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8 April 2022

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April 8, 2022

Abstract

In a two-country model of endogenous growth with international knowledge spillover, corporate income tax competition reproduces the second-best allocation attained by tax harmonization, despite complex externalities. This stems from the positive spillover effect across the border and free trading by Ricardian households in the global financial market. However, such a neutrality result does not hold in the extended model, which includes non-Ricardian households. The equilibrium tax rate under the corporate income tax competition can be excessively high or low, depending on the elasticity of the spillover effect to the share of the firms' locations.

JEL classification: E62; F23; F42; H21; H54

Keywords: corporate income tax; tax competition; spillover; welfare; economic growth; non-Ricardian household

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1 Introduction

In recent years, the locations of business firms have rapidly become borderless under globalization. Many countries consider the corporate income tax (CIT) system as a key instrument for attracting global firms and enjoying economic growth. However, this leads to severe CIT competition. This paper contributes to literature by exploring the welfare consequences of the global CIT competition in a two-country model of endogenous growth, focusing on firms' choices of location and knowledge spillover.

[Figure 1 is inserted here.]

CIT competition appears to be continually intensifying. Figure 1 illustrates the dynamics of the regional average CIT rates in the world. The monotonic decline of all regional CIT rates indicates that CIT competition is a worldwide phenomenon. Therefore, the government of individual countries must address it, since the CIT rate significantly affects international investment and firms' choice of location (Djankov et al. 2010; Feld and Heckemeyer 2011; Brülhart et al. 2012). Thus, the CIT competition exhibits, what is referred to as, "a race to the bottom." To confront this problem, in October 2021, the G20 countries reached an international agreement that would substantially introduce a common minimal CIT rate.[1] In light of this, it is imperative to determine the welfare consequence of CIT competition. Furthermore, we must determine when and how measures should be taken against it. This study tackles these issues.

There are several points to consider in the modern CIT competition in the global economy. First, international knowledge spillover is important. In fact, some empirical studies suggest that knowledge spillover due to domestic and foreign R&D capital improves total factor productivity and enhances economic growth (Coe and Helpman 1995; Coe et al. 2009; Aghion and Jaravel 2015; Schnitzer and Watzinger 2022). Second, productive public spending improves countries' conditions for tax competition by providing the locating firms with environmental benefit, as Görg et al. (2009) and Hauptmeier (2012) empirically demonstrate. Third, the integration of the financial market has raised capital mobility in recent years (Hwang and Kim 2018). More importantly, the accessibility of the global financial market provides more flexible choices of location around the world for firms. Therefore, we incorporate these aspects into our analysis.

[1]For detail, see The Leaders of the G20 (2021).

Our model is a two-country model of endogenous growth with knowledge spillover and productive government spending; the engine of growth is the expanding varieties. The firms choose their locations arbitrarily, considering the growth-enhancing effect of productive government spending. Capital is freely mobile, and CIT is levied according to the residence: the set of the CIT rates of the two countries is the main determinant of the firms' choice of location. Thus, each country faces a strategic situation in selecting its CIT rate. Incorporating this, each country's government sets their optimal CIT rates, that is, the growth- or welfare-maximizing CIT rates. We consider two regimes: the non-cooperative and cooperative policies. Under the cooperative policy, the two governments equalize their CIT rates, choosing one which maximizes welfare globally. In contrast, under the non-cooperative policy, each government sets their own CIT rate, given that of their opponent; this is the case of CIT competition. Comparing the equilibrium CIT rates in both cases, we conduct a welfare evaluation based on the CIT competition.

Our main findings are as follows. First, in the benchmark model with only Ricardian households, the symmetric Nash equilibrium under the CIT competition reproduces the second-best allocation for tax harmonization. This result is surprising since existing studies usually suggest inefficient decentralization. As explained later in detail, this result stems from international knowledge spillover and free trading by Ricardian households in the global financial market. The international knowledge spillover adds the benefit of agglomeration. Since Ricardian households control their assets to secure consumption, this adjusts the capital for firms' entry. This restrains the governments' incentive to expand their own tax bases inefficiently.

