DISCUSSION PAPER SERIES

Discussion paper No.304

The Effects of Financial Frictions on Optimal Corporate Income and Consumption Taxation in an R&D-Driven Growth Model

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December 2025

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SCHOOL OF ECONOMICS

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Abstract

Does reducing the corporate income tax while increasing the consumption tax to satisfy government budget constraints improve welfare? To address this question, this paper examines the welfare-maximizing consumption and corporate income tax rates within a Rivera-Batiz and Romer (1991)-type variety-expanding growth model with financial frictions and heterogeneous R&D productivity. We also explore how these welfare-maximizing tax rates change as financial constraints become less binding due to financial development. The results indicate that under mild and plausible levels of financial frictions, relaxing financial constraints on R&D investment lowers the optimal corporate income tax rate, while raising the optimal consumption tax rate. This finding implies that when financial constraints are eased, enhancing innovation at the expense of current production—by raising the consumption tax and reducing the corporate income tax—improves welfare. The underlying mechanism is that relaxing financial constraints induces entry into R&D only by highly productive entrepreneurs, thereby increasing the average efficiency of R&D investment.

Keywords: Financial Frictions, Corporate Income Tax, Consumption Tax, R&D, Endogenous growth
JEL Classification: E62, H21, H25, O30, O38,

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Acknowledgements: This research was financially supported by the Japan Society for the Promotion of Science: Grants-in-Aid for Scientific Research (C) 25K05016

1 Introduction

Over the past few decades, many OECD countries have experienced a steady decline in corporate income tax rates alongside an upward trend in consumption taxes—particularly value-added tax—as documented in OECD datasets and reports (e.g., OECD Corporate Tax Statistics 2024; OECD Consumption Tax Trends 2024). Figures 1 and 2 illustrate the evolution of these tax rates in G7 countries from 1995 to 2020, with this pattern especially pronounced in the United Kingdom, Germany, and Japan. The rationale for reducing corporate income tax rates lies in their potential to stimulate investment, including research and development, thereby fostering economic growth and improving overall welfare. However, such reductions constrain public revenue, necessitating compensatory measures to maintain fiscal sustainability. In practice, these adjustments have often taken the form of incremental increases in consumption tax rates—a phenomenon consistently observed across numerous OECD countries. This widespread shift in tax structures raises an important question: does this policy mix truly enhance welfare, and if so, what combination of rates achieves the best outcome?

[Figures 1 and 2 about here.]

Meanwhile, the corporate business environment has undergone a major transformation driven by the advancement of financial institutions and markets. Figure 3 reports the evolution of the Financial Development Index (FDI) for G7 countries from 1995 to 2020. The FDI, published by the IMF, is a composite measure designed to capture the overall level of financial sophistication. As shown in Figure 3, the index has improved in nearly all G7 countries. Prior research (e.g., Levine, 2005, 2021) indicates that financial development enhances firm profitability and promotes R&D by expanding long-term funding, channeling resources to high-productivity firms, and enabling rapid financing for innovation. These changes in financial conditions not only affect investment behavior but also influence production, labor demand, and consumption patterns. Consequently, the welfare implications of tax policy cannot be fully understood without considering the role of financial development, which may alter the optimal mix of corporate and consumption tax rates.

[Figure 3 about here.]

Against this backdrop, this article pursues two objectives:(i) to evaluate whether a policy of reducing corporate income tax rates while simultaneously increasing consumption tax rates can enhance overall welfare, and to identify the optimal levels for each tax rate; and (ii) to investigate how these welfare-maximizing tax rates are influenced by the degree of financial development. To this end, the study employs a variety-expanding growth model with financial frictions and heterogeneous R&D productivity. It is well documented that innovation activities require substantial funding, yet entrepreneurs often struggle to secure sufficient resources for R&D, leading to underinvestment. Two main factors contribute to this phenomenon: knowledge nonrivalry (e.g., Romer, 1990) and financial frictions (e.g., Aghion et al., 2005). Knowledge is nonrivalrous, and this externality creates a disincentive effect, discouraging entrepreneurs from raising adequate funds for R&D investment, particularly when external financing is needed. Indeed, corporate finance studies (e.g., Himmelberg and Petersen, 1994; Brown et al., 2009, 2012) provide strong evidence that the availability of external finance is critical for R&D projects. Interestingly, Hajivassiliou and Savignac (2008) and Hottenrott and Peters (2012) find that firms with high R&D capabilities are more likely to face financial constraints. Building on these findings and concerns about the long-run effects of financial frictions, we adopt a Romer (1990)-type endogenous growth model incorporating financial frictions and heterogeneous R&D productivity.

Our model features infinitely lived representative agents who derive utility from consumption and leisure. The final good is produced by competitive firms using differentiated intermediate goods, each supplied by monopolistic firms employing labor. Entrepreneurs engage in R&D to create new intermediate goods; however—as in Romer (1990)—intertemporal knowledge spillovers reduce the private value of innovation relative to its social value, leading to underinvestment. Entrepreneurs differ in R&D productivity and require external financing to fund R&D (Grossman and Helpman, 1991). Following Aghion et al. (2005), moral hazard introduces default risk, which limits entrepreneurs' ability to borrow for R&D investment. These financial constraints distort resource allocation in two dimensions: (i) across entrepreneurs—highly productive ones lack sufficient funds, while less productive ones overinvest, reducing aggregate R&D productivity; and (ii) intertemporally—tight constraints lower overall R&D productivity, increasing welfare losses from reallocating resources away from current production toward R&D. We consider a setting in which greater financial development relaxes credit constraints by making borrower default more difficult.

The government levies linear, time-invariant taxes on consumption, corporate income, and labor, maintaining a balanced budget. A higher consumption tax permits a lower corporate tax, boosting intermediate firm profits and uniformly enhancing the profitability of all entrepreneurs' R&D projects. Given the suboptimal level of R&D investment caused by knowledge spillovers and credit constraints, this policy can potentially improve welfare. However, its effect depends critically on the severity of financial constraints. When constraints are tight, aggregate R&D productivity is too low, and reallocating resources toward R&D by raising the consumption tax while reducing the corporate tax worsens welfare. In this case, the optimal policy sets the consumption tax to zero and relies on a positive corporate tax. Under moderate frictions, however, raising the consumption tax and reducing the corporate tax can enhance welfare, implying an optimal positive mix of both taxes. Specifically, this tax shift has three effects: (i) it decreases labor supply and distorts labor-leisure choices (negative); (ii) it lowers average entrepreneurial productivity by encouraging entry of less productive firms (negative); and (iii) it reallocates resources toward R&D, mitigating underinvestment (positive). As financial development relaxes constraints, the second effect weakens and the third strengthens. Thus, with fewer constraints, the welfare-maximizing corporate tax rate falls while the optimal consumption tax rate rises. These results align with the actual trends in corporate and consumption tax rates observed in Figures 1 and 2.

This paper relates to three main strands of the literature. First, it contributes to studies analyzing the second-best optimal mix of tax policies required to finance a given level of government expenditure within R&D-based growth models (e.g., Iwaisako, 2016; Long and Pelloni, 2017; Annicchiarico et al., 2021; Chen et al., 2023). Building on the seminal work on optimal capital taxation by Judd (1985) and Chamley (1986), Long and Pelloni (2017), Annicchiarico et al. (2021), and Chen et al. (2023) examine the optimal combination of labor and capital taxation and its dependence on factors such as time preference, intertemporal elasticity of substitution, labor share, government spending, and innovation-related externalities, using various R&D-based growth models.[1] However, these studies do not address the optimal mix of corporate income and consumption taxation. Iwaisako (2016) is a notable exception, analyzing the optimal combination of these two taxes within a Grossman and Helpman (1991)-type quality-ladder growth model. Iwaisako (2016) shows that stronger patent protection raises the welfare-maximizing corporate tax rate while lowering the consumption tax rate. While sharing a research interest with Iwaisako (2016), this paper differs by focusing on the role of financial frictions, incorporating heterogeneous R&D productivity, and adopting a variety-expanding growth model. Accordingly, this study serves as a complementary contribution to Iwaisako (2016).

Second, this paper relates to studies examining how financial development affects the effectiveness of economic policies within R&D-based growth models (e.g., Chu et al., 2020; Hori, 2020; Shaw et al., 2023). Chu et al. (2020) extend Aghion et al. (2005) by incorporating patent policy and analyzing how financial development influences the impact of patent protection on innovation. They find that strong credit constraints limit the innovation benefits of patent protection, whereas financial development amplifies them. Hori (2020) introduces heterogeneity in R&D productivity, borrowing constraints, and cash-in-advance constraints into a Grossman and Helpman (1991)-type quality-ladder growth model and examines the relationship between borrowing constraints and optimal monetary policy, showing that this relationship varies significantly depending on whether R&D productivity heterogeneity is present. Shaw et al. (2023) extend Peretto (2007) by introducing a micro-founded R&D financial structure and demonstrate that the effectiveness of policies—such as dividend, corporate, and bond income taxes, as well as monetary policy—depends on how loanable funds are allocated within financial markets. However, these studies do not explore the relationship between financial development and the optimal mix of corporate income and consumption taxation, which is the focus of this paper. Nevertheless, the specification of financial constraints in this study is strongly influenced by Hori (2020).

Third, this paper is related to studies examining the relationship between corporate tax policy and economic growth using R&D-based growth models (Aghion et al., 2016; Peretto, 2007; Suzuki, 2021).[2] These studies show that the growth effect of corporate taxation can be either positive or negative, depending on the model specification. Aghion et al. (2016) and Suzuki (2021) find an inverted U-shaped relationship between the corporate tax rate and economic growth, whereas Peretto (2007) does not establish an explicit link between the two. However, none of these studies address the welfare implications of corporate tax policy or the optimal mix of corporate income and consumption taxation, which is the focus of this paper.

The remainder of the paper is structured as follows. Section 2 introduces the basic model. Section 3 establishes the existence of a steady-state equilibrium and analyzes the growth effects of raising the consumption tax while lowering the corporate income tax. Section 4 evaluates the welfare implications of this tax shift. Section 5 provides numerical simulations to identify the optimal tax mix. Section 6 concludes.

[1] Long and Pelloni (2017) employ a Rivera-Batiz and Romer (1991)-type variety-expanding growth model; Annicchiarico et al. (2021) adopt a scale-free quality-ladder growth model; and Chen et al. (2023) use the scale-invariant R&D-based growth model proposed by Jones and Williams (2000).

[2] This paper is also related to studies on corporate taxation under financial frictions (e.g., Dàvila, E., & Hèbert, 2022) and on the macroeconomic effects of tax reforms (e.g., Barro and Wheaton, 2020), but it focuses on intuitive insights from a tractable R&D-based growth model.

2 Model

We extend the lab equipment-type, variety-expanding growth model of Rivera-Batiz and Romer (1991) by incorporating financial frictions and heterogeneity in R&D productivity, in order to examine their effects on optimal corporate income and consumption tax rates. The approach to introducing financial frictions and R&D productivity heterogeneity largely follows Liu and Wang (2014) and Hori (2020). Since the variety-expanding growth model is well known, We briefly describe its standard features.

