$, where τ_Π represents the rate of the corporate tax. The gross cash flow, F_{it}, distributes as follows:

$$F_{it} = \tau_\Pi \left[F_{it} - \sigma \Phi(R_{it}, Z_{it})\right] + E_{it} d_{it} + J_{it},$$

[6]This functional form is based on Turnovsky (2000).

[7]Although σ is assumed to be zero for simplification in Peretto (2011), we follow the specification of Peretto (2007) in order to see the effects of the tax credit policy for R&D investment as well.

where E_{it}, d_{it}, and J_{it} respectively represent the number of equities authorized by firm i, the pre-tax dividends per share of firm i, and retained earnings of firm i. The first term of the RHS of the above identity represents the amount of corporate tax, the second terms represents the amount of dividends delivered to equity shareholders, and the last term represents retained earnings. Financial constraint of firm i is written by $J_{it} + \dot{E}_{it}v_{it} = \Phi(R_{it}, Z_{it})$, where $\dot{E}_{it}$ and v_{it} respectively represent the number of newly issued equity of firm i and the market value per share of firm i. Since here we do not consider financing by bond issue, the above identity indicates that in-house R&D investment must be financed by retaining earnings, newly issued equities, or both.[8] Along the lines of Peretto (2011), we focus on the scenario where the marginal source of in-house R&D is only limited to retaining earnings. This scenario is called as "New view" in the literature of corporate finance. In this scenario, $\Phi(R_{it}, Z_{it}) = J_{it}$ because of $\dot{E}_{it} = 0$.

Let $V_{it} \equiv E_{it}v_{it}$ and $D_{it} \equiv E_{it}d_{it}$. Without loss of generality, E_{it} is normalized to one. Dividends of firm i is given by

$$D_{it} = (1 - \tau_{\Pi})F_{it} - (1 - \sigma\tau_{\Pi})\Phi(R_{it}, Z_{it}). \tag{6}$$

The return on equity is rewritten by

$$r_t = (1 - \tau_D)\frac{D_{it}}{V_{it}} + (1 - \tau_V)\frac{\dot{V}_{it}}{V_{it}}. \tag{7}$$

where τ_D is the rate of the dividend tax and τ_V is the rate of the capital gains tax.

Integrating (7) forward yields the value of firm i as follows:

$$V_{it} = \int_t^{\infty} \exp\left(\int_t^s -\frac{1}{1-\tau_V} r_v dv\right)\left(\frac{1-\tau_D}{1-\tau_V}\right)\left[(1-\tau_{\Pi})F_{is} - (1-\sigma\tau_{\Pi})\Phi(R_{is}, Z_{is})\right] ds.$$

We consider a symmetric equilibrium by assuming that any new firm starts with the same level of technologies as incumbents so that the subscript i can be dropped. In the equilibrium, $Z_t = \bar{Z}_t$ holds. Each firm maximizes its value, subject to (2) and (4), given $\bar{Z}$. To solve the inter-temporal maximization problem, we define the following current-value

[8] See Turnovsky (1990) for the detailed discussion.

Hamiltonian as

$$H \equiv \frac{1-\tau_D}{1-\tau_V}\left[(1-\tau_\Pi)F_t - (1-\sigma\tau_\Pi)\Phi(R_t, Z_i)\right] + q_t\left[R_t\right],$$

where the co-state variable, q_t, represents a shadow value of in-house R&D. We obtain the following optimal conditions:

$$P_t = \frac{1}{\theta}, \tag{8}$$

$$\tilde{q} \equiv Sq_t = \left[1 + h\frac{R_t}{Z_t}\right], \tag{9}$$

$$r_t = \frac{(1-\tau_V)}{S\eta}\frac{\partial F_t}{\partial Z_t}\frac{1}{q_t} + \frac{(1-\tau_V)h}{2S}\left(\frac{R_t}{Z_t}\right)^2\frac{1}{q_t} + (1-\tau_V)\frac{\dot{q}_t}{q_t}. \tag{10}$$

where for simplifying notation, we define

$$S \equiv \frac{(1-\tau_V)}{(1-\tau_D)(1-\sigma\tau_\Pi)} \quad \text{and} \quad \eta \equiv \frac{1-\sigma\tau_\Pi}{1-\tau_\Pi}.$$

The transversality condition is $\lim_{s\to\infty}\exp\left(-\frac{1}{1-\tau_V}\int_t^s r_v dv\right)Z_s q_s = 0$. From (9), the rate of quality growth is given by

$$\hat{z}_t \equiv \frac{\dot{Z}_t}{Z_t} = \begin{cases} \frac{1}{h}(\tilde{q}_t - 1), & \text{if} \quad \tilde{q}_t > 1, \\ 0, \quad \text{if} \quad \tilde{q}_t \leq 1. \end{cases} \tag{11}$$

(8) represents the pricing rule with constant mark-up. (9) indicates that firms undertake in-house R&D investment up to the point where a tax-adjusted shadow value of in-house R&D (the RHS) is equal to the cost of the innovation (the LHS). Hereafter, $\tilde{q}_t$ is called as modified q along the lines of Hayashi (1982). Where there is no adjustment costs ($h = 0$), modified q always pins down to one.[9] By contrast, in our setting, modified q is endogenously determined and it has a transitional process in equilibrium. (10) represents the no-arbitrage condition of return on in-house R&D. (11) shows that the rate of quality growth is the function of only modified q. Since modified q is derived from the intertemporal optimization

[9]See Peretto (2007, 2011).

problem of firms, all informations relevant to in-house R&D decision are summarized by modified q.

Development of new product requires βZ_t ($\beta > 1$). New entry firms finance by issuing equity. Free-entry condition yields

$$V_t = \beta Z_t \;\Leftrightarrow\; \dot{N}_t > 0. \tag{12}$$

From (6) and (12), the return on equity, (7), is rewritten by

$$r_t = (1-\tau_D)\left[(1-\tau_\Pi)\frac{F_t}{\beta Z_t} - (1-\sigma\tau_\Pi)\frac{\Phi(R_t, Z_t)}{\beta Z_t}\right] + (1-\tau_V)\frac{\dot{Z}_t}{Z_t}. \tag{13}$$

2.3 Households

The economy has identical households who provide labor supply elastically and purchase assets. The labor market and the asset market are supposed to be competitive. Each individual member of households is identically endowed with one unit of time. The population exogenously grows over time at the constant rate, $\lambda > 0$. Without loss of generality, the number of population at time 0 is normalized to one. Hence, the number of population at time t is $e^{\lambda t}$. The household maximizes the following utility function:

$$U_t = \int_t^\infty e^{-(\rho-\lambda)(s-t)}\left[\log C_s e^{-\lambda s} + \zeta \log(1-l_s)\right] ds,$$

where C_t, l_t, $\zeta > 0$, and ρ ($> \lambda$) respectively represent the aggregate consumption, the fraction of the time allocated to work per capita, the measure of preference for leisure, and the rate of the time preference. The budget constraint of the household is given by

$$\dot{N}_t V_t = N_t\left[(1-\tau_D)D_t - \tau_V \dot{V}_t\right] + (1-\tau_L)W_t l_t e^{\lambda t} - (1+\tau_C)C_t - T_t,$$

where τ_L, τ_C, and T_t respectively represent the rate of the labor income tax, the rate of the consumption tax, and the lump-sum tax. Solving the inter-temporal optimization problem yields the following optimal conditions:

$$\frac{\dot{C}_t}{C_t} = r_t - \rho + \lambda, \tag{14}$$

$$l_t = 1 - \frac{(1+\tau_C)\zeta C_t}{(1-\tau_L)W_t e^{\lambda t}}. \tag{15}$$

The transversality condition is $\lim_{s\to\infty} e^{-(\rho-\lambda)(s-t)} a_s \mu_s = 0$, where μ_t represents a shadow value of holdings of assets.

2.4 The government

The government spending is given by $G_t = gY_t$ $(0 < g < 1)$. The share of the government spending to output is assumed to be an exogenously given rate. Along the lines of Peretto (2007, 2011), it is assumed that the government spending does not affect the utility of households and the efficiency of production activities in order to isolate the effects of distortionary taxes from the effects of the government expenditure. The budget constraint of the government is given by

$$G_t = \tau_L W_t N_t L_t + \tau_C C_t + \tau_\Pi N_t \left[F_t - \sigma\Phi(Z_t, R_t)\right] + \tau_D N_t D_t + \tau_V N_t \dot{V}_t + T_t.$$

Since the Ricardian equivalence holds, we can see the same equilibrium dynamics as the economy with public debt.

3 The market equilibrium

3.1 The equilibrium dynamics

In this section, we derive the dynamic system of the market equilibrium. The market equilibrium condition of final goods is given by

$$Y_t = G_t + C_t + N_t \left[X_t + \phi Z_t + \Phi(Z_t, R_t)\right] + \beta Z_t \dot{N}_t. \tag{16}$$

Define the number of firms per capita as $n_t \equiv N_t/e^{\lambda t}$ and the ratio of the aggregate consumption to outputs as $c_t \equiv C_t/Y_t$. In Appendix 1, we show that the labor supply per capita is given by

$$l(c_t) = \frac{1}{1+\Gamma c_t}, \quad \Gamma \equiv \frac{(1+\tau_C)\zeta}{(1-\tau_L)(1-\theta)} > 0. \tag{17}$$

The reduced-form aggregate production function of final goods is given by

$$Y_t = \Omega l(c_t) e^{\lambda t} Z_t, \quad \Omega \equiv \theta^{\frac{2\theta}{1-\theta}} \tag{18}$$

In Appendix 2, we show the following simultaneous differential equation constitutes the dynamical system of the economy (in the case where $\tilde{q}_t > 1$):

$$\dot{n}_t = \left[1-\theta^2 - g - c_t\right] \frac{\Omega l(c_t)}{\beta} - \left[\phi + \frac{(Sq_t)^2-1}{2h} + \beta\lambda\right] \frac{n_t}{\beta}, \tag{19}$$

$$\dot{c}_t = c_t \left[1+\Gamma c_t\right] \left[r_t - \rho - \frac{Sq_t - 1}{h}\right], \tag{20}$$

$$\dot{q}_t = \frac{1}{1-\tau_V} r_t q_t - \frac{\alpha\theta(1-\theta)}{S\eta} \frac{\Omega l(c_t)}{n_t} - \frac{(Sq_t-1)^2}{2Sh}, \tag{21}$$

where from (13), the interest rate is given by

$$r_t = \frac{(1-\tau_V)}{\beta S \eta} \left[\theta(1-\theta) \frac{\Omega l(c_t)}{n_t} - \phi - \eta \frac{(Sq_t)^2 - 1}{2h}\right] + (1-\tau_V) \frac{Sq_t - 1}{h}. \tag{22}$$

See Appendix 3 for the dynamic system in the case where $\tilde{q}_t \leq 1$.