Second, when non-Ricardian households exist and governments incorporate their welfare into the policy objective, the equilibrium CIT rate under non-cooperation does not coincide with that under cooperation, that is, CIT competition does not lead to the second-best allocation. The CIT rate in the Nash equilibrium can be excessively high or low, according to the degree of knowledge spillover. This is because the myopic governments' interference destabilizes the neutrality result in the benchmark model. For example, when the elasticity of the spillover effect to firm locations is small, the equilibrium CIT rate under the tax competition is excessively low. This is because the governments choose to expand their tax bases by attracting more firms and increasing the current income of the households, sacrificing the long-run benefit of the spillover from the opponent.

The first result suggests that we need not conclude an international agreement that restricts CIT rates, since CIT competition is not harmful to global economic welfare. Indeed, it is an extreme result in the stylized model, which includes the homogeneous Ricardian households, perfect capital mobility, and the benevolent governments. However, we can draw out a basic conclusion; knowledge spillover across the borders in the modern world economy mitigates any inefficiency from CIT competition. Meanwhile, the second result suggests the need for international cooperation to avoid inefficiency from CIT competition under realistic circumstances, particularly the increased presence of poor households in many countries in recent years. Summarily, to design CIT regulations for active international business, we should examine the relationship between spillover and growth carefully.

Related Literature

This study aims to contribute to literature by providing a formal analysis on CIT competition, incorporating an important feature of the modern world economy; firms' borderless choices of location and knowledge spillover. In this section, we compare our study to existing studies on CIT in growing economies and tax competition over other taxes.

CIT and growth To our best knowledge, there are few studies on (i) how the CIT rate affects growth and welfare and (ii) the optimal CIT rate for dynamic growth models. This is partly because the zero-profit result makes the role of the CIT in the standard neoclassical growth models obsolete.[2] Some recent studies overcame this problem by using R&D-based growth models with imperfect competition. Peretto (2003) examined effective growth-enhancing tax policies while Peretto (2007, 2011) focused on the welfare effects of a change in the CIT rate. Meanwhile, Iwaisako (2016) investigated a welfare-maximizing CIT rate with a patent protection policy. Aghion et al. (2016) and Hori et al. (2022) addressed both the growth- and welfare-maximizing CIT rates by incorporating productive government spending (e.g., Barro 1990; Futagami et al. 1993). Aghion et al. (2016) focused on corruption of the government, and Hori et al. (2022) considered tax evasion by firms. Suzuki (2021) investigated corporate taxation in a Schumpeterian growth model with an endogenous market structure. In contrast to our study, these studies considered closed economies and did not address CIT competition.

Davis and Hashimoto (2018) explored how the international difference in CIT rates affects growth and welfare, using an R&D-based growth model with two countries. They show that the

[2] See Barro and Sala-i-Martin (2004).

effect of a change in the CIT rates depends on the initial level of the relative CIT rates. They also find that raising the CIT rate benefits the country with a low CIT rate but may benefit or hurt the country with a high CIT rate. However, since CIT revenue is not applied to productive government spending, it remains zero in equilibrium, with no substantial CIT competition.

In this paper, we successfully develop a tractable two-country R&D-based growth model with productive government spending financed by CIT revenue. This enables us to conduct a transparent analysis on CIT competition and the consequence to welfare.

Dynamic tax competition over tax rates other than CIT There are few literature on the theoretical links between tax competition and growth, as mentioned by Rauscher (2005). Most strands of this literature consist of capital tax competition. Competition over capital tax dates back to the static models by Wilson (1986) and Zodrow and Mieszkowski (1986). Wildasin (2003) and Tamai (2008) extend these models into the neoclassical growth models, in which tax revenues are stock-based, that is, the capital available at home becomes the source of tax revenue. Koethenbuerger and Lockwood (2010) and Chu and Yang (2012) examine how stock-based tax competition affects growth in Romer (1986)'s type AK models. The former and latter consider productivity shocks and imperfect capital mobility, respectively.[3] Koethenbuerger and Lockwood (2010) also extend their model to an endogenous growth model with productive government spending, assuming that the local productive spending is financed by local capital tax. Extending this further, Hatfield (2015) considers both capital and labor income taxation. These show that the equilibrium tax rate under tax competition is lower than under centralized policy-making.