2.1 Final good

Competitive final goods firms produce a final good, Y_t, which can be consumed or invested in the creation of new intermediate goods. The final good serves as the numeraire, and its price is normalized to one. The production function is given by

$$Y_t = A_t n_t^{\phi+1-\frac{\epsilon}{\epsilon-1}} \left(\int_0^{n_t} x_{i,t}^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}}, \tag{1}$$

where $x_{i,t}$ is the input of intermediate good $i \in [0, n_t]$, n_t denotes the total number of available intermediate goods and the parameter $\epsilon > 1$ indicates the elasticities of substitution across intermediate goods. The parameter $\phi > 1$ captures the returns to specialization, as emphasized by Ethier (1982).[3] Output in the final goods sector increases with the number of intermediate inputs, provided that ϕ exceeds unity. We assume that A_t grows at an exogenous growth rate $g_A \equiv \dot{A}_t/A_t$, which captures factors other than R&D and is introduced to allow for a plausible numerical parameterization. Let $p_{i,t}$ denote the price of intermediate good i. The demand function for intermediate good i is given by

$$x_{i,t} = \frac{p_{i,t}^{-\epsilon}}{\int_0^{n_t} p_{i,t}^{1-\epsilon} di} Y_t, \tag{2}$$

where $p_{i,t}$ denotes the price of $x_{i,t}$.

2.2 Intermediate goods

Monopolistic firms produce differentiated intermediate goods using a linear technology, requiring one unit of labor to produce one unit of intermediate good $i \in [0, n_t]$. The profit function of each intermediate good firm i is given by $\pi_{x,i,t} = (p_{i,t} - w_t)\, x_{i,t}$. Following Goh and Olivier (2002), we introduce a patent breadth parameter and assume that the maximum markup intermediate goods firms can charge is $\mu > 1$, where μ is a policy instrument determined by the patent authority.[4] Given the demand function (2), firm i can maximize its operating profits by setting $p_{i,t} = \mu w_t \equiv p_t$. This yields

$$x_{i,t} = \frac{Y_t}{n_t p_t} \equiv x_t, \tag{3}$$

$$\pi_{x,i,t} = \frac{\mu - 1}{\mu} \frac{Y_t}{n_t} \equiv \pi_{x,t}. \tag{4}$$

[3] This specification is well known in the growth literature. See, for example, Heijdra (2017), pp. 528-529.

[4] The familiar unconstrained profit-maximizing price is $p_{i,t} = [\epsilon/(\epsilon - 1)]w_t$. We consider the case where $\mu \neq \epsilon/(\epsilon - 1)$ to allow greater flexibility in parameter calibration. Our main results remain unchanged even if $\mu = \epsilon/(\epsilon - 1)$.

Let $q_{i,t}$ denote the value of intermediate goods firm i, measured in units of final goods. Since all firms earn the same level of operating profits, $q_{i,t}$ is independent of i and satisfies

$$r_t q_t = (1 - \tau_{\pi,t})\pi_{x,t} + \dot{q}_t, \tag{5}$$

where r_t is real interest rate and $\tau_{\pi,t}$ is the tax/subsidy rate on corporate income. If $\tau_{\pi,t} > 0$, the government imposes a tax on corporate income, whereas if $\tau_{\pi,t} < 0$, it provides a subsidy. This paper focuses on the case in which the government imposes a uniform tax rate $\tau_{\pi,t} > 0$ on corporate profits. However, the numerical analysis also includes examples of the case where the government subsidizes corporate profits, i.e., $\tau_{\pi,t} < 0$.

For later use, we derive the following equations using (1), (3) and $p_t = \mu w_t$.

$$Y_t = A_t n_t^{\phi} l_{x,t}, \tag{6}$$

$$w_t = \frac{1}{\mu} A_t n_t^{\phi} = \frac{Y_t}{\mu l_{x,t}}, \tag{7}$$

where $l_{x,t} \equiv n_t x_t$ and $l_{x,t}$ denotes the labor used in intermediate goods production. Since only the intermediate goods sector employs labor, $l_{x,t}$ corresponds to the aggregate labor supply Ll_t provided by households in equilibrium.

2.3 Households and Workers/Entrepreneurs

Consider a representative household composed of a continuum of identical agents, with a constant population size of L. The household owns intermediate goods firms, and each agent within the household has access to R&D technology that enables the creation of new intermediate goods. Following Jaimovich and Rebelo (2017) and Chu et al. (2020), we assume that agents in the representative household not only supply labor and make consumption-saving decisions, but also engage in R&D investment as entrepreneurs. This framework allows for a distinction between entrepreneurial rents and corporate income, facilitating comparisons between this study and existing research on corporate taxation and R&D-based growth.[5]

The utility of the representative households at time s is given by

$$U_s = \int_s^{\infty} \frac{\left[c_t(\bar{l} - l_t)^{\eta}\right]^{1-\sigma}}{1-\sigma} L e^{-\rho(t-s)} dt, \tag{8}$$

where c_t is consumption of final goods per agent, $l_t \in [0, \bar{l}]$ is labor supply per agent, $\bar{l}$ is time endowment of each agent, $\rho > 0$ is the subjective discount rate, $\eta > 0$ measures the importance of leisure and $1/\sigma < 1$ is the elasticity of intertemporal substitution. We restrict our attention to the case of $\sigma > 1$ because most empirical evidence suggests that the elasticity of intertemporal substitution is relatively small (e.g., Guvenen 2006).

Let $\varphi \in [\varphi_{min}, \infty]$ denote the productivity of R&D technology. Each agent in the representative household has access to R&D technology and draws a productivity level from a distribution $F(\varphi)$. The variable φ is independently and identically distributed (i.i.d.) across both time and agents. Consider an infinitesimally short time interval of length dt. At each time increment dt, the value of φ is redrawn from the same distribution.

[5]Most models of corporate taxation and R&D-based growth assume perfect competition in the R&D sector, so entrepreneurial rents do not arise. Following Jaimovich and Rebelo (2017), we assume these rents accrue to households.

For analytical convenience, following Liu and Wang (2014), we assume that φ follows a Pareto distribution: $F(\varphi) = 1 - (\varphi_{min}/\varphi)^a$, where $a > 1$ and $\varphi_{min} > 0$.[6] Following Itskhoki and Moll (2018), we consider the limit economy by taking the limit of $dt \to 0$.[7]

Consider the behavior of an agent (i.e., an entrepreneur) within a representative household over the interval $[t, t+dt]$, who draws a productivity level φ at time t. Upon observing φ, the agent chooses the amount of final goods $I_{R,\varphi,t} \geq 0$ to borrow for investment in the invention of new intermediate goods. We assume that each agent cannot undertake R&D investment without borrowing from the representative household and, moreover, cannot repay $I_{R,\varphi,t} \geq 0$ until revenue is earned from the resulting R&D output. Although this assumption may seem counterintuitive—since entrepreneurs are modeled as part of the representative household—it is adopted to simplify the analysis. Abstracting from financial intermediaries and integrating entrepreneurs with households greatly simplifies the model without affecting the main analytical results.[8]

The contribution of agent who draws the productivity φ at time t to the creation of new varieties is governed by the following law of motion: $\dot{n}_{\varphi,t} = \varphi E_t I_{R,\varphi,t}$, where E_t captures the knowledge spillovers. The productivity of R&D increases with the current state of technology, which reflects the cumulative results of past research. This state-of-the-art level is conveniently measured by the ratio of the number of existing varieties to the current output level, n_t/Y_t. Following Barro and Sala-i-Martin (2004, pp. 300-302), We assume that $E_t = E(n_t/Y_t)$, where $E > 0$ is a constant parameter that determines the social productivity of R&D. This linear specification helps eliminate counterintuitive scale effects. As described later, an agent who draws a sufficiently low productivity level may choose not to invest, i.e., $I_{R,\varphi,t} = 0$.

The inventor of a new intermediate good is granted a permanent patent for the newly invented variety. The total number of intermediate goods n_t evolves according to

$$\dot{n}_t = E_t \int_{\varphi_{min}}^{\infty} \varphi I_{R,\varphi,t} dF(\varphi). \tag{9}$$

Based on equation (9) and the assumption that $E_t = E(n_t/Y_t)$, the growth rate of intermediate varieties increases linearly with the output share of the productivity-adjusted, economy-wide R&D investment rate.

We now describe the financial constraints faced by each agent (i.e., entrepreneur). Each agent decides whether to repay the borrowed funds for R&D investment, $I_{R,\varphi,t}$. Following Liu and Wang (2014), we assume that if an agent defaults, they are caught with probability $\theta_R \cdot dt$, where $\theta_R > 0$ is a Poisson arrival rate of being caught. In this case, the agent's revenue is seized, and they are permanently excluded from future access to credit. If the defaulting agent escapes detection with probability $1 - \theta_R \cdot dt$, they remain indistinguishable from non-defaulting agents and retain access to future credit.[9] Given these

[6] The main result holds approximately even without assuming a Pareto distribution for φ, though the analysis then requires more intricate parameter conditions, which are omitted for brevity.

[7] See section 2.1 of Itskhoki and Moll (2018).

[8] Chu et al. (2020) likewise adopt a similar assumption for analytical simplicity.

[9] These credit constraints arise from information asymmetry, as lenders (i.e., the representative household) cannot observe entrepreneurs' actions. Modeling entrepreneurs as independent R&D firms or explicitly incorporating financial intermediaries, as in Hori (2020), would constitute a more natural specification; however, such an extension would not materially affect the qualitative results. To preserve tractability and clearly distinguish entrepreneurial rents from corporate income, thereby facilitating interpretation of the main findings, we adopt a representative household framework in which households and entrepreneurs are integrated.

circumstances, we derive an incentive constraint that ensures no default occurs in equilibrium. Let the values of a non-defaulting and defaulting agent's R&D project with productivity φ at time t be denoted by $v^N_{\varphi,t}$ and $v^D_{\varphi,t}$, respectively. Define $v_{\varphi,t} \equiv max\left\{v^N_{\varphi,t}, v^D_{\varphi,t}\right\}$ and let the expected value be $v_t \equiv \int_{\varphi_{min}}^{\infty} v_{\varphi,t} dF(\varphi)$. Then, the value of a non-defaulting agent's R&D project is given by:

$$v^N_{\varphi,t} = \left(q_t \dot{n}_{\varphi,t} - I_{R,\varphi,t}\right) dt + \frac{v_{t+dt}}{1 + r_t \cdot dt}. \tag{10}$$

Here, $I_{R,\varphi,t}$ is the repayment of loans for R&D investment. Since the productivity φ changes at time $t + dt$, the continuation value v_{t+dt} appears in (10). For a defaulting agent who does not repay $I_{R,\varphi,t}$ and escapes detection with probability $1 - \theta_R \cdot dt$, the value is:

$$\begin{aligned} v^D_{\varphi,t} &= q_t \dot{n}_{\varphi,t} \left(1 - \theta_R \cdot dt\right) dt + \frac{\left(1 - \theta_R \cdot dt\right) v_{t+dt}}{1 + r_t \cdot dt}, \\ &= q_t \dot{n}_{\varphi,t} dt + \frac{\left(1 - \theta_R \cdot dt\right) v_{t+dt}}{1 + r_t \cdot dt}. \end{aligned} \tag{11}$$

The second line uses $(dt)^2 \approx 0$. If $v^N_{\varphi,t} \geq v^D_{\varphi,t}$, agents have no incentive to default. Rearranging this condition using $(dt)^2 \approx 0$, We obtain the incentive constraint:

$$I_{R,\varphi,t} \leq \theta_R v_{t+dt}. \tag{12}$$

All agents face the same borrowing limit $\theta_R v_{t+dt}$. They cannot borrow more than the average value of their R&D project multiplied by θ_R. Agents with higher productivity levels have stronger incentives to invest in R&D, and thus suffer more severely from financial constraints than those with lower productivity. As long as condition (12) is satisfied, we have $v_{\varphi,t} \equiv max\left\{v^N_{\varphi,t}, v^D_{\varphi,t}\right\} = v^N_{\varphi,t}$. We consider a setting in which greater financial development increases θ_R, thereby relaxing credit constraints by making borrower default more difficult.