3.2 The steady state equilibrium

Let $y_t \equiv Y_t/l_t e^{\lambda t}$, which represents outputs per worker. From (18), the growth rate of outputs per worker is given by $\hat{y}_t \equiv \dot{y}_t/y_t = \hat{z}_t = (\tilde{q}_t - 1)/h$. In what follows, we characterize the steady state equilibrium, $\{n^*, c^*, \tilde{q}^*, l^*, r^*, \hat{y}^*\}$. From (20), $\dot{c}_t = 0$ and $c^* > 0$ implies (if $\tilde{q}^* > 1$)

$$r^* = \rho + \frac{\tilde{q}^* - 1}{h}. \tag{23}$$

From (21), $\dot{q}_t = 0$ and $\tilde{q}^* > 1$ implies

$$r^* = (1-\tau_V)\frac{\alpha\theta(1-\theta)}{\eta}\frac{\Omega l(c^*)}{n^*}\frac{1}{\tilde{q}^*} + (1-\tau_V)\frac{(\tilde{q}^*-1)^2}{2h}\frac{1}{\tilde{q}^*}. \tag{24}$$

This equation represents the no-arbitrage condition of return on in-house R&D in the steady state equilibrium. It turns out that a dividend tax cut does not directly affect incentives to in-house R&D. On the other hand, a corporate tax cut, a capital gains tax cut, and a rise in the rate of the tax credit directly enhances incentives to in-house R&D. From (23) and (24), eliminating r^* yields (if $\tilde{q}^* > 1$)

$$\frac{\Omega l(c^*)}{n^*} = \frac{\eta}{\alpha\theta(1-\theta)}\left\{\frac{1}{1-\tau_V}\left[\rho + \frac{\tilde{q}^*-1}{h}\right]\tilde{q}^* - \frac{(\tilde{q}^*-1)^2}{2h}\right\}. \tag{25}$$

Substituting (23) and (25) into (22), we find that $\tilde{q}^*$ is derived from solving $f(\tilde{q}) = 0$ with respect to $\tilde{q}$ where

$$f(\tilde{q}) \equiv \begin{cases} \dfrac{1}{1-\tau_V}\left[\rho + \dfrac{\tilde{q}-1}{h}\right](S\alpha\beta - \tilde{q}) + \dfrac{(\tilde{q}-1)^2}{2h} + \alpha\dfrac{\tilde{q}^2-1}{2h} \\ -S\alpha\beta\dfrac{\tilde{q}-1}{h} + \dfrac{\alpha\phi}{\eta}, \quad \text{if} \quad \tilde{q} > 1, \\ \dfrac{\rho}{1-\tau_V}(S\alpha\beta - \tilde{q}) + \dfrac{\alpha\phi}{\eta}, \quad \text{if} \quad \tilde{q} \leq 1. \end{cases} \tag{26}$$

If $S\alpha\beta \leq 1 - \frac{(1-\tau_V)\alpha\phi}{\eta\rho} < 1$, $f(1) < 0$ and $f'(\tilde{q}) < 0$. In the case, there is no steady state equilibrium with a positive rate of quality growth. If $1 - \frac{(1-\tau_V)\alpha\phi}{\eta\rho} < S\alpha\beta$, $f(1) > 0$. In the case, $f(\tilde{q})$ is depicted as shown by Figure 1. Figure 1 shows that if $1 - \frac{(1-\tau_V)\alpha\phi}{\eta\rho} < S\alpha\beta$, $\tilde{q}^*$ is uniquely determined at the point where $\tilde{q}^*$ is higher than 1. In what follows, we focus on the case where $1 - \frac{(1-\tau_V)\alpha\phi}{\eta\rho} < S\alpha\beta$. In the case, there exists an unique steady state equilibrium with a positive rate of quality growth. See Appendix 2 for the proof.

Since the Jacobian matrix derived from the linear approximation of (19)-(21) in the neighborhood of the steady state equilibrium is too complicated, we cannot analytically examine the local stability of the dynamic system. However, our numerical simulations confirm that the unique steady state is locally saddle-point stable in the benchmark setting

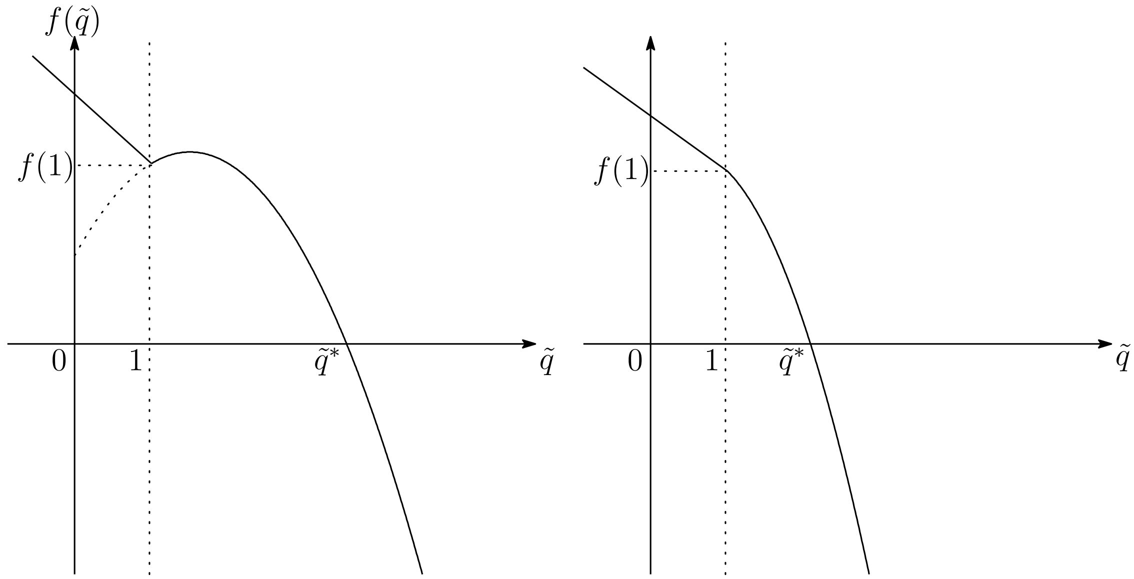


Figure 1: The steady state equilibrium: the left (right) figure represents the case where $f(\tilde{q})$ is inverted U-shapes (monotonically decreasing in $\tilde{q}$) for $\tilde{q} > 1$.

and the subsequent sensitivity analysis as we will see below.[10]

From (19) and (25), $\dot{n}_t = 0$ and $n^* > 0$ implies

$$c^* = \left[1 - \theta^2 - g\right] - \frac{\alpha\theta(1-\theta)}{\varphi(\tilde{q}^*)}\left[\phi + \frac{\tilde{q}^{*2} - 1}{2h} + \beta\lambda\right],$$

where

$$\varphi(\tilde{q}^*) \equiv \frac{\eta}{1-\tau_V}\left[\rho + \frac{\tilde{q}^* - 1}{h}\right]\tilde{q}^* + \eta\frac{(\tilde{q}^* - 1)^2}{2h}.$$

Rewriting (25) yields

$$n^* = \frac{\alpha\theta(1-\theta)\Omega l(c^*)}{\varphi(\tilde{q}^*)}.$$

The mechanism eliminating the scale effect on the steady state growth rate of outputs is consistent with the case where there is no adjustment cost (see Peretto (2007, 2011)). In the steady state equilibrium, modified q is independent of the scale factor of the economy, $l(c^*)$ (see (26)). An increase in production volumes allows in-house R&D expenditure to

[10]Since the dynamic system has one state variable (n_t) and two jump variables (c_t and q_t), it must have two positive characteristic roots and one negative characteristic root. Our numerical simulation reports that the value of three characteristic root corresponding to the dynamic system are -0.4129, 0.2240, and 0.1478 in the benchmark parameter setting.

be spread over more units of goods. Therefore, given the number of firms per capita, more aggregate demand for intermediate goods has a direct positive effect on incentives to in-house R&D. This effect is called as the cost-spreading effect. However, more aggregate demand also attracts entry of a new firm as the value of a firm rises. As a result, the market share per firms shrinks. This results in the lower scale of production of intermediate goods at the level of an individual firm, which lowers incentives to in-house R&D. This effect is called as the market share effect. In the steady state equilibrium, the market share effect perfectly cancels out the cost-spreading effect (see the discussion in Peretto (2007)).[11]

3.3 The steady state effect of tax changes

How a permanent change of tax variables affects the steady state growth rate is also consistent with Peretto (2007, 2011). We can summarizes as follows:

The steady state growth rate of outputs is increasing in the dividend tax rate, the corporate tax rate (if $\sigma \geq 1$), and the R&D tax credit rate. On the other hand, it is decreasing in the corporate tax rate (if $\sigma = 0$). The effect of changes in the corporate tax rate (if $\sigma \in (0, 1)$) and the capital gains tax rate on the long-run growth is ambiguous.

See Appendix 4 for the proof. As previously discussed, a dividend tax cut does not directly affect the return on in-house R&D. On the other hand, a dividend tax cut directly increases the return on equity. Given the aggregate market demand for intermediate goods, the number of firm per capita increases. The production proliferation lowers incentives to in-house R&D through the market share effect. Consequently, a dividend tax cut unambiguously has a negative effect on the long-run growth.[12]

[11] Furthermore, we confirm that comparative statics of parameters in the steady state equilibrium get the similar results as Peretto (2007, 2011). Increases in α, β, and ϕ respectively enhance the steady state growth rate of outputs. Increases in α allow each firm to internalize the positive return derived by its own in-house R&D more intensely. Increases in β and ϕ make it harder for potential entrants to go into the market, reallocating resources from product proliferation to quality improving. On the other hand, the effect of time discount rate, ρ, on growth is ambiguous. Lower household's incentive to hold equities due to an increase in the time discount rate reduces the number of firms per capita, which has positive effect on incentives to in-house R&D, while the corresponding higher interest rate also has negative effect on incentives to in-house R&D. Increases in h reduce the steady state growth rate of output because it directly increases the cost of in-house R&D.

[12] If $\sigma = 1$, the corporate tax cut also has the same qualitative effect as the dividend tax cut. When in-house R&D expenditures are fully deductible against corporate tax, there is no difference between the

On the other hand, the higher rate of the R&D tax credit has an unambiguously positive effect on the long-run growth. It works just like the direct subsidy for in-house R&D.

The growth effect of both a corporate tax cut (if $\sigma \in (0, 1)$) and a capital gains tax cut is ambiguous. These tax cut directly increase both the return on in-house R&D and the return on equity. However, it is shown that if $\sigma = 0$, a corporate tax cut unambiguously enhances the long-run growth. And if β and α is sufficiently low, a capital gains tax cut also enhances the long-run growth.

4 Numerical analysis

4.1 Data and Methodology

Since it is too complicated to analytically examine the transitional adjustment of the aggregate economy to tax changes, we carry out numerical simulation by using relaxation algorithm method developed by Trimborn, Koch, and Steger (2008).[13] We calibrate the model with U.S. data. The benchmark value of fiscal variables and parameters is summarized in Table 1 and Table 2, which hereafter we call as the benchmark parameter setting.