Lejour and Verbon (1997) consider tax competition over capital income tax in Romer (1986)'s type AK model with imperfect capital mobility. The tax revenue is flow-based, and home bias of investment due to the mobility cost of investing abroad is the source of a strategic situation. In contrast, we do not focus on imperfect capital mobility, but on international knowledge spillover. This is because capital mobility has increased significantly in recent years (Hwang and Kim 2018). Miyazawa et al. (2019) consider tax competition when the spillover effect of capital across countries exists. They examine how capital income tax competition affects fiscal sustainability. Our study is similarly relevant, as spillover across countries is important when considering tax

[3] In addition, Becker and Rauscher (2013) consider the imperfect mobility of capital as in Chu and Yang (2012). They show that the relationship between capital mobility and capital tax rates is not monotonic, and that growth and capital mobility are unambiguously positively related.

competition. However, our studies differ because Miyazawa et al. (2019) neither investigate the role of productive spending nor the optimal policies.

In contrast to the existing models on perfect competitive economies, the recent trend of global tax competition is attributed to firms' choices of location when pursuing higher profits (Baldwin and Krugman 2004; Borck and Pflügera 2006). Therefore, CIT competition that levies on firms' profits are realistically important.

2 A Baseline Model

There are two countries, country 1 and country 2, indexed by r or s. The population size of country 1 and country 2 are L_1 and L_2, respectively. These are constant over time.

2.1 Production of final goods

A single final good is one that is freely traded in the perfectly competitive global market. There is a continuum of competitive final good firms indexed by $j \in [0,1]$ across the two countries. Production of a final good by firm j in country $r \in \{1,2\}$ is given by

$$Y_r(j,t) = \int_0^{N_r} x_{r,r}(i_r,t)^\alpha di_r + \int_0^{N_s} x_{s,r}(i_s,t)^\alpha di_s, \qquad \alpha \in (0,1) \tag{1}$$

where, $x_{r,r}(i_r,t)$ ($x_{s,r}(i_s,t)$, resp.) is the input of an intermediate good in industry i_r (i_s, resp.), produced in country r (s, resp.), and used for final good production in country r. N_r (N_s resp.) stands for the variety of intermediate goods in country r (s, resp.).

Each final good firm located in country r must incur sunk cost by $E_r(t) = c_r(t)Y_r(t)$ ($c_r(t) \in (0,1)$) for final good production, where $Y_r(t)$ is the average level of final good produced in period t in country r. We normalize the world price of the final good to be 1. Maximizing profit $Y_r(j,t) - \int_0^{N_r} p_{r,r}(i_r,t)x_{r,r}(i_r,t)di_r - \int_0^{N_s} p_{s,r}(i_s,t)x_{s,r}(i_s,t)di_s - c_r(t)Y_r(t)$ yields $\alpha x_{r,k}(i_k,t)^{\alpha-1} = p_{r,k}(i_k,t)$. By (1), the profit of firm j is reduced to $(1-\alpha)Y_r(j,t) - c_r(t)Y_r(t)$. Since $Y_s(j,t) = Y_s(t)$ and the zero profit condition, $(1-\alpha)Y_s(j,t) - cY_s(t) = 0$ hold in equilibrium, we obtain $c_r(t) = c_r = 1-\alpha$. Thus, we obtain the demand function of an intermediate good $x_{k,r}(i_k,t)$:

$$\alpha x_{k,r}(i_k,t)^{\alpha-1} = p_{k,r}(i_k,t), \quad k = r,s. \tag{2}$$

2.2 Producers of intermediate goods

2.2.1 Entry into the intermediate goods market

Each intermediate good is produced by a monopolistically competitive firm. To operate in period t, each intermediate good firm must invest η unit of the final good in period $t-1$. Intermediate good firms finance the cost of this investment by borrowing from households in country 1 or 2. Because of free access to the global financial market, each agent in the world faces a common gross interest rate between periods $t-1$ and t, which is denoted by $R(t-1)$. Each intermediate good firm operates during one period, as in Young (1998).