The flow budget constraint of representative household is now given by:

$$\dot{B}_t = r_t B_t + (1 - \tau_w) w_t L l_t + (1 - \tau_{\pi,t}) \pi_{x,t} n_t - \int_{\varphi_{min}}^{\infty} I_{R,\varphi,t} dF(\varphi) - (1 + \tau_c) c_t L, \tag{13}$$

where B_t denotes bond holdings of households, τ_w is the wage tax rate and τ_c is the consumption tax rate. The representative household earns labor income $(1 - \tau_w) w_t L l_t$ and receives profits from ownership of intermediate goods firms, given by $(1 - \tau_{\pi,t}) \pi_{x,t} n_t$.

Given initial conditions B_0 and n_0, the representative household chooses c_t, l_t and $I_{R,\varphi,t}$ to maximize its lifetime utility (8), subject to (9), (12) and (13). The first-order conditions are provided in Appendix A. From the household's intra-temporal optimization, the household labor supply is determined by:

$$\eta \frac{c_t}{\bar{l} - l_t} = \frac{(1 - \tau_w) w_t}{1 + \tau_c}. \tag{14}$$

Abstracting from other factors, a higher wage tax τ_w increases labor supply l_t by raising the opportunity cost of leisure, whereas a higher consumption tax τ_c reduces labor supply by lowering that cost. From the household's intertemporal optimization, the familiar Euler equation is derived as:

$$\left[\sigma + (\sigma - 1)\eta\right] \frac{\dot{c}_t}{c_t} = r_t - \rho + \eta(\sigma - 1) \frac{\dot{w}_t}{w_t}. \tag{15}$$

Furthermore, from the first-order condition for $I_{R,\varphi,t}$, the following result is obtained:

$$I_{R,\varphi,t} = \begin{cases} 0, & \text{if } \varphi < \underline{\varphi}_t, \\ \theta_R v_{t+dt}, & \text{if } \varphi \geq \underline{\varphi}_t, \end{cases} \tag{16}$$

where $\underline{\varphi}_t \equiv Y_t/(Eq_t n_t)$. Agents with productivity $\varphi \geq \underline{\varphi}$ engage in R&D activities. Moreover, these agents invest the same amount in R&D because φ is an i.i.d. shock. When θ_R is large, active agents can borrow larger amounts of final goods and invest more intensively in R&D.

Letting $v_{\varphi,t} = v^N_{\varphi,t}$ and substituting $\dot{n}_{\varphi,t} = \varphi E_t I_{R,\varphi,t}$ and (16) into (10), we obtain: $v_{\varphi,t} = \pi_{R,\varphi,t}\theta_R v_{t+dt}dt + v_{t+dt}/(1+r_t \cdot dt)$, where $\pi_{R,\varphi,t} \equiv max\{\varphi/\underline{\varphi}_t - 1, 0\}$. Aggregating over φ gives: $v_t = \pi_{R,t}\theta_R v_{t+dt}dt + v_{t+dt}/(1 + r_t \cdot dt)$, where $\pi_{R,t} \equiv \int_{\varphi_{min}}^{\infty} \pi_{R,\varphi,t} dF(\varphi) = \int_{\underline{\varphi}_t}^{\infty} (\varphi/\underline{\varphi}_t - 1)dF(\varphi)$. Taking the limit of $dt \to 0$, we derive the equilibrium condition for the expected value of R&D project as

$$r_t v_t = \pi_{R,t}\theta_R v_t + \dot{v}_t. \tag{17}$$

Furthermore, aggregating (16) over φ and taking the limit as $dt \to 0$ yields:

$$I_{R,t} = \int_{\varphi_{min}}^{\infty} I_{R,\varphi,t} dF(\varphi) = \theta_R v_t \left[1 - F(\underline{\varphi}_t)\right]. \tag{18}$$

Similarly, substituting (16) into (9) and taking the limit as $dt \to 0$, we obtain

$$\dot{n}_t = n_t \frac{E\theta_R v_t}{Y_t} \int_{\underline{\varphi}_t}^{\infty} \varphi dF(\varphi). \tag{19}$$

Combining (18) and (19), we derive:

$$\frac{\dot{n}_t}{n_t} = E\Gamma(\underline{\varphi}_t)\frac{I_{R,t}}{Y_t} \equiv g_{n,t}, \tag{20}$$

where $\Gamma(\underline{\varphi}_t) \equiv \int_{\underline{\varphi}_t}^{\infty} \varphi dF(\varphi)/[1 - F(\underline{\varphi}_t)]$ and $\Gamma'(\underline{\varphi}_t) > 0$. $\Gamma(\underline{\varphi}_t)$ denotes the average productivity of active agents (entrepreneurs), representing the aggregate productivity of R&D. A higher threshold $\underline{\varphi}_t$ leads to higher aggregate R&D productivity. Hereafter, let $g_{n,t}$ denote the growth rate of intermediate goods varieties. From (20), the ratio of R&D investment to output is given by $I_{R,t}/Y_t = g_{n,t}/[E\Gamma(\underline{\varphi}_t)]$.

2.4 Government

Since the government cannot use lump-sum taxation, it finances its spending through distortionary taxes on labor income, consumption, and corporate profits. The government's balanced budget constraint is given by:

$$G_t = \tau_w l_t L + \tau_c c_t L + \tau_{\pi,t}\pi_{x,t} n_t, \tag{21}$$

where G_t denotes total government spending. We assume that government spending is a fixed share of final output: $G_t = \zeta Y_t$, with ζ representing the government's spending-to-output ratio. Following Aghion et al. (2013) and Iwaisako (2016), equation (21) abstracts from government debt to focus on the optimal mix of corporate income and consumption taxes. In the analysis that follows, we assume the government adjusts $\tau_{\pi,t}$ to satisfy the budget constraint.

2.5 Equilibrium Conditions

The credit market equilibrium condition is given by $B_t = 0$, reflecting the assumption of a closed economy with zero net bond supply. Labor market equilibrium is defined as $Ll_t = l_{x,t}$. The final goods market clears according to: $Y_t = c_t L + I_{R,t} + G_t$. By substituting (20) and the government spending identity $G_t = \zeta Y_t$ into the goods market clearing condition, the aggregate consumption-output ratio can be expressed as a function of $g_{n,t}$ and $\underline{\varphi}_t$:

$$\frac{c_t L}{Y_t} = 1 - \zeta - \frac{g_{n,t}}{E\Gamma(\underline{\varphi}_t)}. \tag{22}$$

Furthermore, by substituting equations (7), (22), and $Ll_t = l_{x,t}$ into (14), labor supply can also be expressed as a function of $g_{n,t}$ and $\underline{\varphi}_t$:

$$l_t = \frac{\bar{l}}{1 + \frac{1+\tau_c}{1-\tau_w}\mu\eta\left[1 - \zeta - \frac{g_{n,t}}{E\Gamma(\underline{\varphi}_t)}\right]}. \tag{23}$$

We will use these two equations to rigorously analyze the properties of equilibrium in subsequent sections.

Finally, by substituting equations (4), (7), (22), and $Ll_t = l_{x,t}$ into (21), the equilibrium corporate tax rate $\tau_{\pi,t}$ can also be expressed as a function of $g_{n,t}$ and $\underline{\varphi}_t$:

$$\tau_{\pi,t} = \frac{\mu}{\mu - 1}\left\{\zeta - \frac{\tau_w}{\mu} - \tau_c\left[1 - \zeta - \frac{g_{n,t}}{E\Gamma(\underline{\varphi}_t)}\right]\right\}. \tag{24}$$

From (24), abstracting from other factors, a higher government spending share of final output ζ increases the equilibrium corporate tax rate, whereas a higher wage tax τ_w and a higher consumption tax τ_c reduce it. The equilibrium value of $\tau_{\pi,t}$ may become negative if the wage tax rate τ_w and the consumption tax rate τ_c are sufficiently high.

3 Steady-State Equilibrium

This section derives the steady-state equilibrium in which both $g_{n,t}$ and $\underline{\varphi}_t$ remain constant over time. We define $Q_t \equiv (A_t n_t^{\phi})/(q_t n_t)$ and $V_t \equiv (A_t n_t^{\phi})/v_t$. At the steady-state equilibrium, both Q_t and V_t become constant. In the following discussion, we omit the time index t from the variables that are constant overtime in the steady state. Given the assumption that the distribution of φ follows a Pareto distribution, $F(\varphi) = 1 - (\varphi_{min}/\varphi)^a$, where $a > 1$ and $\varphi_{min} > 0$, the steady-state values of g_n and $\underline{\varphi}$ are determined by

$$g_n = \frac{\frac{\theta_R}{a-1}\left(\frac{\varphi_{min}}{\underline{\varphi}}\right)^a - (\sigma - 1)g_A - \rho}{(\sigma - 1)\phi} \equiv \Lambda(\underline{\varphi}; \theta_R), \tag{25}$$

$$g_n = \frac{\left[(1 + \tau_c)(1 - \zeta) - \frac{1-\tau_w}{\mu}\right] E\underline{\varphi} - (\sigma - 1)g_A - \rho}{(\sigma - 1)\phi + \frac{1}{a} + (1 + \tau_c)\left(1 - \frac{1}{a}\right)} \equiv \Omega(\underline{\varphi}; \tau_c). \tag{26}$$

Appendix B derives these two equations.

[Figure 4 about here.]

Using equations (25) and (26), as shown in Figure 4, we obtain the steady-state equilibrium values of g_n^* and $\underline{\varphi}^*$. From (25), $\Lambda(\underline{\varphi};\theta_R)$ is a decreasing function of $\underline{\varphi}$ and equals zero when $\underline{\varphi} = \underline{\varphi}_a(\theta_R)$, where $\underline{\varphi}_a(\theta_R) \equiv \{\frac{\theta_R}{(a-1)[(\sigma-1)g_A+\rho]}\}^{1/a}\varphi_{min}$. Moreover, since $\partial\Lambda(\underline{\varphi};\theta_R)/\partial\theta_R > 0$, it follows that $\underline{\varphi}_a'(\theta_R) > 0$ and $\lim_{\theta_R\to\infty}\underline{\varphi}_a(\theta_R) = \infty$. Similarly, from (26), $\Omega(\underline{\varphi};\tau_c)$ is a increasing function of $\underline{\varphi}$ and equals to zero when $\underline{\varphi} = \underline{\varphi}_b(\tau_c)$, where $\underline{\varphi}_b(\tau_c) \equiv \frac{(\sigma-1)g_A+\rho}{[(1+\tau_c)(1-\zeta)-\frac{1-\tau_w}{\mu}]E}$. As shown in Appendix C, since $\partial\Omega(\underline{\varphi};\tau_c)/\partial\tau_c > 0$, it follows that $\underline{\varphi}_b'(\tau_c) < 0$ and $\lim_{\tau_c\to\infty}\underline{\varphi}_b(\tau_c) = 0$. In the following analysis, we focus on the case where the steady-state equilibrium values of g_n^* is non-negative. As suggested by Figure 4, a non-negative steady-state growth rate $g_n^* \geq 0$ is achieved only if the condition $\underline{\varphi}_b(\tau_c) \leq \underline{\varphi}_a(\theta_R)$ holds. More precisely, we impose the following parameter restrictions.