As the benchmark, we choose the value of all tax variables along the lines of Peretto (2011).[14] θ and ρ is respectively set to 0.30 and 0.04, which is conventional value in the macroeconomic literature. λ is set to 0.01, which is consistent with the average annual population growth rate in the U.S. economy. The choice of the parameter associated with adjustment costs, h, is less clear. According to Schubert and Turnovsky (2011), the parameter of adjustment costs for physical capital investment is generally assumed within

dividend tax and the corporate tax.

[13] Trimborn, Koch, and Steger (2008) details the relaxation algorithm. They also provide MATLAB programs for the relaxation algorithm, which are downloadable for free at http://www.wiwi.uni-siegen.de/vwli/forschung/relaxation/matlab_applications.html?lang=de. By using this method, Strulik and Trimborn (2010) examines how anticipated and temporary tax reforms affect on the aggregate economy in the framework of the neoclassical (exogenous) growth model with endogenous corporate finance.

[14] R&D costs is in fact fully deductible against the corporate tax liability in the U.S. tax code. However, the setting of $\sigma = 0$ allows us to clearly see the fundamental distinction between the corporate tax and the dividend tax. If R&D costs is assumed to be fully deductible ($\sigma = 1.0$), a corporate tax cut has the same qualitative effects on the economy as a dividend tax cut.

10-15 in the literature (e.g., Ortigueira and Santos (1997) and Auerbach and Kotlikoff (1987)). Nadiri (1989) and Himmelberg and Petersen (1994) report that the extent to which adjustment costs for R&D investment is the same or more than that of physical capital investment. And so we set $h = 12.0$ as the benchmark. The parameter associated with entry costs, β, is also less clear. Following Peretto (2011), we set $\beta = 6.55$ as the benchmark.[15] α and ϕ is respectively set to 0.141 and $\phi = 0.266$ so that the steady state consumption ratio and the steady state growth rate of outputs respectively is 0.69 and 0.02. ζ is set to 1.459 so that the fraction of time devoted to labor supply is 0.33. Table 3 reports the value of the steady state equilibrium, $\{n^*, c^*, \tilde{q}^*, l^*, r^*, \hat{y}^*\}$, which is characterized under the benchmark parameter setting.

Table 1: Tax variables (benchmark)

g	τ_D	τ_Π	τ_V	σ	τ_C	τ_L
0.143	0.35	0.335	0.20	0	0.05	0.256

Table 2: Parameters (benchmark)

α	θ	h	ϕ	β	ζ	ρ	λ
0.141	0.30	12.0	0.266	6.55	1.459	0.04	0.01

Table 3: Steady state equilibrium values (benchmark)

n^*	c^*	$\tilde{q}^*$	l^*	r^*	$\hat{y}^*$
0.0256	0.69	1.24	0.33	0.06	0.02

In what follows, we investigate what the transitional adjustment of key macro variables and welfare consequences are induced by the following specific tax changes: 10 percentage point reduction of the dividend tax rate, the corporate tax rate, and the capital gains tax rate, and 20 percentage point rise of the tax credit rate. Besides, with respect to how each tax change comes into effect, we consider the following three different implementation scenarios: (1) an unanticipated and permanent change, (2) an anticipated and permanent change, and (3) an unanticipated and temporary change. In the every scenario, the economy initially (at $t = 0$) stays in the steady state equilibrium before the tax change. In the

[15] See Peretto (2011) for the detailed explanation for this estimation.

implementation scenario of (1), each tax change suddenly hits at $t = 5$ and lasts forever from then on. In the implementation scenario of (2), all economic agent expect at $t = 0$ that each tax change implements at $t = 5$ and last forever from then on. In the implementation scenario of (3), each tax change hits unexpectedly at $t = 0$ and reverts to the initial level after $t = 10$. The implementation period of this reversion is expected by all economic agents at $t = 0$.

Figure 2-5 show the transitional path of key macro variables in response to each tax change with the different implementation scenarios as mentioned above in the benchmark parameter setting. Specifically, each panel of these figures respectively represent the transitional path of the number of firms per capita (n_t), the consumption ratio (c_t), modified q ($\tilde{q}_t$), hours worked per capita (l_t), the market interest rate (r_t), the growth rate of outputs per worker ($\hat{y}_t$), the ratio of the after-tax dividends to the value of a firm, and the ratio of the distortionary tax revenue to GDP. The horizontal axis in each panel measures years. In the vertical axis, r_t and $\hat{y}_t$ are measured by the actual value and all the other variables are measured by the percentage deviation from the level of the initial steady state equilibrium before the tax change.

Table 4 reports the welfare consequences of the tax changes. The welfare evaluation is measured as consumption equivalent: how much constant relative increases in the annual consumption per capita must be required so that the intertemporal utility of households in the case when the economy remains in the initial steady state equilibrium before the tax changes becomes equal to that in the case when the economy moves to the new steady state equilibrium from the initial due to the tax changes.[16]

4.2 The dividend tax cut

Figure 1-(a) shows the transitional path of the key macro variables in response to the permanent dividend tax cut by 10 percentage points comparing the unanticipated and

[16]More formally, the welfare evaluation is conducted as follows. $U_0^O(c^O, l^O, \hat{y}^O, n^O)$ is defined as the level of the intertemporal utility of households in the case when the economy remains in the initial steady state equilibrium before a tax change. And $U_0^N(c_t^N, l_t^N, \hat{y}_t^N, n_t^N)$ is defined as that in the case when the economy moves to the new steady state equilibrium from the initial due to a tax change. Here, we measure consumption equivalent by δ which is defined as the value to satisfy $U_0^O(c^O(1+\delta), l^O, \hat{y}^O, n^O) = U_0^N(c_t^N, l_t^N, \hat{y}_t^N, n_t^N)$. See Appendix 5 for how to calculate the value of intertemporal utility of households.

Table 4: Welfare gains of tax changes (benchmark)

Policy change	Unanticipated (Permanent)	Anticipated (Permanent)	Temporary
$\Delta t_D = -0.1$	-14.0	-11.17	-8.19
$\Delta t_\Pi = -0.1$	5.03	5.67	0.64
$\Delta t_V = -0.1$	13.56	10.78	7.86
$\Delta \sigma = 0.2$	10.86	9.58	4.87

Note: Welfare gains are measured in consumption equivalent and expressed in percentage points.

anticipated case under the benchmark parameter setting. If the permanent tax cut is unanticipated, the consumption ratio falls by around 10 percentage points when the tax cut is implemented (that is, at $t = 5$). And then it gradually rises toward the new steady state level. Hours worked reacts conversely. This is because the lump-sum tax increases (or the lump-sum transfer decreases) to finance the tax cut. Actually, the ratio of the distortionary tax revenue to GDP decreases. The number of firms per capita starts to rise at $t = 5$, while modified q instantaneously falls. After the implementation of the tax cut, they converge to the new steady state level. The growth rate of outputs per capita falls to 0.0148 at $t = 5$ and then it converges to 0.0152. The unanticipated tax cut does not directly change firm's investment decision, while it directly increases the value of a firm. Therefore, it has a negative impact on in-house R&D through the market share effect as previously discussed. The interest rate jumps up at $t = 5$ because the tax cut directly raises the after-tax dividends. However, the interest rate gradually decreases during the transition and it eventually falls below the initial steady state level. As Table 4 shows, this tax change yields welfare costs of around 14 percentage points of annual consumption per capita. The negative welfare consequence is derived from not just the lower consumption and leisure time of households but also the slowdown of economic growth.

The impulse responses become quite different in the case where the permanent tax cut is expected in advance. Households and firms take into account the future tax cut. Hence they change their decisions when the news arrives (that is, at $t = 0$). At $t = 0$, all variables rather than the state variable (the number of firms per capita) instantaneously change. The consumption ratio falls by around 2 percentage points. And it further decreases during the announcement phase. After the tax cut is implemented (at $t = 5$), it gradually converges to the new steady state level. Surprisingly, at $t = 0$, modified q jumps up. The growth rate of outputs per worker rises to 0.0250. During the announcement phase, the modified q further increases and the growth rate of outputs per worker continues to rise. After the implementation of the tax cut, the modified q drastically drops to a lower value than the initial steady state level and the growth rate of outputs per worker falls from 0.02 to 0.015. And then the both values converge to the new steady state level. During the announcement phase, the number of firms per capita gradually rises through the general equilibrium effect.

Why the implementation lag of the tax cut has a positive effect on in-house R&D investment during the announcement phase? A lower dividend tax rate directly raises the value of a firm given its dividend payments. The future dividend tax cut proportionately raises the contribution of future gross cash flows to the value of a firm and the future cost of in-house R&D. By contrast, it does not change the current cost of in-house R&D. As a result, firms adjust the timing of dividend payments by changing their investment schedule of in-house R&D. That is, firms increase in-house R&D investment during the announcement phase in order to raise the subsequent dividend payments.

Although we take into account the announcement effect, the welfare effect remains in negative. The welfare costs are estimated to be the loss of around 11.17 percentages points of annual consumption per capita. However, the welfare costs are reduced compared to the unanticipated case. This is because the growth rate of outputs per worker temporarily rises during the announcement phase and the consumption and hours worked adjust more smoothly.

Figure 2-(b) shows the transitional path in the case of the temporary tax cut. When the tax cut is implemented (that is, at $t = 0$), all variables rather than the state variable instantaneously change. After the tax cut is terminated (that is, at $t = 10$), all variables reverts to the initial steady state level. Remarkably, during the implementation, modified q declines more sharply compared to the case of the permanent tax. At $t = 0$, the growth rate of outputs per worker falls to 0.0125. And then it further decreases until the tax

cut is terminated. This is because firms have an incentive to alter the timing of dividend payments. During the implementation, firms intend to raise their dividend payments. Hence firms reduce their R&D investment. Consequently, the temporary dividend tax cut also yields welfare costs. They are estimated to be around 8.2 percentage points of annual consumption per capita.

4.3 The corporate tax cut

Figure 3-(a, b) shows impulse responses to the corporate tax cut by 10 percentage points under the benchmark parameter setting. The transitional path of n_t, c_t, l_t is respectively similar to that in the case of the dividend tax cut. On the other hand, modified q adjusts somewhat differently. If the tax cut is unanticipated, at $t = 5$, the modified q jumps up and the growth rate of outputs per workers rises to 0.0219. And then they gradually increases to the new steady state level. If the tax cut is anticipated, at $t = 0$, modified q jumps up and the growth rate of outputs per worker rises to 0.0210. And then they gradually increases to the new steady state level. If the tax cut is temporary, the growth effect is always positive during the transition.

Why the tax cut always has a positive effect on growth? Recall that in-house R&D investment is not deductible against the corporate tax under the benchmark parameter setting. The tax cut increases the contribution of the gross cash flow to the value of a firm while it does not change the cost of in-house R&D. Hence the tax cut directly enhances an incentive to in-house R&D. The tax cut also increases the number of firms per capita. However, the negative effect through the product proliferation does not perfectly offset the positive direct effect on growth. It is shown that welfare effects are positive irrespective of how it is implemented. If in-house R&D investment is fully deductible, however, the corporate tax has the same qualitative effects as the dividend tax.