Let us denote the operating profit of firm i_r in period t, located in country $r \in \{1,2\}$ by $\pi_r(i_r,t)$. In Section 2.2.2, we discuss $\pi_r(i_r,t)$ in detail. When the intermediate good firms become located in country r, CIT is imposed on their operating profits at the rate of τ_r. Therefore, the net profit of intermediate good firm i_r, choosing to be located in country $r \in \{1,2\}$, is given by

$$\Pi_r(i_r,t-1) = \frac{(1-\tau_r)\pi_r(i_r,t)}{R(t-1)} - \eta.$$

Free entry into the intermediate goods market across countries implies

$$(1-\tau_1)\pi_1(i_1,t) = (1-\tau_2)\pi_2(i_2,t) = \eta R(t-1). \tag{3}$$

2.2.2 Maximization of operating profits

Each intermediate good firm $i_r \in N_r(t)$ located in country r produces intermediate goods for country k by employing labor in country r, $l_{r,k}(i_r,t)$, using the following technology:

$$x_{r,k}(i_r,t) = Ah_r(t)l_{r,k}(i_r,t), \qquad A>0, \quad k=r,s. \tag{4}$$

Here, $h_r(t)$ is the common labor productivity per capita to all industry i_r in country r and given by

$$h_r(t) = \frac{G_r(t)^\gamma \Theta_r(N_r(t),N_s(t))^{1-\gamma}}{L_r}, \qquad r\neq s, \quad \gamma\in(0,1). \tag{5}$$

Regarding (5), note the following two points. First, public service in country r, $G_r(t)$, has positive externality for producing intermediate goods in country r. Thus, it may be regarded as an infrastructure used by firms located in country r (e.g, Barro 1990).

Second, the spillover function $\Theta_r(N_r(t), N_s(t))$ indicates that knowledge spillovers regarding the stock of both the home, $N_r(t)$, and foreign country, $N_s(t)$, enhance production.[4] We assume that $\Theta_r(N_r(t), N_s(t))$ is continuous and homogeneous of degree 1 in both arguments. Then, we can write it in the intensive form:

$$N_r(t)\Theta_r\left(1, \frac{N_s(t)}{N_r(t)}\right) \equiv N_r(t)\vartheta_r(n_{rs}(t)) \quad \text{with } n_{rs} \equiv \frac{N_s(t)}{N_r(t)}, \tag{6}$$

where $\vartheta_r(n_{rs})$ satisfies $\vartheta_r(\cdot) > 0$ for $n_{rs} \geq 0$, $\lim_{n_{rs}\to+\infty} \vartheta_r(n_{rs}) = +\infty$, and $\vartheta_r'(\cdot) > 0$. Two functions $\vartheta_r(n_{rs})$ and $\vartheta_s(n_{sr})$ is not necessarily of the same form.

Each intermediate good firm $i_r \in N_r(t)$ located in country r sells its products to the home country, $x_{r,r}(i_r, t)$, and exports to the foreign country, $x_{r,s}(i_r, t)$. There is a transaction cost for international trading; exporting $x_{r,s}(i_r, t)$ costs $\zeta l_{r,s}(i_r, t)$ unit of labor additionally ($\zeta \geq 0$). Next, intermediate good firm i_r located in country r chooses $l_{r,r}(i_r, t)$ and $l_{r,s}(i_r, t)$ to maximize its profit