Assumption 1 .

(1). $1 - \frac{1}{\mu}\frac{1-\tau_w}{1+\tau_c} > \zeta$,

(2). $\varphi_{min} < \underline{\varphi}_b(\tau_c)$,

(3). $\left[\frac{\underline{\varphi}_b(\tau_c)}{\varphi_{min}}\right]^a (a-1)[(\sigma-1)g_A+\rho] \leq \theta_R$,

Assumptions 1.1 and 1.2 ensure the existence of a parameter region in which the condition $\Omega(\underline{\varphi};\tau_c) > 0$ holds. Assumption 1.1 requires a sufficiently small value for the government's spending-to-output ratio ζ, while Assumption 1.2 requires either a relatively low level of social productivity of R&D (E) or a high exogenous productivity growth rate g_A. Furthermore, Assumption 1.3 reformulates the condition $\underline{\varphi}_b(\tau_c) \leq \underline{\varphi}_a(\theta_R)$ in terms of θ_R. For later use, we define $\underline{\theta_R}(\tau_c)$ as the value of θ_R that satisfies $\underline{\theta}_R(\tau_c) = [\underline{\varphi}_b(\tau_c)/\varphi_{min}]^a(a-1)[(\sigma-1)g_A+\rho]$, where the steady-state equilibrium values of g_n^* becomes zero. Since $\underline{\varphi}_b'(\tau_c) < 0$, it follows that $\underline{\theta_R}'(\tau_c) < 0$. Given these Assumptions, Appendix D proves the following proposition.

Proposition 1 . *Suppose that $\sigma > 1$ and that φ follows a Pareto distribution. Under the Assumption 1, there exists a unique $\underline{\theta_R}(\tau_c)$ that satisfies $\underline{\varphi}_b(\tau_c) = \underline{\varphi}_a(\underline{\theta_R}(\tau_c))$ given $\tau_c \geq 0$. If θ_R is larger than $\underline{\theta_R}(\tau_c)$, there exists a unique steady-state equilibrium, where $g_n^* \geq 0$ holds and we have*

(1). $\frac{\partial g_n^*}{\partial\theta_R} > 0$, $\frac{\partial\underline{\varphi}^*}{\partial\theta_R} > 0$, $\lim_{\theta_R\to\underline{\theta_R}(\tau_c)} g_n^* = 0$ *and* $\lim_{\theta_R\to\underline{\theta_R}(\tau_c)} \underline{\varphi}^* = \underline{\varphi}_b(\tau_c)$,

(2). $\frac{\partial g_n^*}{\partial\tau_c} > 0$ *and* $\frac{\partial\underline{\varphi}^*}{\partial\tau_c} < 0$,

(3). $\frac{\partial\Gamma(\underline{\varphi}^*)}{\partial\tau_c} < 0$ *and* $\frac{\partial\Gamma(\underline{\varphi}^*)}{\partial\theta_R} > 0$.

If the financial constraint is not too severe (i.e., $\theta_R > \underline{\theta_R}(\tau_c)$), entrepreneurs have sufficient incentives to engage in R&D, thereby sustaining positive variety growth. As summarized in Proposition 1.1, when θ_R is larger, entrepreneurs with higher productivity levels borrow and invest more in their R&D projects, whereas those with lower productivity levels may choose not to invest. These factors enhance the aggregate productivity of R&D and increase the variety growth rate g_n^*.

Additionally, as outlined in Proposition 1.2, an increase in the consumption tax rate raises the variety growth rate, but also leads to the entry of entrepreneurs with lower productivity into R&D activities. A higher consumption tax allows the government to reduce the corporate income tax, which increases the profits of intermediate goods firms and uniformly enhances the value of all entrepreneurs' R&D projects. As a result, overall investment in R&D increases, positively influencing the variety growth rate g_n^*, while also encouraging the participation from less productive entrepreneurs.

Consequently, as stated in Proposition 1.3, the impact on the average productivity level of active entrepreneurs engaged in R&D (i.e., $\Gamma(\underline{\varphi}^*)$) differs significantly between an increase in θ_R and an increase in τ_c. While a rise in θ_R leads to an increase in $\Gamma(\underline{\varphi}^*)$, a rise in the consumption tax rate τ_c results in a decrease in $\Gamma(\underline{\varphi}^*)$.

4 Welfare analysis of taxation

This section examines the welfare-maximizing tax rates on corporate income and consumption under a balanced budget constraint, assuming that the labor income tax rate remains constant. Welfare is derived as a function of the consumption tax rate, since the corporate income tax rate is endogenously determined by the consumption tax rate through the balanced budget condition.

From (6) and the condition $Ll_t = l_{x,t}$, the equilibrium output growth rate, g_Y^* is given by $g_Y^* = g_A + \phi g_n^*$. Given this relationship, Appendix E shows that the lifetime utility of a representative household per agent is given by:

$$U = \frac{U_0}{L} = \frac{[c_0(\bar{l} - l_0)^\eta]^{1-\sigma}}{1-\sigma} \frac{1}{\rho + (\sigma - 1)g_Y^*}, \tag{27}$$

where

$$c_0 \equiv A_0 N_0^\phi \frac{\left[1 - \zeta - \frac{g_n^*}{E\Gamma(\underline{\varphi}^*)}\right] \bar{l}}{1 + \frac{1+\tau_c}{1-\tau_w}\mu\eta \left[1 - \zeta - \frac{g_n^*}{E\Gamma(\underline{\varphi}^*)}\right]},$$

$$\bar{l} - l_0 = \frac{\frac{1+\tau_c}{1-\tau_w}\mu\eta \left[1 - \zeta - \frac{g_n^*}{E\Gamma(\underline{\varphi}^*)}\right]}{1 + \frac{1+\tau_c}{1-\tau_w}\mu\eta \left[1 - \zeta - \frac{g_n^*}{E\Gamma(\underline{\varphi}^*)}\right]} \bar{l}.$$

Here, A_0 and N_0 are initial value of A_t and N_t, respectively. By differentiating U with respect to τ_c, we obtain

$$\text{sign}\left\{\frac{dU}{d\tau_c}\right\} = \underbrace{\frac{\partial U}{\partial \tau_c}}_{(<0)} + \underbrace{\frac{\partial U}{\partial \Gamma(\underline{\varphi}^*)}}_{(>0)} \underbrace{\frac{\partial \Gamma(\underline{\varphi}^*)}{\partial \underline{\varphi}^*}}_{(>0)} \underbrace{\frac{\partial \underline{\varphi}^*}{\partial \tau_c}}_{(<0)} + \frac{\partial U}{\partial g_n^*} \underbrace{\frac{\partial g_n^*}{\partial \tau_c}}_{(>0)}, \tag{28}$$

$$\frac{1}{\tilde{U}} \frac{\partial U}{\partial \tau_c} = -\frac{\eta\mu}{(1-\tau_w)(1+\tau_c)} \frac{(1+\tau_c)\left[1 - \zeta - \frac{g_n^*}{E\Gamma(\underline{\varphi}^*)}\right] - \frac{1-\tau_w}{\mu}}{1 + \frac{1+\tau_c}{1-\tau_w}\mu\eta\left[1 - \zeta - \frac{g_n*}{E\Gamma(\underline{\varphi}^*)}\right]} < 0, \tag{29}$$

$$\frac{1}{\tilde{U}} \frac{\partial U}{\partial \Gamma(\underline{\varphi}^*)} = \frac{(1+\eta)\frac{g_n^*}{E}\frac{1}{\Gamma(\underline{\varphi}^*)^2}}{\left[1 - \zeta - \frac{g_n^*}{E\Gamma(\underline{\varphi}^*)}\right]\left\{1 + \frac{1+\tau_c}{1-\tau_w}\mu\eta\left[1 - \zeta - \frac{g_n^*}{E\Gamma(\underline{\varphi}^*)}\right]\right\}} > 0, \tag{30}$$

$$\frac{1}{\tilde{U}} \frac{\partial U}{\partial g_n^*} = \frac{\phi}{\rho + (\sigma-1)g_Y^*} - \frac{\frac{1+\eta}{E\Gamma(\underline{\varphi}^*)}}{\left[1 - \zeta - \frac{g_n^*}{E\Gamma(\underline{\varphi}^*)}\right]\left\{1 + \frac{1+\tau_c}{1-\tau_w}\mu\eta\left[1 - \zeta - \frac{g_n^*}{E\Gamma(\underline{\varphi}^*)}\right]\right\}}, \tag{31}$$

where $\tilde{U} \equiv (1-\sigma)U > 0$. Appendix F provides a more detailed derivation of (28) and a thorough explanation of the sign condition $\frac{1}{\tilde{U}}\frac{\partial U}{\partial \tau_c} < 0$ in (29).[10]

The consumption tax influences welfare through three key mechanisms. First, it directly affects the labor-leisure trade-off, as reflected in the first term of (28). Second, it alters the allocation of R&D investment across entrepreneurs with heterogeneous productivity levels via its impact on the average productivity of active entrepreneurs, $\Gamma(\underline{\varphi}^*)$, as captured by the second term. Third, it indirectly shapes the intertemporal allocation of resources between current production and R&D investment through its effect on the variety growth rate g_n^*, which corresponds to the third term.

Abstracting from other factors, an increase in the consumption tax reduces labor supply and distorts the labor-leisure choice, thereby negatively affecting welfare through the first channel. Furthermore, as shown in Proposition 1.2, a higher consumption tax encourages entry by entrepreneurs with lower productivity into R&D activities, reducing the average productivity of active entrepreneurs. Consequently, welfare is also negatively affected through the second channel. However, with respect to the third channel—the intertemporal allocation of resources between current production and R&D investment—the welfare effect of a consumption tax increase is inherently ambiguous. As explained in (9), intertemporal knowledge spillovers imply that the accumulation of past R&D investment determines the current social productivity of R&D. The magnitude of this externality depends on the parameter ϕ and contributes to underinvestment in R&D. While credit constraints exacerbate this underinvestment, they also influence the average productivity of R&D investment. Therefore, when θ_R is sufficiently large and financial constraints are mild, raising the consumption tax while reducing the corporate income tax can help correct underinvestment in R&D and potentially improve overall welfare. Conversely, when θ_R is sufficiently small and financial constraints are severe, the average productivity of R&D investment may be too low for a consumption tax increase to enhance welfare through this channel. In this case, we establish the following proposition.