4.4 The capital gains tax cut

Figure 4-(a) shows impulse responses due to the unanticipated (or anticipated) and permanent capital gains tax cut by 10 percentage points under the benchmark case. Remarkably,

the tax cut increases both the number of firms per capita and the growth rate of economy in the new steady state. If the permanent tax cut is unanticipated, modified q initially jumps up and then converges to the new steady state level. During the transition, the growth rate of per capita is always higher than the initial level. This tax cut yields welfare gains of around 13.56 percentage points of annual consumption per capita.

If the permanent tax cut is anticipated, however, the growth rate slows down during the announcement phase. Future capital gains tax cuts reduces the future cost of R&D. Hence firms have an incentive to reduce their current in-house R&D investments and raise their current dividend payments. The temporary slowdowns of growth during the announcement phase has a negative effect on welfare. Anticipated tax cuts make households behavior more smoothly, yielding a positive effect on welfare. However, the positive effect cannot offset the negative effect derived from the temporary slowdown of growth. As a result, the anticipated tax cut reduces welfare gains by 2.77 percentage points.

Figure 4-(b) shows impulse response due to the temporary capital gains tax cut by 10 percentages points under the benchmark case. Remarkably, the growth rate of economy accelerates during the implementation. The temporal acceleration of growth is sharply higher than the permanent effect. The temporary tax cut reduces the cost of in-house R&D during the implementation. Hence firms increase in-house R&D investment during the implementation. Consequently, the temporary capital gains tax cut also yields welfare gains. They are estimated to be around 7.86 percentage points of annual consumption per capita.

4.5 Increases in the rate of the R&D tax credit

Figure 5-(a) shows impulse responses due to the unanticipated (or anticipated) and permanent rise of the R&D tax credit rate by 20 percentage points under the benchmark case. The tax change increases the steady state growth rate of economy but reduces the steady state number of firm per capita. Besides, in the steady state, the tax changes is shown to be self-financing. The ratio of distortionary tax revenues to GDP is higher than the initial level. Hence the steady state consumption ratio is higher than the initial level. If

the permanent tax change is unanticipated, during the transition, the growth rate and the consumption ratio are also higher than the initial revel. As a result, it yields welfare gains which is estimated to be around 10.86 percentage points of annual consumption per capita.

On the other hand, if the permanent tax changes is anticipated, modified q decreases and so the growth rate falls during the announcement phase. The reason is parallel to that in the case of the capital gains tax cut. Future rises of the R&D tax credit rate directly reduce the future cost of in-house R&D. As a result, the implementation lag of the tax change reduce the welfare gains by 1.28 percentage points of annual consumption per capita.

Figure 5-(b) shows impulse response due to the temporary rise of the tax credit rate by 20 percentages points under the benchmark case. The growth effect is also parallel to that in the case of the temporary capital gains tax cut. The temporal acceleration of growth is sharply higher than the permanent effect. The temporary rise of the tax credit rate reduces the cost of in-house R&D during the implementation. Firms have an incentive to change the timing of dividend payments. Hence firms increases their in-house R&D investment during the implementation. Consequently, the temporary capital gains tax cut also yields welfare gains. They are estimated to be around 4.87 percentage points of annual consumption per capita.

5 Sensitivity analysis

5.1 Parameter changes

We conduct the robustness check by changing some parameters. Firstly, we consider increasing or decreasing the value of less clear parameter, h and β. Secondly, we also consider the case of $\sigma = 1.0$ as the real tax code in the U.S. sets to $\sigma = 1.0$. In any case, we reestimate α and ϕ so that the consumption ratio and growth rate of output in the steady state before tax changes keep the same level under the benchmark setting. Only results of the corporate tax cut in $\sigma = 1.0$ qualitatively changes. This is because a corporate tax cut has the same effects as a divided tax cut if in-house R&D investment is fully deductible. For the other cases, our main findings in the benchmark analysis qualitatively hold. Besides, we also consider the case in which labor supply is inelastic (that is, $\zeta = 0$). In this case, our main findings in the benchmark analysis qualitatively hold. Table 5 reports the welfare consequences of tax changes in those alternative parameter setting.

5.2 Social returns to product variety

In the model as described thus far, the number of firms (product variety) per capita does not directly contribute to the production of final goods. It only affects degree of the market competition among intermediate goods firms. This indirect channel distorts incentives to in-house R&D. In what follows, we relax this somewhat extreme feature. Along the lines of Peretto (2007, 2011), we consider the case where there exists social positive returns to product variety of intermediate goods in the production of final goods as follows:

$$Y_t = n_t^{v} \int_0^{N_t} X_{it}^{\theta} \left(Z_{it}^{\alpha} \bar{Z}_t^{1-\alpha} L_{it} \right)^{1-\theta} di, \quad v > 0,$$

where the contribution to product variety on output of final goods is assumed to be external to all agents. In this case, the reduce-form production function of final goods is rewritten by

$$Y_t = n_t^{\kappa} \Omega l(c_t) e^{\lambda t} Z_t, \quad \kappa \equiv \frac{v}{1-\theta}.$$

The dynamic system of the economy is modified as follows:

$$\begin{aligned}
\dot{n}_t &= \left[1 - \theta^2 - g - c\right] \frac{\Omega l(c_t)}{\beta n_t^{-\kappa}} - \left[\phi + \frac{(Sq_t)^2 - 1}{2h} + \beta\lambda\right] \frac{n_t}{\beta}, \\
\dot{c}_t &= c_t \left[1 + \Gamma c_t\right] \left[r_t - \rho - \frac{Sq_t - 1}{h} - \kappa \frac{\dot{n}_t}{n_t}\right], \\
\dot{q}_t &= \frac{1}{1-\tau_V} r_t q_t - \frac{\alpha\theta(1-\theta)}{S\eta} \frac{\Omega l(c_t)}{n_t^{1-\kappa}} - \frac{(Sq_t - 1)^2}{2Sh},
\end{aligned}$$

where

$$r_t = \frac{(1-\tau_V)}{\beta S \eta} \left[\theta(1-\theta) \frac{\Omega l(c_t)}{n_t^{1-\kappa}} - \phi - \eta \frac{(Sq_t)^2 - 1}{2h}\right] + (1-\tau_V) \frac{Sq_t - 1}{h}.$$

The growth rate of output per worker is given by $\frac{\tilde{q}_t - 1}{h} + \kappa \frac{\dot{n}_t}{n_t}$. In the steady state, the number of firms per capita is constant. The steady state growth rate of output is only dependent of modified q as is the case $\eta = 0$. If $\kappa > 0$, the steady state number of firms per capita is given by $(n^*)^{\frac{1}{1-\kappa}}$, where n^* is the value of the steady state number of firms per capita in the case $\kappa = 0$. Other steady state values coincide with those in the case $\kappa = 0$. Therefore, permanent taxation effects on variables in the steady state equilibrium are consistent with the case $\kappa = 0$.

The transitional responses of macro variables rather than the growth rate of output per worker are qualitatively consistent with the case $\kappa = 0$. The growth rate of output per worker is also dependent of the growth rate of the number of firms per capita during the transition. If the intensity of the growth rate of product variety dominates that of the growth rate of quality, the transitional path of the growth rate of output per worker is modified compared to the case $\kappa = 0$. As an example, Figure 6 (a, b) shows that impulse responses to the dividend tax cut by 10 percentages points in the case $\kappa = 0.3$. In this case, even if the tax cut is unanticipated and permanent (or temporary), the growth rate of output per worker initially jumps up. However, the other variables moves in the similar way as the case $\kappa = 0$. That is, in this case, the positive growth rate of product variety initially offsets the growth rate of quality, resulting in the initial jump of the growth rate of output per worker. Our main findings about investment decision of in-house R&D of firms holds qualitatively.

However, in the case $\eta > 0$, welfare of households is also dependent of the number of firms per capita. Higher product variety directly increases welfare of households. So we need to check the robustness about welfare consequences for tax changes. Table 6 reports the welfare consequences of tax changes in the case $\eta = 0.1, 0.3, 0.5$, and 0.7. The table shows that as the value of the spillover parameter increases the welfare losses from the dividend tax cut diminish. The welfare gains from the corporate tax cut and the capital gains tax cut rise. And the welfare gains from rise of the R&D tax credit rate diminish. However, the sign of those welfare effects does not change. And, in any tax change, the welfare effect of the implementation lag qualitatively holds.

6 Policy implications and Conclusion remarks

In what follows, we summarize our results. The dividend tax cut is not an effective policy instrument irrespective of how it is implemented. The intuition of the negative effect of the tax cut on the long-run growth is same as Peretto (2007, 2011). The tax cut yields product proliferation and reduce incentives to in-house R&D of firms through the market share effect. However, the welfare losses of the tax cut diminishes by the implementation lags of the tax cut. The implementation lags allow firms to adjust the timing of their dividend payments to the tax schedule by changing their investment decisions of in-house R&D. The future dividend tax cut increases both the contribution of future gross cash flow to the value of firms and the future cost of in-house R&D. Hence firms increases current in-house R&D investment during the announcement phase in order to raise the subsequent dividend payments. Besides, the announcement also allows households to adjust the timing of consumption and leisure time more smoothly. If the tax cut is temporary, during the implementation, firms reduce the current investment in order to raise the current dividend payments. As a result, the temporary tax cut also yields a negative effect on growth and welfare.

On the other hand, the capital gains tax cut and rises of the R&D tax credit rate are effective policy instrument. The intuition of the long-run effect is also same as Peretto (2007, 2011).[17] However, the effectiveness of these policy is worsened by the implementation lags. The announcement of the future tax changes reduces the future cost of in-house R&D. Hence firms increases the current dividend payments and reduce the current R&D investment in order to increases the future R&D investment. If these tax changes are temporary, during the transition, the current cost of in-house R&D are reduced. Hence, firms increases the current in-house R&D investment. As a result, the temporary these tax changes yields positive effect on growth and welfare.[18]

Therefore, when considering how to design the corporate taxation policy, the policy

[17]Theoretically, the long-run effect of the capital gains tax cut is ambiguous. However, in our calibration, the long-run effect is positive.

[18]The corporate tax cut seems to be also effective policy instruments. However, if in-house R&D investment is fully deductible against the corporate tax liability, the qualitative effect of the corporate tax coincides with the dividend tax cut.

makers are careful about the dynamic responses of forward looking investment decisions of firms which consider the timing of dividend payments.

A Appendix

A.1 Appendix 1

The perfect distribution in the final goods sector yields (letting $L_{it} = L_t$):

$$\theta^2 Y_t = N_t X_t, \tag{A-1}$$

$$(1-\theta)Y_t = W_t N_t L_t. \tag{A-2}$$

Using the definition of c_t, (A-2), and the market equilibrium condition of labor, $N_t L_t = e^{\lambda t} l_t$, (15) can be rewritten to (17). Substituting (2) and the market equilibrium condition of labor into (1) yields (18).