$$\pi_r(i_r, t) = [p_{r,r}(i_r, t)x_{r,r}(i_r, t) - w_r(t)l_{r,r}(i_r, t)] + [p_{r,s}(i_r, t)x_{r,s}(i_r, t) - w_r(t)(1+\zeta)l_{r,s}(i_r, t)], \tag{7}$$

subject to (2) and (4), given the wage rate in country r, $w_r(t)$. The first order condition is

$$\alpha^2 A^\alpha h_r(t)^\alpha l_{r,r}(i_r, t)^{\alpha-1} = w_r(t), \tag{8}$$

$$\alpha^2 A^\alpha h_r(t)^\alpha l_{r,s}(i_r, t)^{\alpha-1} = (1+\zeta)w_r(t), \quad r \in \{1, 2\}. \tag{9}$$

From (8) and (9), all firms choose the same level of labor demand, $l_{r,r}(i_r, t) = l_{r,r}(t)$ and $l_{r,s}(i_r, t) = l_{r,s}(t)$. Therefore, $x_{r,k}(t)$, $p_{r,k}(t)$, and $\pi_r(t)$ are all independent of index i_r. Furthermore, (8) and (9) lead to

$$l_{r,s}(t) = \phi l_{r,r}(t), \quad r \in \{1, 2\}, \tag{10}$$

[4] This type of knowledge spillover is common to the literature on economic growth (e.g., Benassy 1998).

where $\phi \equiv (1/(1+\zeta))^{\frac{1}{1-\alpha}} \in (0,1]$. From (4) and (10), we obtain

$$x_{r,s}(t) = \phi x_{r,r}(t), \qquad r \in \{1,2\}.$$

Substituting (8), (9), (10), and $1+\zeta = \phi^{\alpha-1}$ into (7) and applying (2) and (4), we obtain

$$\pi_r(t) = \alpha(1-\alpha)(1+\phi^{\alpha})A^{\alpha}\left[h_r(t)l_{r,r}(t)\right]^{\alpha}, \qquad r \in \{1,2\}. \tag{11}$$

2.3 Household

The utility function of a representative household residing in country $r \in \{1,2\}$ is

$$U_r(0) = \sum_{t=0}^{\infty}\left(\frac{1}{1+\rho}\right)^t u(C_r(t)), \qquad u(C_r(t)) = \frac{C_r(t)^{1-\sigma}}{1-\sigma},\ \sigma > 0, \tag{12}$$

where $u(C_r(t)) = \ln C_r(t)$ when $\sigma = 1$. Here, $C_r(t)$, $\rho > 0$, and $1/\sigma$ denote consumption in period t, the subjective discount rate, and the intertemporal elasticity of substitution, respectively. The representative household supplies one unit of labor inelastically. The household's budget constraint is given by $W_r(t) = R(t-1)W_r(t-1) + w_r(t) - C_r(t)$, where $W_r(t-1)$ is asset holding at the end of period $t-1$. The household's utility maximization yields

$$\frac{C_r(t+1)}{C_r(t)} = \left[\frac{R(t)}{1+\rho}\right]^{1/\sigma} \tag{13}$$

and the transversality condition is

$$\lim_{t\to\infty}\frac{C_r(t)^{-\sigma}W_r(t-1)}{(1+\rho)^t} = 0. \tag{14}$$

2.4 Government

We assume that the government in country $r \in \{1,2\}$ keeps a balanced budget in each period. The aggregate CIT revenue of the government in country r, $\tau_r\pi_r(t)N_r(t)$, is allocated to productive government spending, $G_r(t)$. Thus, the government's budget constraint is given by

$$G_r(t) = \tau_r\pi_r(t)N_r(t), \qquad r \in \{1,2\}. \tag{15}$$

2.5 Equilibrium

The clearing condition for the labor market in country r is $L_r = \int_0^{N_r} [l_{r,r}(t) + (1+\zeta) l_{r,s}(t)] di_r$. Using (10) and $(1+\zeta) = \phi^{\alpha-1}$, we can reduce it to