Proposition 2 . *Suppose that Proposition 1 holds and the following inequality holds:*

$$E\Gamma(\underline{\varphi}_b(0)) < \frac{\rho+(\sigma-1)g_A}{\phi}\frac{1+\eta}{(1-\zeta)\left[1+\frac{\mu\eta}{1-\tau_w}(1-\zeta)\right]}, \tag{32}$$

and $\tau_c = 0$. If θ_R is sufficiently close to $\underline{\theta_R}(0)$, we have $\frac{dU}{d\tau_c}\mid_{\tau_c=0} < 0$

The condition in (32) ensures that the relation $\frac{1}{\tilde{U}}\frac{\partial U}{\partial g_n^*} < 0$ in (31) holds when $\theta_R \approx \underline{\theta_R}(0)$ and $\tau_c = g_n^* = 0$. Furthermore, Appendix G demonstrates that condition (32) is satisfied when θ_R is sufficiently small. These results suggest that, for sufficiently low values of θ_R, the third channel—the intertemporal allocation of resources between current production and R&D investment—also exerts a negative effect on welfare. Consequently, introducing a consumption tax, coupled with a reduction in the corporate income tax, results in a deterioration of welfare.

The intuition behind this result is as follows. When financial constraints are severe, entrepreneurs with low productivity engage in R&D, leading to low aggregate productivity of R&D activities. Under these conditions, an increase in the consumption tax rate

[10] Using (7), (22) and the identity $Ll_t = l_{x,t}$, note that the expression $\frac{1}{\tilde{U}}\frac{\partial U}{\partial \tau_c}$ can be rewritten as: $\frac{1}{\tilde{U}}\frac{\partial U}{\partial \tau_c} = -\frac{\eta\mu L}{(1-\tau_w)(1+\tau_c)Y_t}\frac{(1+\tau_c)c_t-(1-\tau_w)w_t}{1+\frac{1+\tau_c}{1-\tau_w}\mu\eta\left[1-\zeta-\frac{g_n{}^*}{E\Gamma(\underline{\varphi}^*)}\right]}$. Hence, the condition $\frac{1}{\tilde{U}}\frac{\partial U}{\partial \tau_c} < 0$ implies that $(1+\tau_c)c_t > (1-\tau_w)w_t$.

reallocates resources from current production toward R&D investment, which may further reduce welfare. Thus, introducing a consumption tax is not optimal in an economy characterized by severe financial frictions and heterogeneity in R&D productivity.

Before proceeding to the numerical analysis in the next chapter—where θ_R is sufficiently high and financial constraints are relatively mild—the remainder of this section focuses on examining the characteristics of the third channel, namely the intertemporal allocation of resources between current production and R&D investment, by analyzing a special case with exogenous labor supply (i.e., $\eta = 0$) and log utility (i.e., $\sigma = 1$).

When $\eta = 0$, the first channel—the labor-leisure trade-off— disappears due to the assumption of exogenous labor supply. Furthermore, when $\sigma = 1$, the equilibrium value of $\underline{\varphi}^*$ is solely determined by (25) as $\underline{\varphi}^*(\theta_R) = [\frac{\theta_R}{\rho(a-1)}]^{\frac{1}{a}}\varphi_{min}$, which is independent of the value of τ_c. As a result, the second channel—the allocation of R&D investment across heterogeneous entrepreneurs— also vanishes. Consequently, only the third channel remains, and the welfare effect of a consumption tax increase is characterized by the following equation:

$$\frac{1}{\rho}\frac{dU}{d\tau_c} = \frac{\phi\left[(1-\zeta)\Gamma(\underline{\varphi}^*(\theta_R)) - \frac{\rho}{\phi} - g_n^*\right]}{\rho E\Gamma(\underline{\varphi}^*(\theta_R))\left[1-\zeta-\frac{g_n^*}{E\Gamma(\underline{\varphi}^*(\theta_R))}\right]}\underbrace{\frac{\partial g_n^*}{\partial \tau_c}}_{(>0)}, \tag{33}$$

where $\Gamma(\underline{\varphi}^*(\theta_R)) = \frac{a}{a-1}\underline{\varphi}^*(\theta_R)$ and $g_n^* = \Omega(\underline{\varphi}^*(\theta_R);\tau_c)$. Hence, the sign of $dU/d\tau_c$ depends solely on the sign of $(1-\zeta)\Gamma(\underline{\varphi}^*(\theta_R)) - \rho/\phi - g_n^*$, which can be expressed as:

$$\text{sign}\left\{\frac{dU}{d\tau_c}\right\} = \text{sign}\left\{\Upsilon\left(\underline{\varphi}^*(\theta_R),\tau_c\right)\right\}, \tag{34}$$

where

$$\Upsilon\left(\underline{\varphi}^*(\theta_R),\tau_c\right) \equiv (1-\zeta)E\frac{a}{a-1}\underline{\varphi}^*(\theta_R) - \frac{\rho}{\phi} - \Omega(\underline{\varphi}^*(\theta_R);\tau_c).$$

Note that $\Upsilon\left(\underline{\varphi}^*(\theta_R),\tau_c\right)$ satisfies the following properties:

- $\frac{\partial\Upsilon\left(\underline{\varphi}^*(\theta_R),\tau_c\right)}{\partial\tau_c} = -\frac{\partial\Omega(\underline{\varphi}^*(\theta_R);\tau_c)}{\partial\tau_c} < 0,$
- $\Upsilon\left(\underline{\varphi}^*(\theta_R),0\right) = E\underline{\varphi}^*(\theta_R)\left(\frac{1-\zeta}{a-1}+\frac{1-\tau_w}{\mu}\right)+\frac{\phi-1}{\phi}\rho > 0,$
- $\lim_{\tau_c\to\infty}\Upsilon\left(\underline{\varphi}^*(\theta_R),\tau_c\right) = -\frac{\rho}{\phi}.$

From (34), these properties of $\Upsilon\left(\underline{\varphi}^*(\theta_R),\tau_c\right)$ imply the existence of a unique tax rate τ_c^* such that $dU/d\tau_c = 0$ when $\tau_c = \tau_c^*$, $dU/d\tau_c > 0$ for $\tau_c < \tau_c^*$, and $dU/d\tau_c < 0$ for $\tau_c > \tau_c^*$. This confirms a hump-shaped relationship between the consumption tax rate and welfare, with an interior optimum τ_c^* that maximizes welfare. Furthermore, as shown in Appendix H, since the relation $\partial\Upsilon\left(\underline{\varphi}^*(\theta_R),\tau_c\right)/\partial\varphi^*(\theta_R) > 0$ holds, with noting $\Upsilon\left(\underline{\varphi}^*(\theta_R),\tau_c^*\right) = 0$, we can confirm the following property:

$$\frac{d\tau_c^*}{d\theta_R} = -\frac{\frac{\partial\Upsilon\left(\underline{\varphi}^*(\theta_R),\tau_c\right)}{\partial\varphi^*(\theta_R)}\frac{\partial\varphi^*(\theta_R)}{\partial\theta_R}}{\frac{\partial\Upsilon\left(\underline{\varphi}^*(\theta_R),\tau_c\right)}{\partial\tau_c}} > 0. \tag{35}$$

The optimal consumption tax rate τ_c^* that maximizes welfare increases as financial constraints become less binding. Intuitively, when financial constraints are relaxed, only highly productive entrepreneurs engage in R&D investment, thereby raising the average productivity of R&D activities. Consequently, reallocating resources away from current production toward R&D—by increasing the consumption tax and reducing the corporate tax—has greater potential to improve welfare. Thus, the welfare-maximizing consumption tax rate τ_c^* also rises. Based on this discussion, we establish the following proposition:

Proposition 3 . *In the special case of exogenous labor supply (i.e., $\eta = 0$) and log utility (i.e., $\sigma = 1$), the relationship between the consumption tax rate and welfare is hump-shaped, with an interior optimum rate τ_c^* that maximizes welfare. Furthermore, τ_c^* rises as financial constraints become less binding.*

5 Numerical Analysis

Section 4 focuses on two cases: one with extremely severe financial frictions, and another with exogenous labor supply (i.e., $\eta = 0$) and log utility (i.e., $\sigma = 1$). The numerical analysis in this section examines the optimal consumption tax rate under mild and plausible levels of financial frictions. The objective is not to determine the precise value of the optimal consumption tax rate, as the model is too stylized to allow for such identification. Instead, the analysis emphasizes the qualitative effects of financial frictions on the optimal consumption tax rate.

5.1 Model Parameterization

We set the discount rate to $\rho = 0.05$ and normalize the initial levels of technology and the number of intermediate goods to $A_0 = 1$ and $N_0 = 1$, respectively. The inverse of the intertemporal elasticity of substitution is set to $\gamma = 2$, implying an elasticity of 0.5, which aligns with values commonly used in the business cycle literature. The patent breadth parameter is set to $\mu = 1.3$, yielding a markup consistent with the estimates provided by Britton et al. (2000) and Gali et al. (2007). Based on World Development Indicators (2025), the average share of government consumption in the United States GDP during 2000-2024 is 14.8%. Accordingly, we set the government spending-to-output ratio to $\zeta = 0.15$.

The parameter ϕ captures the return to specialization. Its closest empirical counterpart is the "elasticity of productivity with respect to variety" estimated by Broda et al. (2006), which ranges from 0.05 to 0.2. However, these estimates—derived from international trade data—do not fully align with the concept of specialization returns as defined in this paper. Following Brunnschweiler et al. (2021), we adopt a conservative approach and set the baseline value of ϕ at the lower end of the empirical range, $\phi = 0.05$.

Given that the long-run growth rate of per capita GDP in the United States is approximately 2%, we calibrate the model parameters such that $g_Y = g_A + \phi g_n = 0.02$. Comin (2004) suggests that only about 0.2% of this growth may be attributable to R&D investment, while Chu (2010) estimates that domestic R&D accounts for roughly 0.8%. As a benchmark, following Hori (2020), we take the average of these two estimates and assume that R&D investment contributes 0.5% to growth, i.e., $\phi g_n = 0.005$. Accordingly, we set $g_A = 0.015$. Given $\phi = 0.05$, this implies $g_n = 0.005/0.05 = 0.1$.

According to the OECD Main Science and Technology Indicators (2025), R&D expenditure as a share of GDP in 2020 was 2.70% for the OECD average, 3.42% for the

United States, and 5.83% for Israel. Based on these figures, we assume in the benchmark that $I_R/Y = 0.05$. From (20), since $E\Gamma(\underline{\varphi}) = g_n/(\frac{I_R}{Y})$, these assumptions imply $E\Gamma(\underline{\varphi}) = 0.1/0.05 = 2$.

We normalize the labor supply, denoted by l to 1, and set the time endowment $\bar{l}$ such that the ratio $l/\bar{l} = 0.33$, reflecting the average share of time spent working in the United States. Given the benchmark values for the wage tax rate $\tau_w = 0$ and the consumption tax rate $\tau_c = 0.1$, we use (23) to calibrate the leisure preference parameter η so that $\eta = \frac{1-\frac{l}{\bar{l}}}{\frac{l}{\bar{l}}} \frac{1}{\frac{1+\tau_c}{1-\tau_w}\mu\left(1-\zeta-\frac{I_R}{Y}\right)} \approx 1.7747$. The consumption tax rate τ_c is also varied from 0 to 0.3 to examine the optimal consumption tax rate.

Equations (25) and (26) characterize the equilibrium values of $\underline{\varphi}$ and g_n. Following Hori (2020), we use these equations to obtain information on parameter values related to the Pareto distribution of R&D technology productivity (a, φ_{min}), the degree of credit constraint (θ_R), and the social productivity of R&D investment (E). Let us first define $\Theta_R \equiv \theta_R(E\varphi_{min})^a$. In the following numerical simulation, we use Θ_R as a measure of the sensitivity of financial frictions, instead of θ_R. Using Θ_R, (25) can be written as

$$g_n = \frac{\frac{\Theta_R}{(a-1)(E\underline{\varphi})^a} - (\sigma-1)g_A - \rho}{(\sigma-1)\phi} \equiv \Lambda(E\underline{\varphi};\Theta_R), \tag{36}$$

where we treat $E\underline{\varphi}$ as endogenous variable rather than $\underline{\varphi}$.