A.2 Appendix 2

Dividing both sides of (16) by Y_t and using the definition of n_t and c_t, (A-1), (18), and (12), we obtain

$$1 - \theta^2 - g - c_t = \frac{n_t}{\Omega l(c_t)} \left[\phi + \frac{\Phi(R_t, Z_t)}{Z_t} + \beta \left(\frac{\dot{n}_t}{n_t} + \lambda \right) \right]. \tag{A-3}$$

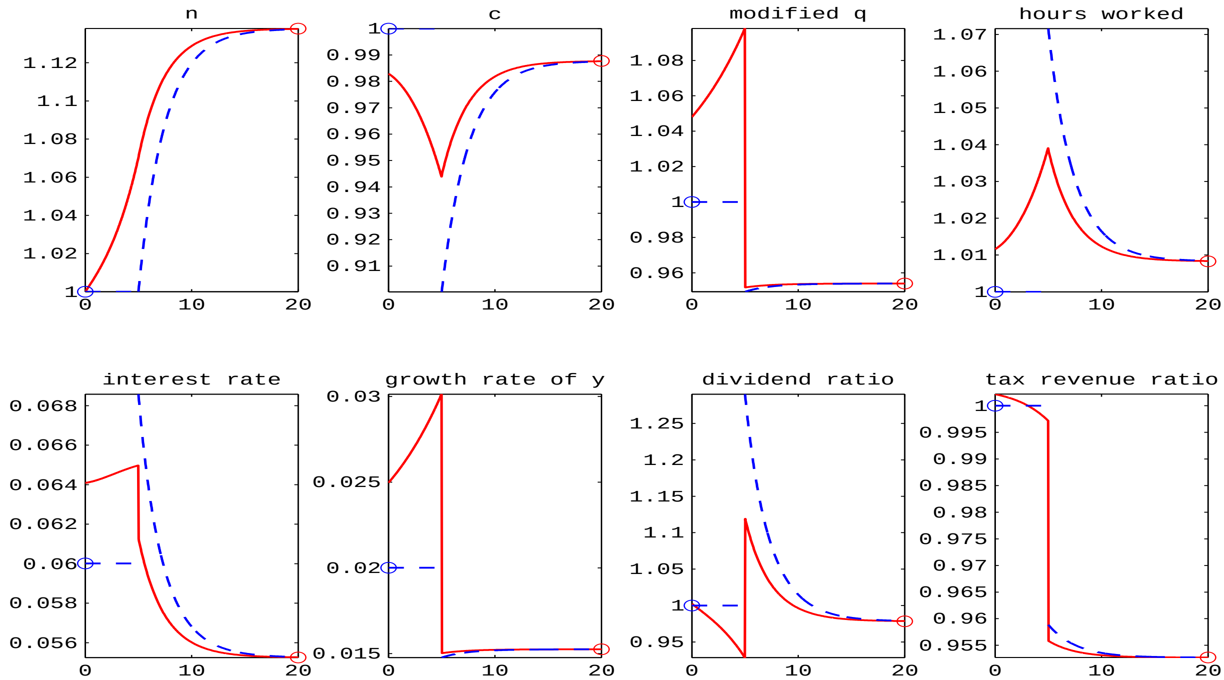
Dividing (5) by Z_t and using (11), we obtain

$$\frac{\Phi(R_t, Z_t)}{Z_t} = \frac{(Sq_t)^2 - 1}{2h}. \tag{A-4}$$

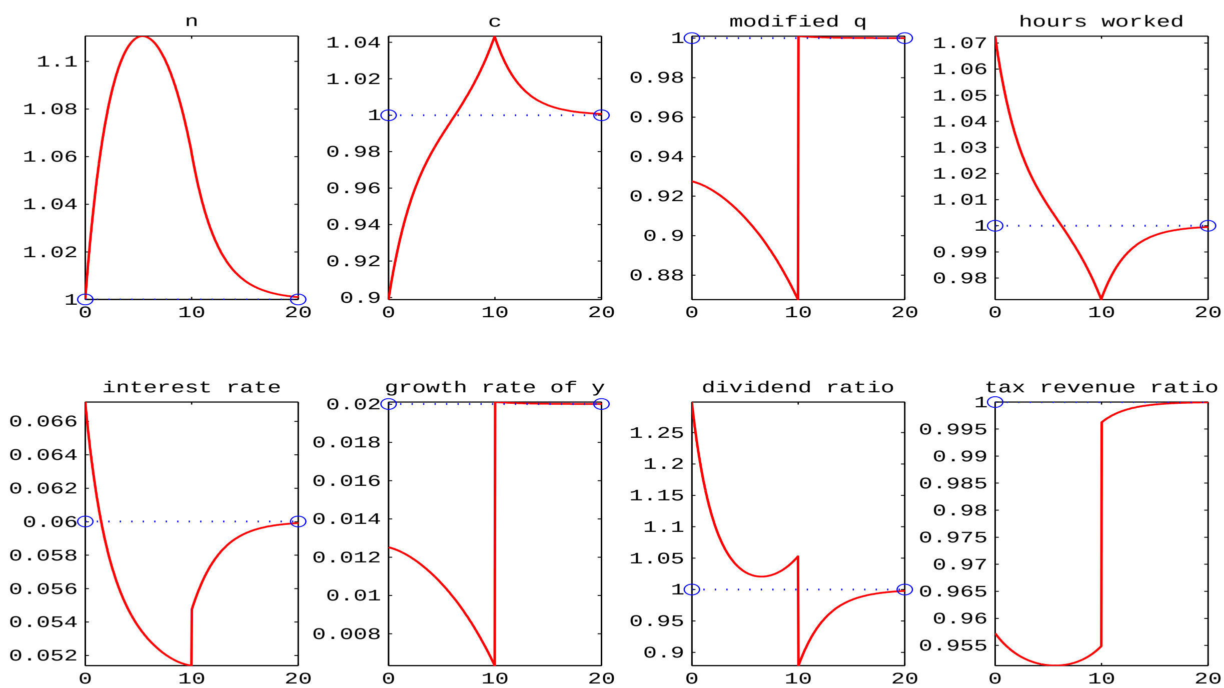
Substituting (A-4) into (A-3) and using (17), we obtain (19).

From (A-1), the definition of n_t, and (18), we obtain

$$\frac{F_t}{Z_t} = \left(\frac{1-\theta}{\theta} \right) \frac{X_t}{Z_t} - \phi,$$

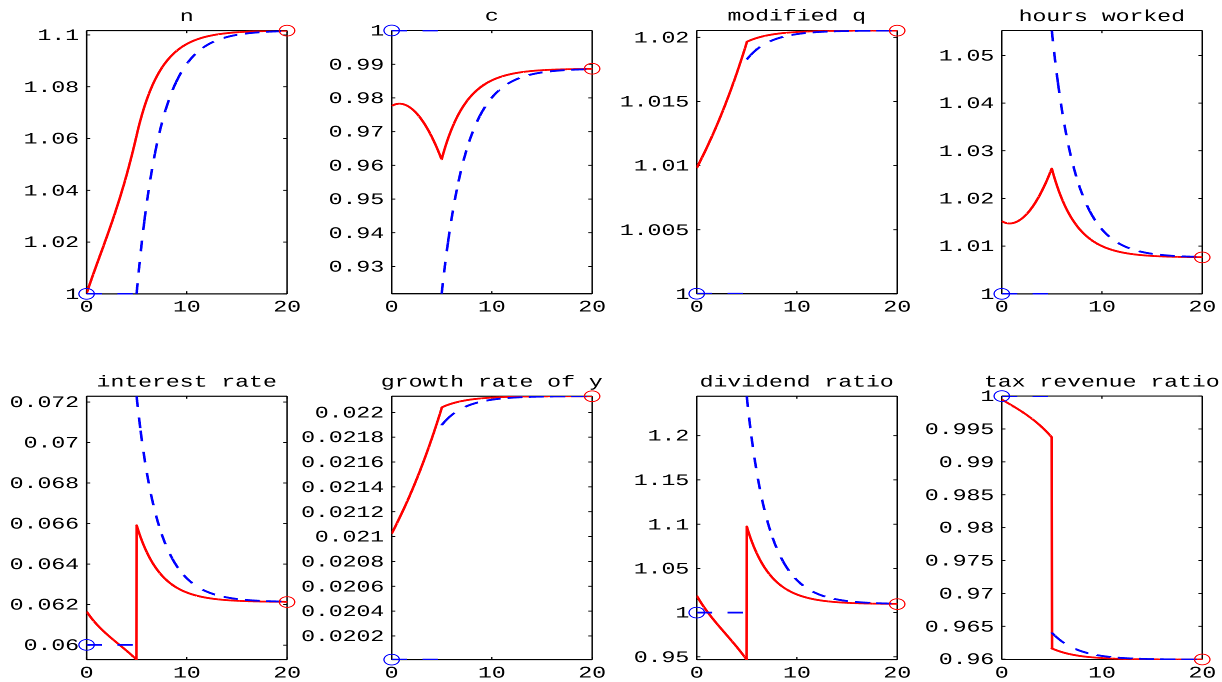


(a) **Anticipated vs. unanticipated permanent reduction of the dividend tax rate by 10 percentage points in the benchmark setting**. Solid (Dashed) lines plots the impulse response of each variable to the anticipated (unanticipated) tax cut. The circle marks on the left (right) vertical axis indicates the steady state level before (after) the tax cut.

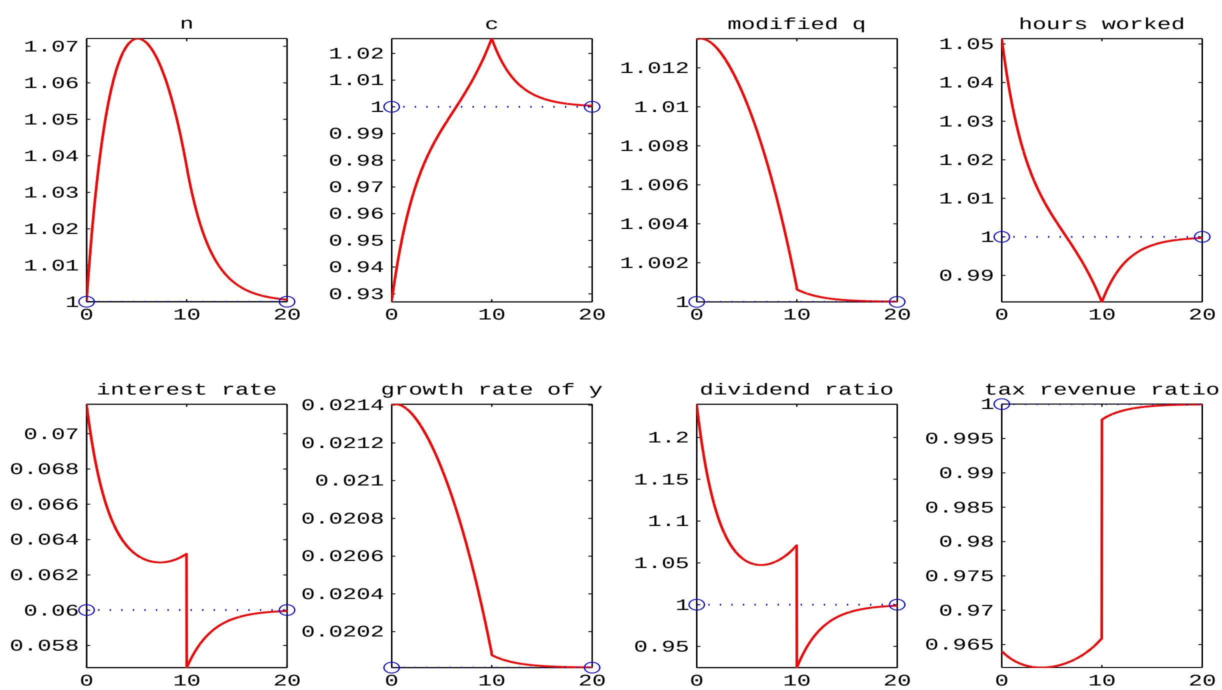


(b) **Temporary reduction of the dividend tax cut by 10 percentage points in the benchmark setting**. The circle mark on the vertical axis indicates the initial level.