$$L_r = N_r(t)(1+\phi^{\alpha}) l_{r,r}(t). \tag{16}$$

The asset market clears by

$$W_1(t-1)L_1 + W_2(t-1)L_2 = \eta(N_1(t) + N_2(t)). \tag{17}$$

Substituting (5), (6), (15) and (16) into (11), we obtain

$$\pi_r(t) = (1-\alpha)\tilde{A}(\phi)\tau_r^{\frac{\beta}{1-\beta}} \vartheta_r(n_{rs}(t))^{\frac{\alpha-\beta}{1-\beta}}, \tag{18}$$

where $\beta \equiv \alpha\gamma < \alpha$ and $\tilde{A}(\phi) \equiv \left\{(1+\phi^{\alpha})^{1-\alpha} A^{\alpha} \alpha (1-\alpha)^{\beta}\right\}^{\frac{1}{1-\beta}}$. Substituting (18) with $\pi_s(t) = (1-\alpha)\tilde{A}(\phi)\tau_s^{\frac{\beta}{1-\beta}} \vartheta_s\left(n_{sr}(t)\right)^{\frac{\alpha-\beta}{1-\beta}}$ into (3) yields

$$\left[\frac{\vartheta_r(n_{rs})}{\vartheta_s(n_{sr})}\right]^{\frac{\alpha-\beta}{1-\beta}} = \left[\frac{\vartheta_r(n_{rs})}{\vartheta_s(n_{rs}^{-1})}\right]^{\frac{\alpha-\beta}{1-\beta}} = \frac{1-\tau_s}{1-\tau_r}\left(\frac{\tau_s}{\tau_r}\right)^{\frac{\beta}{1-\beta}}. \tag{19}$$

Define $\varphi(n_{rs}) \equiv \vartheta_r(n_{rs})/\vartheta_s(n_{rs}^{-1})$. Then,

$$n_{rs}\left(\tau_r, \tau_s\right) = \varphi^{-1}\left(\left(\frac{1-\tau_s}{1-\tau_r}\right)^{\frac{1-\beta}{\alpha-\beta}} \left(\frac{\tau_s}{\tau_r}\right)^{\frac{\beta}{\alpha-\beta}}\right). \tag{20}$$

We obtain the following remark by (19), (20),

$$\varphi'(n_{rs}) = \frac{\vartheta_r'(n_{rs})}{\vartheta_s(n_{rs}^{-1})} + \frac{\vartheta_r(n_{rs})\vartheta_s'(n_{rs}^{-1})}{\vartheta_s(n_{rs}^{-1})^2 n_{rs}^2} > 0, \tag{21}$$

$\varphi(0) = \frac{\vartheta_r(0)}{\lim_{n_{sr}\to+\infty} \vartheta_s(n_{sr})} = 0$, and $\lim_{n_{rs}\to+\infty} \varphi(n_{rs}) = \frac{\lim_{n_{rs}\to+\infty} \vartheta_r(n_{rs})}{\vartheta_s(0)} = +\infty$.

Remark 1.

(i) $n_{rs}(\tau_r, \tau_s)$ is constant over time and uniquely determined for any $\tau_r \in (0,1)$ and $\tau_s \in (0,1)$.

(ii) A decrease in the CIT rate of the foreign country ($s \in \{1,2\}$) increases (decreases) the

production share of the foreign country (s), if and only if $\tau_s \geq (<) \beta$ *i.e.,*

$$\frac{\partial n_{rs}}{\partial \tau_s} \gtreqless 0 \qquad \text{for} \qquad \tau_s \lesseqgtr \beta$$

Note that the number of firms globally, $N_r(t) + N_s(t)$, is a predetermined variable, while the individual values, $N_r(t)$ and $N_s(t)$, are jump variables. This is because the level of households' asset holding at the end of the previous period provides that number; however, the factor market balance constrains firms' locations. See the equilibrium condition of the asset and labor market, (17) and (16), respectively. Thus, n_{rs}, which is defined by $N_s(t)/N_r(t)$, jumps immediately after the policy changes in (τ_r, τ_s). Besides, this ratio is constant over time in equilibrium.