Moreover, since $\Gamma(\underline{\varphi}) = \frac{a}{a-1}\underline{\varphi}$, (26) can be written as

$$g_n = \frac{\left[(1+\tau_c)(1-\zeta) - \frac{1-\tau_w}{\mu}\right]E\underline{\varphi} - (\sigma-1)g_A - \rho}{(\sigma-1)\phi + 1 + \tau_c\frac{E\underline{\varphi}}{E\Gamma(\underline{\varphi})}} \equiv \Omega(E\underline{\varphi};\tau_c). \tag{37}$$

Accordingly, equations (36) and (37) jointly determine the equilibrium values of $E\underline{\varphi}$ and g_n, which are reported in the subsequent numerical analysis. Given the benchmark values of τ_c, τ_w, ζ, μ, σ and ϕ and the assumptions for g_A, g_n, $E\Gamma(\underline{\varphi})$, (37) determines the value of $E\underline{\varphi}$. Then, we use $\Gamma(\underline{\varphi}) = \frac{a}{a-1}\underline{\varphi}$ and the assumption of $E\Gamma(\underline{\varphi})$ to determine the value of a. Finally, we use (36) to determine the value of Θ_R. Under the benchmark assumption, we get $E\underline{\varphi} \approx 1.0574$, $a \approx 2.1218$, and $\Theta_R \approx 0.0884$.

5.2 Numerical Results

Figures 5-a to 5-f illustrate how key variables respond to changes in the consumption tax rate τ_c (ranging from 0 to 0.3) under different levels of financial restriction Θ_R. Specifically, the panels show: the R&D productivity threshold $E\underline{\varphi}$ (Figure 5-a), output growth rate g_Y (Figure 5-b), labor supply per agent l (Figure 5-c), initial consumption c_0 (Figure 5-d), corporate income tax rate τ_π (Figure 5-e) and welfare U (Figure 5-f). Welfare gains in Figure 5-f are expressed in terms of consumption, using the equilibrium under $\tau_c = 0$ as a reference point.[11] Solid lines represent the benchmark case ($\Theta_R = 0.0884$), while dashed and dash-dotted lines correspond to $\Theta_R = 0.0707$ (80% of benchmark) and $\Theta_R = 0.1061$ (120% of benchmark), respectively.

[Figure 5 about here.]

[11] Welfare gains are computed as follows: for each τ_c, calculate U_{τ_c}. Then, holding g_Y and l at their levels under $\tau_c = 0$, determine the initial consumption c_{τ_c} that yields the same welfare as U_{τ_c}. The percentage difference between c_0 and c_{τ_c} is then reported.

Consistent with Proposition 1, a higher consumption tax rate τ_c and the associated decline in the corporate tax rate τ_π reduce the R&D productivity threshold $E\underline{\varphi}$ and increase the output growth rate g_Y. These changes also lower labor supply l by reducing the opportunity cost of leisure and decrease initial consumption c_0 through intertemporal resource reallocation. Consequently, the relationship between τ_c and welfare U is hump-shaped: on one hand, a higher τ_c reduces welfare by diverting resources from current production, increasing entry of low-productivity entrepreneurs into R&D, and distorting labor-leisure choices; on the other hand, it improves welfare by stimulating R&D activity and mitigating distortions from intertemporal knowledge spillovers. Under the benchmark parameter values, the third channel—the intertemporal allocation of resources between current production and R&D investment—plays a significant role, yielding welfare effects of a consumption tax similar to those obtained in Section 3 under exogenous labor supply (i.e., $\eta = 0$) and log utility (i.e., $\sigma = 1$).

Figures 5-a to 5-f also show that, consistent with Proposition 1, for a given value of τ_c, relaxing the credit constraint Θ_R from 0.0707 to 0.1061 increases both the R&D productivity threshold $E\underline{\varphi}$ and the output growth rate g_Y. These changes positively affect labor supply l, while slightly reducing initial consumption c_0 through intertemporal resource reallocation. Furthermore, as shown in Figure 2-f, the optimal consumption tax rate τ_c^* that maximizes welfare rises with Θ_R. Table 1 indicates that the τ_c^* increases from 0.06 to 0.16 as Θ_R rises from 0.0707 to 0.1061, while the corresponding optimal corporate tax rate τ_π^* falls from 0.4372 to 0.1121. Thus, once again, under our benchmark parameters, the third channel—the intertemporal allocation of resources between current production and consumption, and investment in R&D—plays a critical role. As indicated by Proposition 3, relaxing the credit constraint Θ_R restricts R&D participation to the high productive entrepreneurs, thereby raising the average efficiency of R&D investment. This mechanism amplifies the welfare gains from reallocating resources away from current production toward R&D investment, as induced by an increase in the consumption tax. As a result, the optimal consumption tax rate tends to be higher, while the corresponding optimal corporate tax rate is lower. Moreover, Figures 2-e and 2-f suggest that if the value of Θ_R is sufficiently large, the optimal corporate tax rate τ_π^* can become negative. Given that our benchmark parameterization assumes a non-negligible intertemporal knowledge spillover effect, such outcomes are entirely predictable.

[Table 1 about here.]

6 Concluding Remarks

This paper investigates whether reducing corporate income tax while increasing consumption tax—subject to government budget constraints—can enhance welfare. Using a variety-expanding growth model with financial frictions and heterogeneous R&D productivity, we analyze welfare-maximizing tax rates and their sensitivity to financial constraints. Our results show that as financial constraints become less binding—reflecting improvements in financial institutions—the optimal corporate income tax rate declines, whereas the optimal consumption tax rate rises. This suggests that when financial constraints are eased, promoting innovation at the expense of current production—by raising the consumption tax and lowering the corporate income tax—improves welfare. These findings underscore the importance of incorporating financial development into the de-sign of tax policies aimed at fostering long-term growth and welfare.

To present our theoretical results clearly, we employ a tractable R&D-based growth model with simplifying assumptions. While these assumptions facilitate intuitive analytical insights, they also entail several limitations. Before concluding, we highlight the key limitations and outline directions for future research. First, in our variety-expansion framework, intertemporal knowledge spillovers create a gap between private and social incentives for R&D, such that raising the consumption tax and reducing the corporate income tax improves welfare. Two additional externalities contribute to this gap: the consumer-surplus effect, which leads to underinvestment because entrepreneurs overlook household benefits from innovation; and the profit-destruction effect, which leads to overinvestment as entrepreneurs pursue private gains without accounting for negative impacts on others. In our CES production function setting, these forces largely offset each other, leaving knowledge spillovers as the primary distortion. A more advanced model could better capture these interactions and deepen our understanding of the relationship between financial development and optimal tax policy.

Second, this study adopts a representative household model in which households and entrepreneurs are integrated, thereby facilitating the separation of entrepreneurial rents from corporate income. Nevertheless, as argued by Hori (2020), modeling entrepreneurs as independent R&D firms or incorporating financial intermediaries would constitute a more natural specification. Moreover, taxation on the corporate income of such independent R&D firms or financial intermediaries may partially include taxes on entrepreneurial rents. Consequently, extending the framework to a more detailed and realistic numerical model that explicitly incorporates financial intermediaries and R&D firms, and conducting a more comprehensive analysis of the relationship between financial development and optimal tax policy, represents a promising direction for future research.

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Appendix A: Utility Maximization of Households

The first-order conditions of the utility maximization of households are given by:

$$c_t\colon\; c_t^{-\sigma}(\bar{l}-l_t)^{\eta(1-\sigma)} = \lambda_{c,t}(1+\tau_c)\,, \tag{A.1}$$

$$l_t\colon\; \eta c_t^{1-\sigma}(\bar{l}-l_t)^{\eta(1-\sigma)-1} = \lambda_{c,t}(1-\tau_w)w_t, \tag{A.2}$$

$$I_{R,\varphi,t}\colon\; I_{R,\varphi,t} \;=\; \begin{cases} 0, & \text{if } \lambda_{n,t}E_t\varphi < \lambda_{c,t}, \\ \theta_R v_{t+dt}, & \text{if } \lambda_{n,t}E_t\varphi \geq \lambda_{c,t}, \end{cases} \tag{A.3}$$

$$B_t\colon\; -\dot{\lambda}_{c,t} + \rho\lambda_{c,t} = \lambda_{c,t}r_t, \tag{A.4}$$

$$n_t\colon\; -\dot{\lambda}_{n,t} + \rho\lambda_{n,t} = \lambda_{n,t}(1-\tau_{\pi,t})\pi_{x,t}. \tag{A.5}$$

Here, $\lambda_{c,t}$ and $\lambda_{n,t}$ are the costate variables associated with the budget constraint (13) and the law of motion for n_t in (9), respectively. Equation (A.3) reflects the incentive constraint implied by (12). The transversality conditions for B_t and n_t are given by $\lim_{t\to\infty}\lambda_{c,t}B_t e^{-\rho t} = 0$ and $\lim_{t\to\infty}\lambda_{n,t}n_t e^{-\rho t} = 0$.

From (A.1) and (A.2), we derive (14). Let us define the following variable: $q_t \equiv \lambda_{n,t}/\lambda_{c,t}$. This variable q_t represents the shadow value of n_t measured in units of final goods (i.e., the value of intermediate goods firm). Differencing q_t with respect to time and rearranging terms using (A.4) and (A.5), we obtain the familiar arbitrage condition given in (5). Moreover, by substituting $q_t \equiv \lambda_{n,t}/\lambda_{c,t}$ and $E_t = E(n_t/Y_t)$ into (A.3), we derive (16).