Figure 2

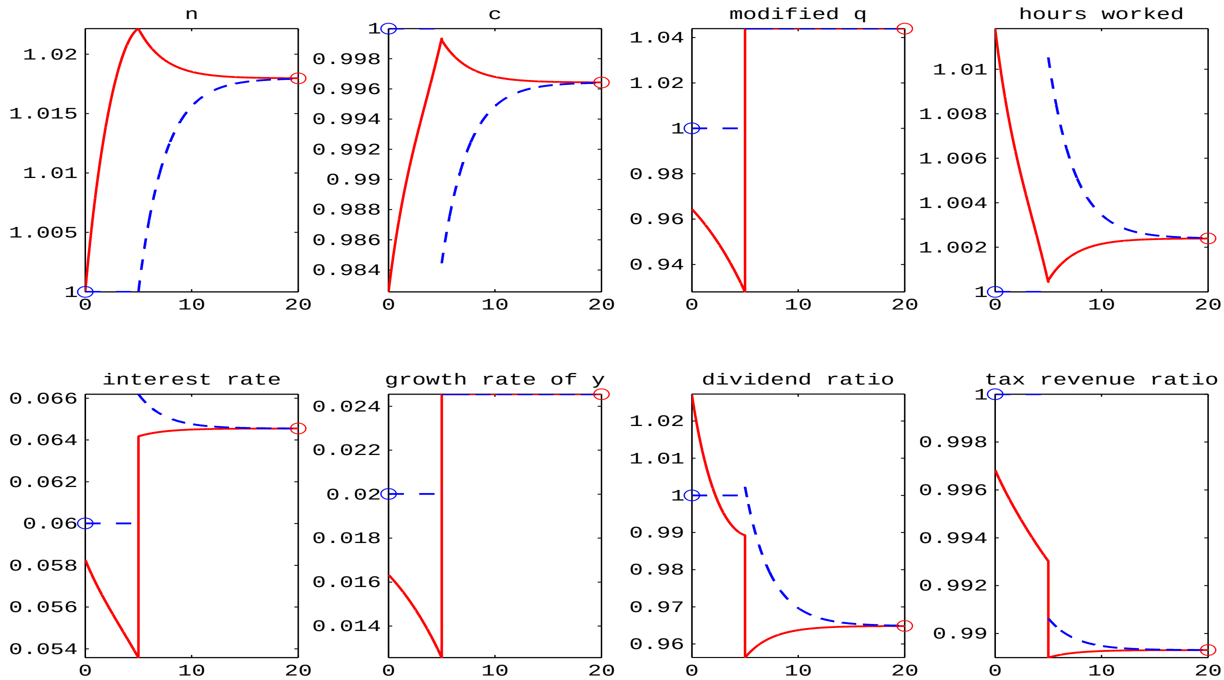


(a) **Anticipated vs. unanticipated permanent reduction of the corporate tax rate by 10 percentage points in the benchmark setting**. Solid (Dashed) lines plots the impulse response of each variable to the anticipated (unanticipated) tax cut. The circle marks on the left (right) vertical axis indicates the steady state level before (after) the tax cut.

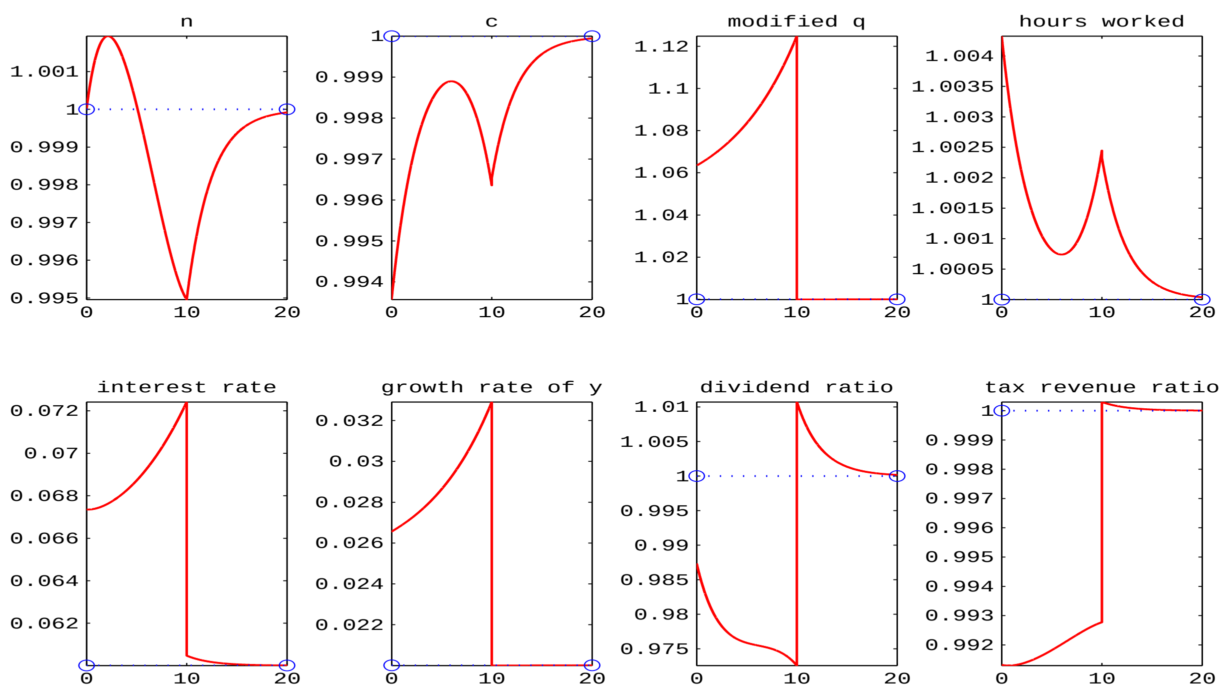


(b) **Temporary reduction of the corporate tax cut by 10 percentage points in the benchmark setting**. The circle mark on the vertical axis indicates the initial level.

Figure 3

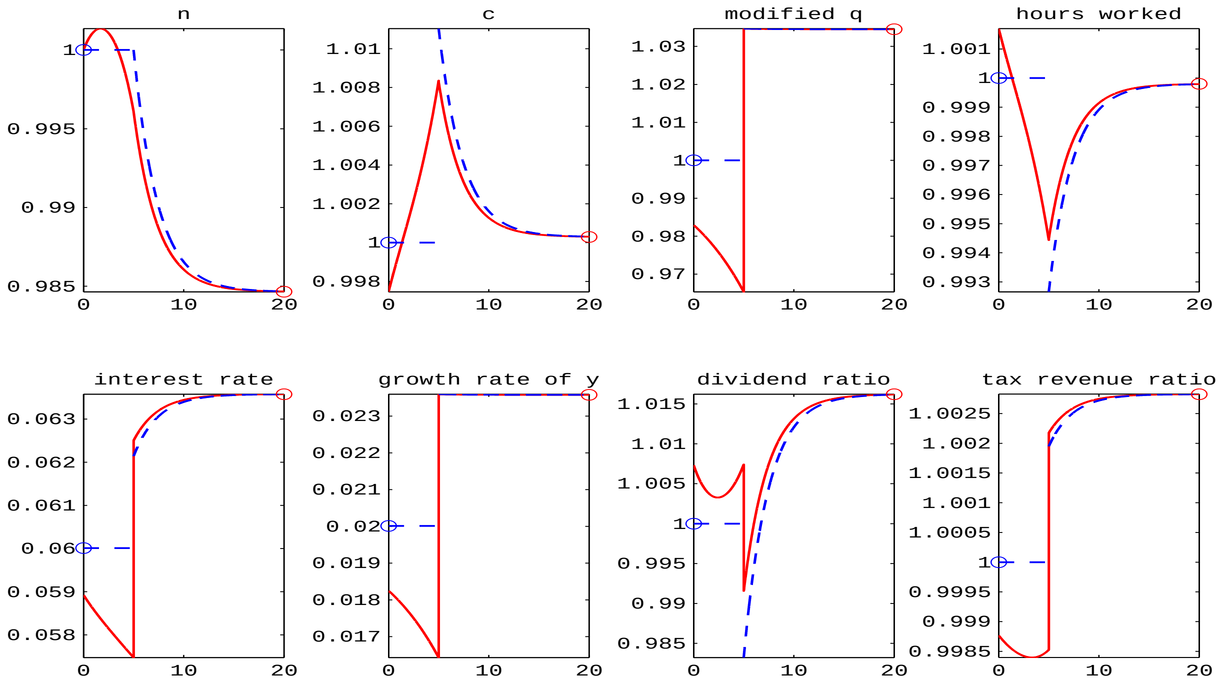


(a) **Anticipated vs. unanticipated permanent reduction of the capital gains tax rate by 10 percentage points in the benchmark setting**. Solid (Dashed) lines plots the impulse response of each variable to the anticipated (unanticipated) tax cut. The circle marks on the left (right) vertical axis indicates the steady state level before (after) the tax cut.