Furthermore, the relationship between the production share of the home country, n_{rs}, and the CIT of the foreign country, τ_s, features the following two opposite effects. A decrease in the CIT rate of the home country attracts firms due to the lowered tax burdens.[5] Meanwhile, it decreases the tax revenue for productive public spending and the benefit of location at the home country. See Dewit et al. (2018). The former (latter) dominates the latter (former) when CIT is higher (lower) than β. We should note such opposing effects of *tax base externalities*. These opposite *tax base externalities* affect the decision making of policy makers in each country, as we shall examine in subsequent sections.

Substituting (20) into (18), we obtain

$$\pi_r(\tau_r, \tau_s) = (1-\alpha)\tilde{A}(\phi)\tau_r^{\frac{\beta}{1-\beta}} \vartheta_r(n_{rs}(\tau_r, \tau_s))^{\frac{\alpha-\beta}{1-\beta}}, \tag{22}$$

Equation (22) indicates that the operating profit of the intermediate goods firms is constant over time and expressed as the function of the two countries' CIT rates, τ_r and τ_s. From (3) and (22), we obtain the following relationship on the after-tax profits of firms between two countries:

$$(1-\tau_1)\tau_1^{\frac{\beta}{1-\beta}} \vartheta_1(n_{12}(\tau_1, \tau_2))^{\frac{\alpha-\beta}{1-\beta}} = (1-\tau_2)\tau_2^{\frac{\beta}{1-\beta}} \vartheta_2(n_{21}(\tau_2, \tau_1))^{\frac{\alpha-\beta}{1-\beta}} \tag{23}$$

Note that (23) holds for any $\tau_1 \in (0,1)$ and $\tau_2 \in (0,1)$ because $n_{rs}(\tau_r, \tau_s)$ is determined to satisfy $(1-\tau_r)\pi_r = (1-\tau_s)\pi_s$. Equation (23), therefore, connects the two countries through

[5] This is a standard home market effect in New Economic Geography literature, such as Baldwin et al. (2003) and Davis and Hashimoto (2018).

international knowledge spillover and free entry of firms across countries.

Consider the case where $\partial n_{21}/\partial \tau_1 < 0$, i.e., $\tau_1 > \beta$. A decrease in τ_1 increases the number of the firms located in country 1 and increases their after-tax profits, $(1-\tau_1)\pi_1$, through benefits of agglomeration. Meanwhile, a decrease in τ_1 reduces the number of the firms located in country 2, but increases the firms' market power by mitigating competition through the positive spillover effect from abroad. This increases the after-tax profits, $(1-\tau_2)\pi_2$, as well. Thus, a change in the CIT rate moves the after-tax profits in both countries in the same direction.

Next, notice that (11) with (8) yields $w_r(t)l_{r,r}(t) = \frac{\alpha}{(1-\alpha)(1+\phi^\alpha)}\pi_r(t)$. Thus, substituting (16) and (22) into the left and right hand-side, respectively, we obtain the aggregate wage income:

$$w_r(t)L_r = \alpha\tilde{A}(\phi)\tau_r^{\frac{\beta}{1-\beta}}\vartheta_r(n_{rs}(\tau_r,\tau_s))^{\frac{\alpha-\beta}{1-\beta}}N_r(t). \tag{24}$$