Appendix B: Derivation of (25) and (26)

From equations (6), (7), and the labor market condition $Ll_t = l_{x,t}$, we derive the growth rates of wages and output as follows: $\dot{w}_t/w_t = g_A + \phi g_{n,t}$, and $\dot{Y}_t/Y_t = g_A + \phi g_{n,t} + \dot{l}_t/l_t$. Furthermore, using (22), the growth rate of consumption is given by:

$$\frac{\dot{c}_t}{c_t} = \frac{\dot{Y}_t}{Y_t} - \frac{\frac{\partial}{\partial t}\left(\frac{g_{n,t}}{E\Gamma(\underline{\varphi}_t)}\right)}{1-\zeta-\frac{g_{n,t}}{E\Gamma(\underline{\varphi}_t)}}.$$

Substituting this expression into the Euler equation (15), and rearranging terms using the identities $\dot{w}_t/w_t = g_A + \phi g_{n,t}$ and $\dot{Y}_t/Y_t = g_A + \phi g_{n,t} + \dot{l}_t/l_t$, we obtain the following expression for the interest rate r_t:

$$r_t = \sigma(g_A + \phi g_{n,t}) + \rho + [\sigma + (\sigma-1)\eta]\left[\frac{\dot{l}_t}{l_t} - \frac{\frac{\partial}{\partial t}\left(\frac{g_{n,t}}{E\Gamma(\underline{\varphi}_t)}\right)}{1-\zeta-\frac{g_{n,t}}{E\Gamma(\underline{\varphi}_t)}}\right]. \tag{A.6}$$

By substituting (4) into (5) and rearranging it using the definition $\underline{\varphi}_t \equiv Y_t/(Eq_t n_t)$, we obtain $\dot{q}_t/q_t = r_t - (1-\tau_{\pi,t})\frac{\mu-1}{\mu}E\underline{\varphi}_t$. Hence, from the definition $Q_t \equiv (A_t n_t^{\phi})/(q_t n_t)$, we derive the following expression for the interest rate:

$$r_t = g_A + (\phi-1)g_{n,t} + (1-\tau_{\pi,t})\frac{\mu-1}{\mu}E\underline{\varphi}_t - \frac{\dot{Q}_t}{Q_t}. \tag{A.7}$$

Similarly, using the definition $V_t \equiv (A_t n_t^{\phi})/v_t$ and (17), we obtain:

$$r_t = g_A + \phi g_{n,t} + \theta_R \int_{\underline{\varphi}_t}^{\infty} (\varphi/\underline{\varphi} - 1) dF(\varphi) - \frac{\dot{V}_t}{V_t}, \tag{A.8}$$

To conduct steady-state analysis, we set $\dot{l}_t = \frac{\partial}{\partial t}\left(\frac{g_{n,t}}{E\Gamma(\underline{\varphi}_t)}\right) = \dot{V}_t = \dot{Q}_t = 0$ in equations (A.6), (A.7) and (A.8).[12] Eliminating r_t from equations (A.6) and (A.8) and rearranging the resulting expression yields:

$$g_n = \frac{\theta_R \int_{\underline{\varphi}_t}^{\infty} (\varphi/\underline{\varphi} - 1) dF(\varphi) - (\sigma - 1) g_A - \rho}{(\sigma - 1)\phi}. \tag{A.9}$$

Given that φ follows a Pareto distribution and the relation $\int_{\underline{\varphi}_t}^{\infty} (\varphi/\underline{\varphi} - 1) dF(\varphi) = \frac{(\varphi_{min}/\underline{\varphi})^a}{a-1}$ holds, we obtain (25).

Similarly, from equations (A.6) and (A.7), we derive:

$$g_n = \frac{\left[(1+\tau_c)(1-\zeta) - \frac{1-\tau_w}{\mu}\right] E\underline{\varphi} - (\sigma - 1) g_A - \rho}{(\sigma - 1)\phi + 1 - \frac{\underline{\varphi}}{\Gamma(\underline{\varphi})} + (1+\tau_c)\frac{\underline{\varphi}}{\Gamma(\underline{\varphi})}}. \tag{A.10}$$

Since $\Gamma(\underline{\varphi}) = \frac{a}{a-1}\underline{\varphi}$ holds under the Pareto distribution, we obtain (26).

Appendix C: The property of (26)

$$\frac{\partial \Omega(\underline{\varphi}; \tau_c)}{\partial \tau_c} = \frac{E\underline{\varphi}\left\{(1-\zeta)\left[(\sigma-1)\phi + \frac{1}{a}\right] + \left(1 - \frac{1}{a}\right)\frac{1-\tau_w}{\mu}\right\} + \left(1 - \frac{1}{a}\right)\left[(\sigma - 1) g_A + \rho\right]}{\left[(\sigma-1)\phi + \frac{1}{a} + (1+\tau_c)\left(1 - \frac{1}{a}\right)\right]^2} > 0.$$

Appendix D: Proof of Proposition 1

Here, we express the equilibrium values of $\underline{\varphi}^*$ and g_n^* as $\underline{\varphi}^*(\theta_R, \tau_c)$ and $g_n^*(\theta_R, \tau_c)$, respectively. By differentiating equations (25) and (26) with respect to θ_R and τ_c, we obtain:

$$\frac{\partial \underline{\varphi}^*(\theta_R, \tau_c)}{\partial \theta_R} = \frac{\frac{\partial \Lambda(\underline{\varphi}^*; \theta_R)}{\partial \theta_R}}{\frac{\partial \Omega(\underline{\varphi}^*; \tau_c)}{\partial \underline{\varphi}} - \frac{\partial \Lambda(\underline{\varphi}^*; \theta_R)}{\partial \underline{\varphi}}} > 0,$$

$$\frac{\partial \underline{\varphi}^*(\theta_R, \tau_c)}{\partial \tau_c} = -\frac{\frac{\partial \Omega(\underline{\varphi}^*; \tau_c)}{\partial \tau_c}}{\frac{\partial \Omega(\underline{\varphi}^*; \tau_c)}{\partial \underline{\varphi}} - \frac{\partial \Lambda(\underline{\varphi}^*; \theta_R)}{\partial \underline{\varphi}}} < 0.$$

Furthermore, from equations (25) and (26), we have $g_n^*(\theta_R, \tau_c) = \Lambda(\underline{\varphi}^*(\theta_R, \tau_c); \theta_R) = \Omega(\underline{\varphi}^*(\theta_R, \tau_c); \tau_c)$. Differentiating these expressions with respect to θ_R and τ_c yields:

$$\frac{\partial g_n^*(\theta_R, \tau_c)}{\partial \theta_R} = \underbrace{\frac{\partial \Omega(\underline{\varphi}^*(\theta_R, \tau_c); \tau_c)}{\partial \underline{\varphi}^*(\theta_R, \tau_c)}}_{(>0)} \underbrace{\frac{\partial \underline{\varphi}^*(\theta_R, \tau_c)}{\partial \theta_R}}_{(>0)} > 0,$$

[12] Note that $\underline{\varphi}_t$ can be expressed as a function of Q_t and l_t. By substituting (6) and the condition $Ll_t = l_{x,t}$ into the definition $\underline{\varphi}_t \equiv Y_t/(Eq_t n_t)$, and rearranging using the definition of Q_t, we obtain: $\underline{\varphi}_t = (Q_t L l_t)/E$.

$$\frac{\partial g_n^*(\theta_R,\tau_c)}{\partial \tau_c} = \underbrace{\frac{\partial \Lambda(\underline{\varphi}^*(\theta_R,\tau_c);\theta_R)}{\partial \underline{\varphi}^*(\theta_R,\tau_c)}}_{(<0)} \underbrace{\frac{\partial \underline{\varphi}^*(\theta_R,\tau_c)}{\partial \tau_c}}_{(<0)} > 0.$$

Finally, from the definition of $\Gamma(\underline{\varphi}^*(\theta_R,\tau_c))$, we obtain:

$$\frac{\partial \Gamma(\underline{\varphi}^*(\theta_R,\tau_c))}{\partial \theta_R} = \underbrace{\frac{\partial \Gamma(\underline{\varphi}^*(\theta_R,\tau_c))}{\partial \underline{\varphi}^*(\theta_R,\tau_c)}}_{(>0)} \underbrace{\frac{\partial \underline{\varphi}^*(\theta_R,\tau_c)}{\partial \theta_R}}_{(>0)} > 0,$$

$$\frac{\partial \Gamma(\underline{\varphi}^*(\theta_R,\tau_c))}{\partial \tau_c} = \underbrace{\frac{\partial \Gamma(\underline{\varphi}^*(\theta_R,\tau_c))}{\partial \underline{\varphi}^*(\theta_R,\tau_c)}}_{(>0)} \underbrace{\frac{\partial \underline{\varphi}^*(\theta_R,\tau_c)}{\partial \tau_c}}_{(<0)} < 0.$$

Appendix E: Derivation of (27)

From (22), we obtain $c_t = \left[1 - \zeta - \frac{g_n^*}{E\Gamma(\underline{\varphi}^*)}\right](Y_0/L)e^{g_Y^* t}$. From (6) and the condition $Ll_t = l_{x,t}$, we have $Y_0 = A_0 N_0^{\phi} Ll^*$. By substituting these results along with (23) into (8), we derive (27).

Appendix F: Derivation of (28)

By differentiating (27) with respect to τ_c, we obtain

$$\frac{1}{\tilde{U}}\frac{dU}{d\tau_c} = \frac{1}{\tilde{U}}\frac{\partial U}{\partial \tau_c} + \frac{1}{\tilde{U}}\frac{\partial U}{\partial \Gamma(\underline{\varphi}^*)}\frac{\partial \Gamma(\underline{\varphi}^*)}{\partial \underline{\varphi}^*}\frac{\partial \underline{\varphi}^*}{\partial \tau_c} + \frac{1}{\tilde{U}}\frac{\partial U}{\partial g_n^*}\frac{\partial g_n^*}{\partial \tau_c}, \tag{A.11}$$

where $\tilde{U} \equiv (1-\sigma)U > 0$. By multiplying both sides by $\tilde{U} \equiv (1-\sigma)U$, we obtain (28).

Next, we further explain the sign condition $\frac{1}{\tilde{U}}\frac{\partial U}{\partial \tau_c} < 0$ in (29). By substituting $\Gamma(\underline{\varphi}^*) = \frac{\underline{\varphi}^*}{1-\frac{1}{a}}$ and (26) into (29), we obtain

$$\frac{1}{\tilde{U}}\frac{\partial U}{\partial \tau_c} = -\frac{\eta\mu}{(1+\tau_c)} \frac{\left[(1+\tau_c)(1-\zeta) - \frac{1-\tau_w}{\mu}\right]\left[(\sigma-1)\phi + \frac{1}{a}\right] + (1+\tau_c)\left(1-\frac{1}{a}\right)\frac{(\sigma-1)g_A+\rho}{E\underline{\varphi}^*}}{\left\{1-\tau_w + (1+\tau_c)\mu\eta\left[1-\zeta-\frac{g_n*}{E\Gamma(\underline{\varphi}^*)}\right]\right\}\left[(\sigma-1)\phi + \frac{1}{a} + (1+\tau_c)\left(1+\frac{1}{a}\right)\right]} < 0. \tag{A.12}$$

Appendix G: Further analysis of condition (32)

By substituting $\Gamma(\underline{\varphi}^*) = \frac{\underline{\varphi}^*}{1-\frac{1}{a}}$ and $\underline{\varphi}_b(0) \equiv \frac{(\sigma-1)g_A+\rho}{[1+(1-\zeta)-\frac{1-\tau_w}{\mu}]E}$ into (32), we obtain

$$\theta_R < \frac{(a-1)^{1+a}[(\sigma-1)g_A+\rho]^{1+a}}{a^a}\left[\frac{1+\eta}{\phi\varphi_{min}(1-\zeta)\left[1+\frac{\mu\eta}{1-\tau_w}(1-\zeta)\right]E}\right]. \tag{A.13}$$

Hence, the condition in (32) is satisfied, when θ_R is sufficiently small value to satisfy (A.13) and is sufficiently close to $\underline{\theta_R}(0)$.