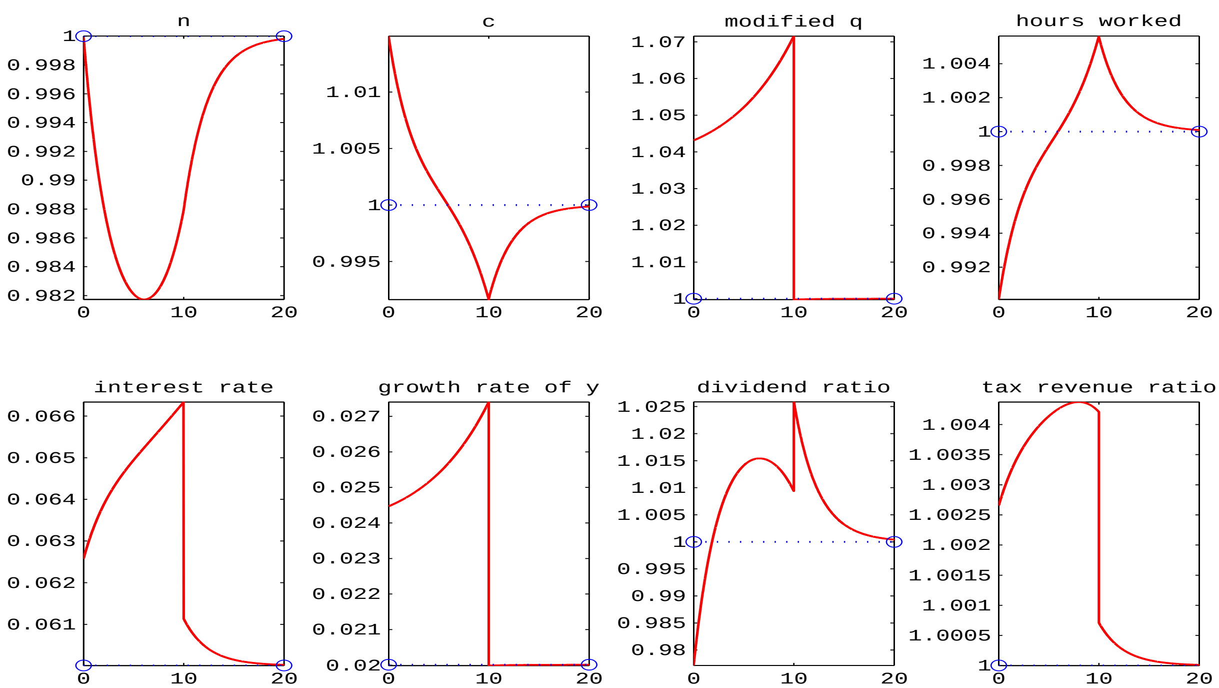


(b) **Temporary reduction of the capital gains tax cut by 10 percentage points in the benchmark setting**. The circle mark on the vertical axis indicates the initial level.

Figure 4

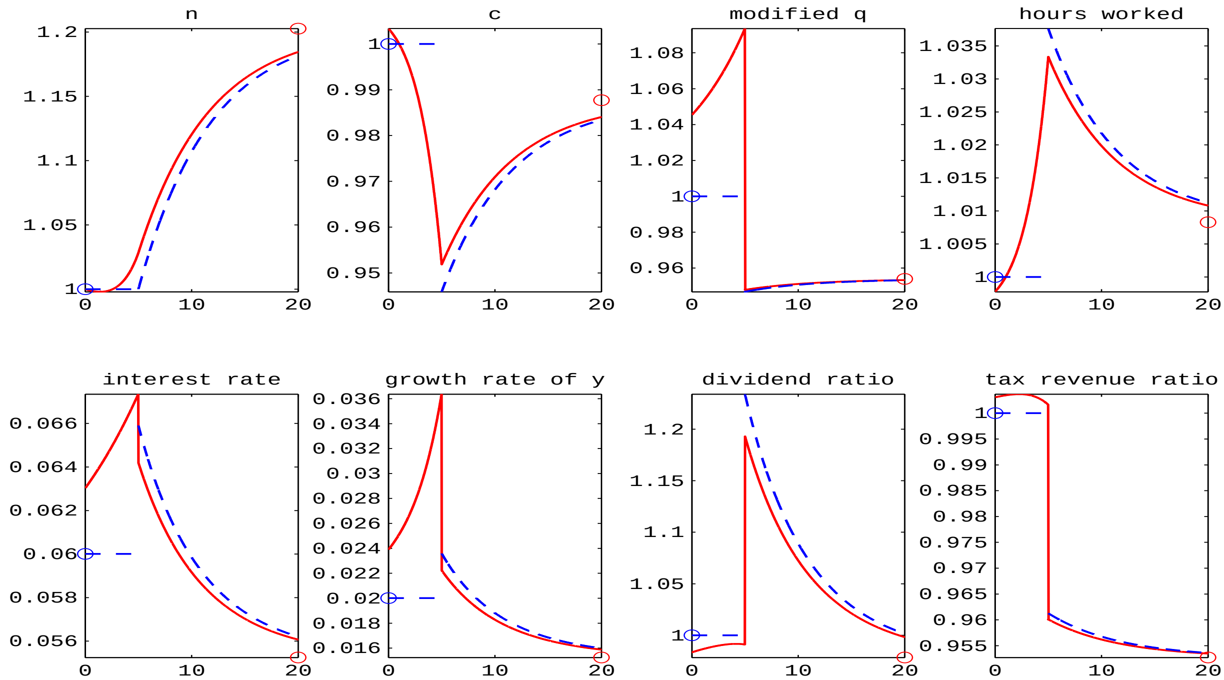


(a) **Anticipated vs. unanticipated permanent rise of the tax credit rate by 20 percentage points in the benchmark setting**. Solid (Dashed) lines plots the impulse response of each variable to the anticipated (unanticipated) change. The circle marks on the left (right) vertical axis indicates the steady state level before (after) rise of the tax credit.

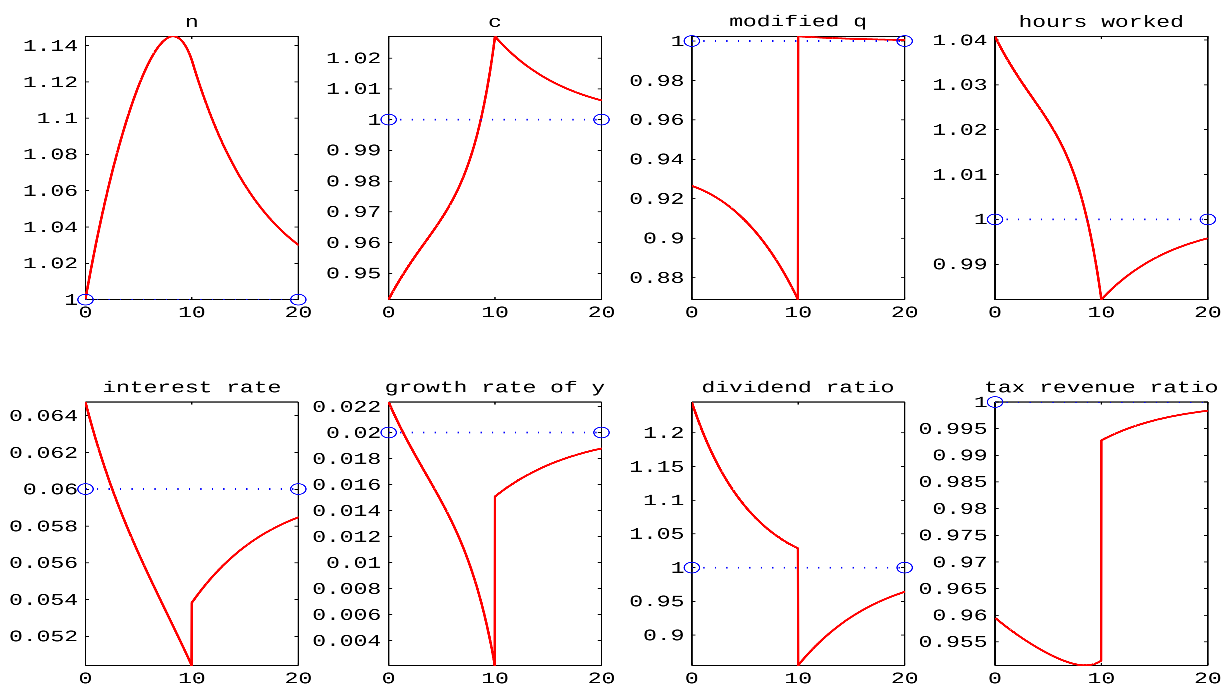


(b) **Temporary rise of the tax credit rate by 20 percentage points in the benchmark setting**. The circle mark on the vertical axis indicates the initial level.

Figure 5



(a) **Anticipated vs. unanticipated permanent reduction of the dividend tax rate by 10 percentage points in the case of $\kappa = 0.3$.** Solid (Dashed) lines plots the impulse response of each variable to the anticipated (unanticipated) tax cut. The circle marks on the left (right) vertical axis indicates the steady state level before (after) the tax cut.



(b) **Temporary reduction of the dividend tax cut by 10 percentage points in the case of** $\kappa = 0.3$. The circle mark on the vertical axis indicates the initial level.

Figure 6

$$= \theta(1-\theta)\frac{\Omega l(c_t)}{n_t} - \phi. \tag{A-5}$$

Using (A-4), (A-5), and (11), (13) is rewritten by

$$r_t = \frac{(1-\tau_D)(1-\tau_\Pi)}{\beta}\left[\theta(1-\theta)\frac{\Omega l(c_t)}{n_t} - \phi\right] - \frac{(1-\tau_D)(1-\sigma\tau_\Pi)}{\beta}\left[\frac{(Sq_t)^2-1}{2h}\right]$$
$$+ (1-\tau_V)\frac{Sq_t - 1}{h}.$$

Then, from the definition of S and η, rearranging the above equation yields (interest rate) From logarithmic differentiation of c_t with respect to time yields

$$\frac{\dot{c}_t}{c_t} = \frac{\dot{C}_t}{C_t} - \frac{\dot{Y}_t}{Y_t} = r_t - \rho + \lambda - \left\{\frac{\dot{l}(c_t)}{l(c_t)} + \lambda + \frac{\dot{Z}_t}{Z_t}\right\}.$$

Using (17) and (11), the above equation is rewritten by

$$\frac{\dot{c}_t}{c_t} = r_t - \rho + \frac{\Gamma\dot{c}_t}{1+\Gamma c_t} - \frac{Sq_t - 1}{h}. \tag{A-6}$$

Rearranging (A-6) yields (20).

From (2), (8), and the market equilibrium condition of labor, given $\bar{Z}_t$ and L_t, we obtain

$$\frac{\partial F_t}{\partial Z_t} = \alpha\theta(1-\theta)\frac{\Omega l(c_t)}{n_t}. \tag{A-7}$$

Using the definition of S and η, (11), and (A-7), (10) is rewritten by

$$\frac{\alpha\theta(1-\theta)}{S\eta}\frac{\Omega l(c_t)}{n_t} + \frac{(Sq_t-1)^2}{2Sh} = \frac{1}{1-\tau_V}r_t q_t - \dot{q}_t.$$

Then, using (17), it yields (21).