Appendix H: Property of (34)

By differentiating $\Upsilon\left(\underline{\varphi}^*(\theta_R), \tau_c\right)$ with respect to $\underline{\varphi}^*(\theta_R)$, we obtain

$$\frac{\partial \Upsilon\left(\underline{\varphi}^*(\theta_R), \tau_c\right)}{\partial \underline{\varphi}^*(\theta_R)} = E \frac{\frac{1-\zeta}{a} + \left(1 - \frac{1}{a}\right) \frac{1-\tau_w}{\mu}}{\left(1 - \frac{1}{a}\right)\left[\frac{1}{a} + (1+\tau_c)\left(1 - \frac{1}{a}\right)\right]} > 0. \tag{A.14}$$

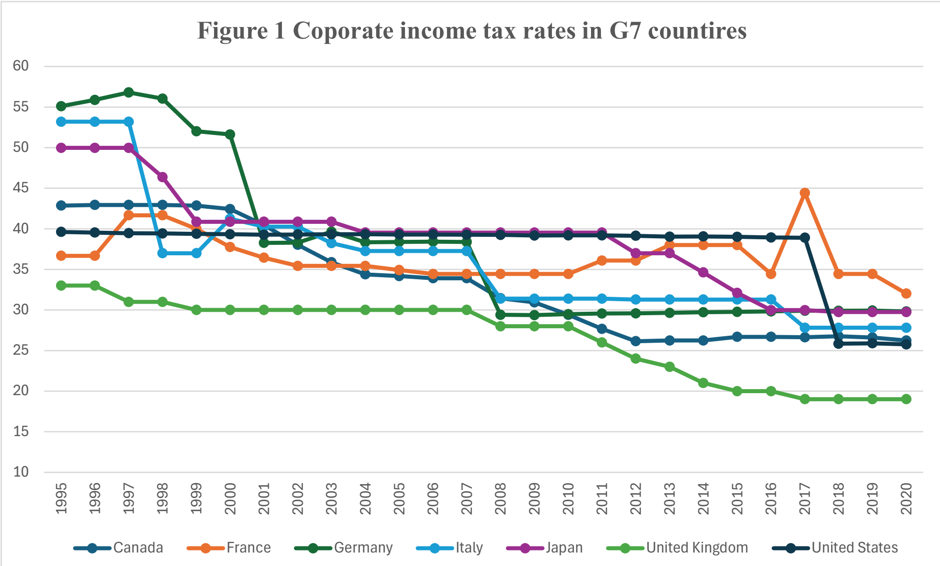

Figure 1: Corporate income tax rates in G7 countries
Source: Tax Foundation. (Year). OECD corporate income tax rates 1981-2013; OECD, Tax Database, Statutory corporate income tax rate

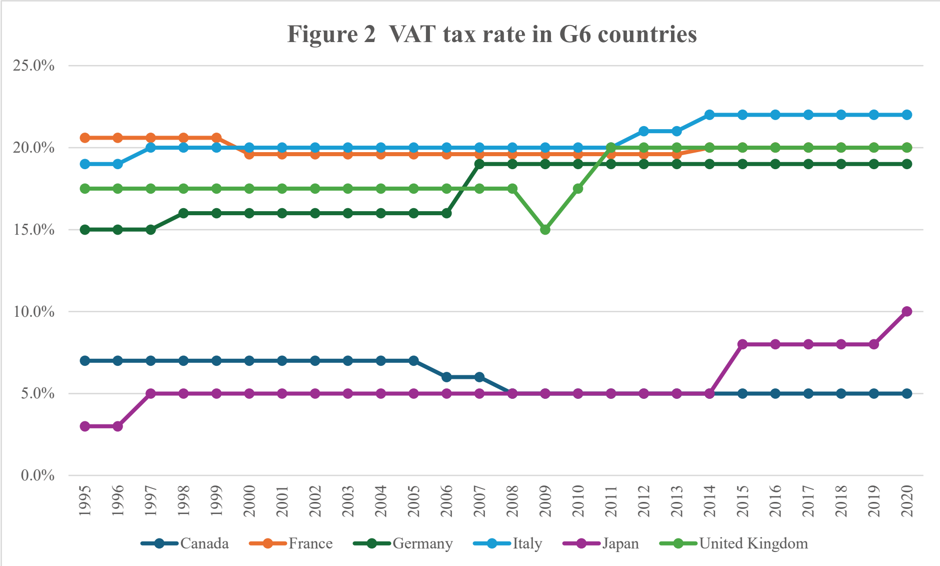

Figure 2: VAT tax rate in G6 countries.
Source: OECD Tax Database. Taxes on Consumption: Value Added Tax/Goods and Services Tax (VAT/GST). USA data were excluded from Figure 2 due to the absence of a federal VAT.

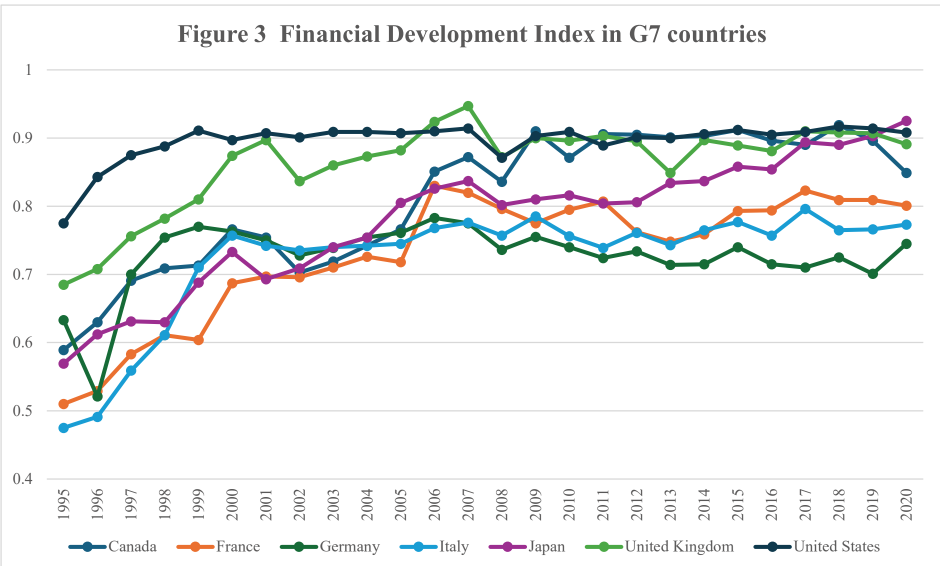

Figure 3: Financial Development Index in G7 countries
Source: IMF Database. Financial Development Index

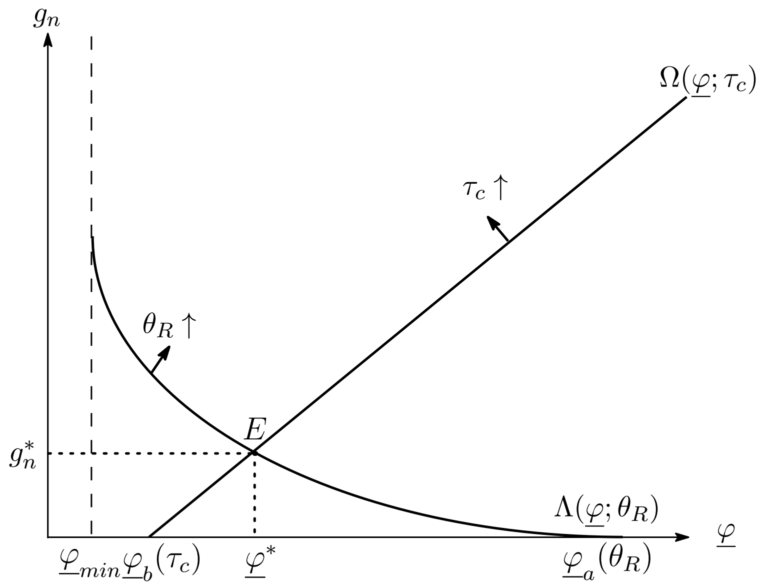

Figure 4: Steady-state equilibrium

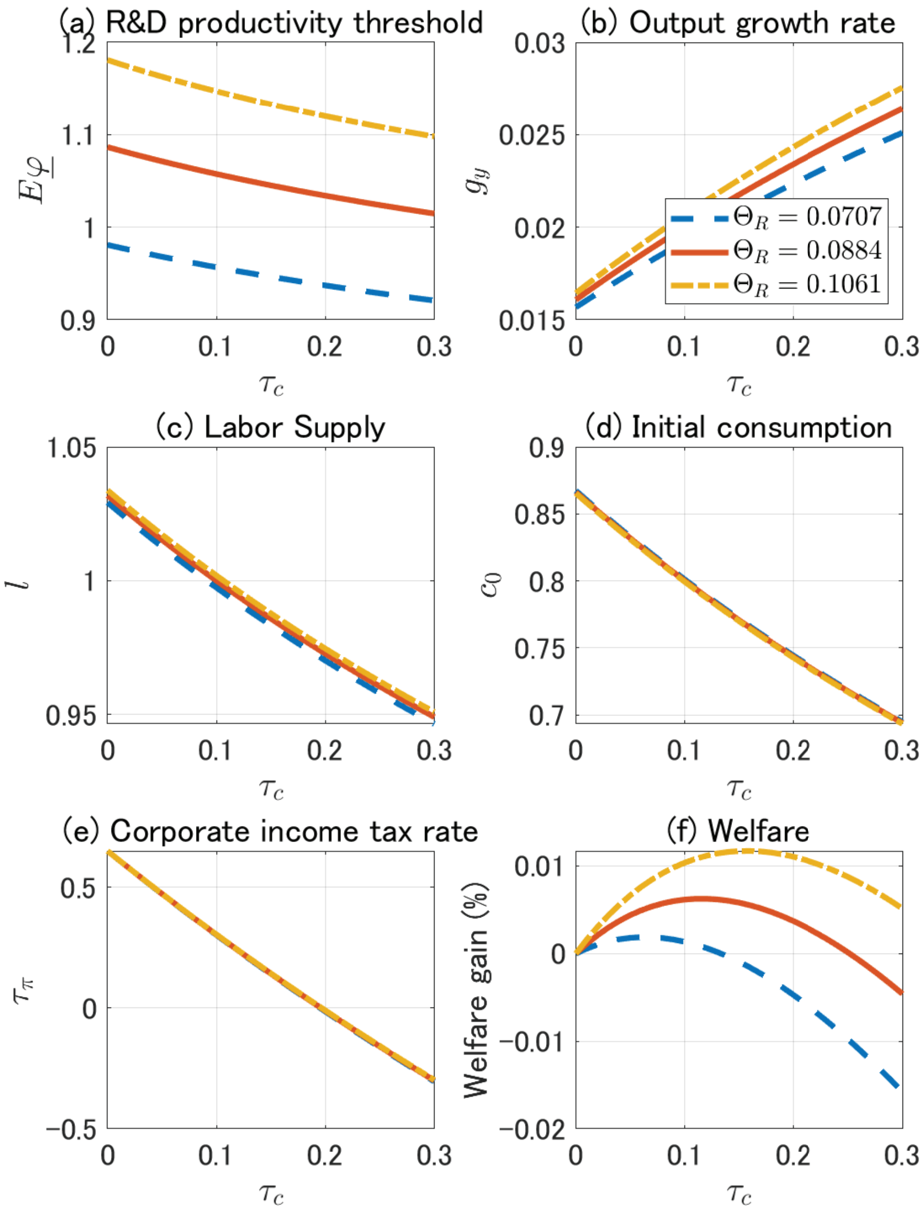

Figure 5: The effects of τ_c for $\Theta_R = 0.0707, 0.0884$ and 0.1061.

Table 1: Optimal Consumption Tax and Corporate Income Tax Rates

Θ_R	0.0707	0.0796	0.0884	0.0972	0.1061
τ_c^*	0.0600	0.0900	0.1200	0.1400	0.1600
τ_π^*	0.4372	0.3360	0.2379	0.1744	0.1121