A.3 Appendix 3

The dynamical system of the economy where $q_t \leq 1$ is constituted by

$$
\begin{aligned}
\dot{n}_t &= \left[1-\theta^2-g-c_t\right]\frac{\Omega l(c_t)}{\beta}-\left[\phi+\beta\lambda\right]\frac{n_t}{\beta},\\
\dot{c}_t &= c_t\left[1+\Gamma c_t\right]\left[r_t-\rho\right],\\
\dot{q}_t &= \frac{1}{1-\tau_V}r_t q_t-\frac{\alpha\theta(1-\theta)}{S\eta}\frac{\Omega l(c_t)}{n_t},
\end{aligned}
$$

where the interest rate is given by

$$
r_t=\frac{(1-\tau_V)}{\beta S\eta}\left[\theta(1-\theta)\frac{\Omega l(c_t)}{n_t}-\phi\right].
$$

A.4 Appendix 4

Differentiating (26) with respect to $\tilde{q}$ yields

$$
f'(\tilde{q}) \equiv \begin{cases}
\left[1+\alpha-\dfrac{2}{1-\tau_V}\right]\dfrac{\tilde{q}}{h}+\left[\dfrac{1}{1-\tau_V}-1\right]\dfrac{S\alpha\beta+1}{h}-\dfrac{\rho}{1-\tau_V}, & \text{if} \quad \tilde{q}>1,\\
-\dfrac{\rho}{1-\tau_V}, \quad \text{if} \quad \tilde{q}\leq 1.
\end{cases}
$$

And second order differentiating (26) with respect to $\tilde{q}$ yields

$$
f''(\tilde{q}) \equiv \begin{cases}
\left[1+\alpha-\dfrac{2}{1-\tau_V}\right]\dfrac{1}{h}<0, \quad \text{if} \quad \tilde{q}>1,\\
0, \quad \text{if} \quad \tilde{q}\leq 1.
\end{cases}
$$

Here,

$$
\lim_{\tilde{q}\to 1+0} f'(\tilde{q})=\frac{1}{h(1-\tau_V)}\left[\tau_V(S\alpha\beta-1)-(1-\alpha)-h\rho\right].
$$

If $S\alpha\beta \leq 1-\frac{(1-\tau_V)\alpha\phi}{\eta\rho}$ (<1), $f(1)<0$ and $\lim_{\tilde{q}\to 1+0} f'(\tilde{q})<0$. Then, $f'(\tilde{q})<0$ for $\tilde{q}>1$ as $f''(\tilde{q})<0$ for $\tilde{q}>1$. Therefore, in this case, $f(\tilde{q})$ has only one solution of $\tilde{q}$ which value is less than one. That is, there is no steady state equilibrium with positive growth rate of output. On the other hand, if $1 - \frac{(1-\tau_V)\alpha\phi}{\eta\rho} < S\alpha\beta$, $f(1) > 0$. No matter whether $\lim_{\tilde{q}\to 1+0} f'(\tilde{q}) < 0$ is positive or negative, $f(\tilde{q})$ has unique solution of $\tilde{q}$ which value is higher than one as depicted in Figure 1.

A.5 Appendix 5

Differentiating the LHS of (26) with respect to τ_D, τ_Π, t_V, and σ respectively yields

$$\begin{aligned}
\frac{\partial f(\tilde{q}^*)}{\partial \tau_D} &= \left\{ \frac{\alpha\beta}{1-\tau_V}\rho + \left[\frac{1}{1-\tau_V} - 1 \right] \alpha\beta \frac{\tilde{q}^*-1}{h} \right\} \frac{1}{(1-\tau_D)} S > 0, \\
\frac{\partial f(\tilde{q}^*)}{\partial \sigma} &= \left\{ \frac{\alpha\beta}{1-\tau_V}\rho + \left[\frac{1}{1-\tau_V} - 1 \right] \alpha\beta \frac{\tilde{q}^*-1}{h} \right\} \frac{\tau_\Pi}{(1-\sigma\tau_\Pi)} S + \frac{\alpha\phi}{\eta^2} \frac{\sigma}{(1-\tau_\Pi)} > 0, \\
\frac{\partial f(\tilde{q}^*)}{\partial \tau_\Pi} &= \left\{ \frac{\alpha\beta}{1-\tau_V}\rho + \left[\frac{1}{1-\tau_V} - 1 \right] \alpha\beta \frac{\tilde{q}^*-1}{h} \right\} \frac{\sigma}{(1-\sigma\tau_\Pi)} S - \frac{\alpha\phi(1-\sigma)}{(1-\sigma\tau_\Pi)^2} \gtreqless 0., \\
&= -\alpha\phi < 0, \quad \text{if } \sigma = 0, \\
&= \left\{ \frac{\alpha\beta}{1-\tau_V}\rho + \left[\frac{1}{1-\tau_V} - 1 \right] \alpha\beta \frac{\tilde{q}^*-1}{h} \right\} \frac{1}{(1-\tau_\Pi)} S > 0, \quad \text{if } \sigma = 1, \\
\frac{\partial f(\tilde{q}^*)}{\partial \tau_V} &= -\frac{\rho}{(1-\tau_V)^2}\tilde{q}^* + \frac{\tilde{q}^*-1}{h(1-\tau_V)} \left[S\alpha\beta - \frac{\tilde{q}^*}{1-\tau_V} \right] \equiv \Gamma(\tilde{q}^*) \gtreqless 0.
\end{aligned}$$

$$\begin{aligned}
\Gamma(1) &= -\frac{\rho}{(1-\tau_V)^2} < 0, \\
\Gamma'(\tilde{q}^*) &= \frac{1}{(1-\tau_V)^2 h} \left[-2\tilde{q}^* - h\rho + 1 + S\alpha\beta(1-\tau_V) \right] \gtreqless 0, \\
\Gamma'(\tilde{q}^*) &= -\frac{2}{(1-\tau_V)^2 h} < 0.
\end{aligned}$$

Because $f(\tilde{q}^*)$ is decreasing function of $\tilde{q}^*$ in the neighborhood around the steady state solution, this derivation implies that the steady state growth rate is increasing function of τ_D, τ_Π (if $\sigma = 1$) and is decreasing σ, τ_Π (if $\sigma = 0$) and the effect of tax change of τ_Π (if $\sigma \in (0,1)$) and τ_V is ambiguous. However, if $S\alpha\beta < (1+h\rho)/(1-\tau_V)$, $\Gamma(\tilde{q}^*) < 0$ for $\tilde{q}^* \geq 1$. Then, it is shown that if $S\alpha\beta < (1+h\rho)/(1-\tau_V)$, the steady state growth rate is decreasing function of τ_V.

A.6 Appendix 6

We define $\Psi_t \equiv U_t - \frac{1}{\rho-\lambda}\log Z_t$. From the definition of c_t, (11), and (18), differentiating Ψ_t with respect to time yields

$$\dot{\Psi}_t = (\rho-\lambda)\Psi_t - \log\Omega - \log c_t - \log l_t - \zeta\log(1-l_t) - \frac{1}{\rho-\lambda}\frac{Sq_t-1}{h}.$$

In the steady state, Ψ_t is constant over time. Calculating the dynamic path of Ψ_t numerically by using the relaxation algorithm, we can obtain the initial value of Ψ_t, that is $\Psi_0 = U_0 - \frac{1}{\rho-\lambda}\log Z_0$. Without loss of generality, Z_0 is normalized to one. Hence, we obtain $U_0 = \Psi_0$.

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Table 5: Welfare gains of tax changes (parameter changes)

Tax change	Unanticipated (Permanent)	Anticipated (Permanent)	Temporary
$\beta = 3.275$ *(with $\alpha = 0.277$ and $\phi = 0.125$)*			
$\Delta t_D = -0.1$	-14.94	-12.21	-8.52
$\Delta t_\Pi = -0.1$	5.09	5.76	0.58
$\Delta t_V = -0.1$	15.33	12.63	8.3
$\Delta \sigma = 0.2$	11.55	10.3	5.05
$\beta = 9.825$ *(with $\alpha = 0.0945$ and $\phi = 0.408$)*			
$\Delta t_D = -0.1$	-13.7	-10.85	-8.08
$\Delta t_\Pi = -0.1$	5.03	5.65	0.66
$\Delta t_V = -0.1$	13.04	10.25	7.72
$\Delta \sigma = 0.2$	10.66	9.36	4.81
$h = 8.0$ *(with $\alpha = 0.133$ and $\phi = 0.267$)*			
$\Delta t_D = -0.1$	-15.44	-11.41	-9.98
$\Delta t_\Pi = -0.1$	5.87	6.55	0.89
$\Delta t_V = -0.1$	15.1	11.05	9.7
$\Delta \sigma = 0.2$	12.37	10.37	6.05
$h = 18.0$ *(with $\alpha = 0.153$ and $\phi = 0.265$)*			
$\Delta t_D = -0.1$	-12.5	-10.55	-6.64
$\Delta t_\Pi = -0.1$	4.2	4.77	0.44
$\Delta t_V = -0.1$	12.02	10.15	6.29
$\Delta \sigma = 0.2$	9.39	8.59	3.88
$\sigma = 1.0$ *(with $\alpha = 0.0955$ and $\phi = 0.260$)*			
$\Delta t_D = -0.1$	-13.86	-11.05	-8.08
$\Delta t_\Pi = -0.1$	-13.6	-10.83	-7.95
$\Delta t_V = -0.1$	12.95	10.15	7.69
$\Delta \sigma = 0.2$	17.06	15.0	7.55
$\zeta = 0$			
$\Delta t_D = -0.1$	-14.23	-9.93	-7.12
$\Delta t_\Pi = -0.1$	4.81	4.64	0.53
$\Delta t_V = -0.1$	13.5	9.16	6.72
$\Delta \sigma = 0.2$	10.87	8.20	4.18

Note: Welfare gains are measured in consumption equivalent and expressed in percentage points. Other values of the tax variables and parameters are sames as the benchmark setting.

Table 6: Welfare gains of tax changes (positive social spillover of product variety)

Tax change	Unanticipated (Permanent)	Anticipated (Permanent)	Temporary
$\kappa = 0.1$			
$\Delta t_D = -0.1$	-13.08	-10.17	-7.95
$\Delta t_\Pi = -0.1$	5.88	6.59	0.83
$\Delta t_V = -0.1$	13.73	10.98	7.86
$\Delta \sigma = 0.2$	10.72	9.43	4.82
$\kappa = 0.3$			
$\Delta t_D = -0.1$	-10.75	-7.78	-7.12
$\Delta t_\Pi = -0.1$	8.07	8.88	1.42
$\Delta t_V = -0.1$	14.17	11.53	7.85
$\Delta \sigma = 0.2$	10.35	9.1	4.66
$\kappa = 0.5$			
$\Delta t_D = -0.1$	-7.57	-4.65	-5.86
$\Delta t_\Pi = -0.1$	11.08	11.93	2.35
$\Delta t_V = -0.1$	14.76	12.25	7.85
$\Delta \sigma = 0.2$	9.87	8.68	4.43
$\kappa = 0.7$			
$\Delta t_D = -0.1$	-3.07	-0.22	-4.11
$\Delta t_\Pi = -0.1$	15.34	16.22	3.61
$\Delta t_V = -0.1$	15.54	13.24	7.86
$\Delta \sigma = 0.2$	9.23	8.13	4.13

Note: Welfare gains are measured in consumption equivalent and expressed in percentage points. Other values of tax variables and parameters are same as the benchmark setting.