Furthermore, by (22) and (3), the interest rate, $R(t)$, and the after-tax operating profit, $(1-\tau_r)\pi_r$, takes the symmetric constant value:

$$\begin{aligned} R(\tau_r,\tau_s) = \frac{(1-\tau_r)\pi_r(\tau_r,\tau_s)}{\eta} &= \eta^{-1}(1-\alpha)\tilde{A}(\phi)(1-\tau_r)\tau_r^{\frac{\beta}{1-\beta}}\vartheta_r(n_{rs}(\tau_r,\tau_s))^{\frac{\alpha-\beta}{1-\beta}} \\ \left(= \frac{(1-\tau_s)\pi_s(\tau_s,\tau_r)}{\eta}\right. &\left. = \eta^{-1}(1-\alpha)\tilde{A}(\phi)(1-\tau_s)\tau_s^{\frac{\beta}{1-\beta}}\vartheta_s(n_{sr}(\tau_s,\tau_r))^{\frac{\alpha-\beta}{1-\beta}}\right). \end{aligned} \tag{25}$$

Substituting (25) into (13) leads to

$$\frac{C_1(t+1)}{C_1(t)} = \frac{C_2(t+1)}{C_2(t)} = \left[\frac{R(\tau_r,\tau_s)}{1+\rho}\right]^{\frac{1}{\sigma}} \equiv g_C(\tau_r,\tau_s). \tag{26}$$

The CIT rates in both countries affect economic growth through the net profits of the firms located in both countries. A high CIT rate decreases the net profits of the firms directly and has negative effects on growth; meanwhile, it increases the productive government spending, which enhances growth. These opposite *growth externalities* affect the decision making of the government in each country. In the subsequent sections, we address the interactions between growth externalities and tax base externalities (in Remark 1) as a response of tax policy changes.

Equation (22) can also be rewritten (15) as

$$G_r(t) = \tau_r\pi_r(\tau_r,\tau_s)N_r(t). \tag{27}$$

Substituting (27) together with (4), (16), and (19) into (1), we obtain

$$Y_r(t) = \frac{\tilde{A}(\phi)}{(1+\phi^\alpha)\alpha}\left[\tau_r^{\frac{\beta}{1-\beta}}\vartheta_r(n_{rs}(\tau_r,\tau_s))^{\frac{\alpha-\beta}{1-\beta}}N_r(t) + \phi^\alpha\tau_s^{\frac{\beta}{1-\beta}}\vartheta_s(n_{sr}(\tau_s,\tau_r))^{\frac{\alpha-\beta}{1-\beta}}N_s(t)\right], \quad (28)$$

for $r \in \{1,2\}$ and $r \neq s$. See Appendix A for the derivation of (28) in detail.

Finally, we consider the market clearing condition for final goods. We can derive it by summing up the households' budget constraint in the two countries: $W_1(t)L_1 + W_2(t)L_2 = R[W_1(t-1)L_1 + W_2(t-1)L_2] + w_1(t)L_1 + w_2(t)L_2 - C_1(t)L_1 - C_2(t)L_2$. Associating this with (5), (8), (16), (17), (25), (27), (28), and the total sunk costs of the final goods sector, $E_1(t)+E_2(t) = (1-\alpha)(Y_1(t)+Y_2(t))$, we obtain the market clearing condition for the final good: $\eta(N_1(t+1)+N_2(t+1)) = Y_1(t)+Y_2(t)-E_1(t)-E_2(t)-(G_1(t)+G_2(t))-C_1(t)L_1-C_2(t)L_2$. Appendix B provides more detail on the derivation. Besides, as shown in Appendix B, this market clearing condition is reduced to

$$\eta\sum_{r=1}^{2}N_r(t+1) = \sum_{r,s=1,r\neq s}^{2}\tilde{A}(\phi)[1-(1-\alpha)\tau_r]\tau_r^{\frac{\beta}{1-\beta}}\vartheta_r(n_{rs}(\tau_r,\tau_s))^{\frac{\alpha-\beta}{1-\beta}}N_r(t) - \sum_{r=1}^{2}C_r(t)L_r. \quad (29)$$

Putting $z_1(t) \equiv C_1(t)L_1/N_1(t)$ ($z_2(t) \equiv C_2(t)L_2/N_2(t)$) and using (19), (26), and (29), we obtain the following dynamic system (See Appendix C):

$$\frac{z_1(t+1)}{z_1(t)} = \frac{\eta\,[1+n_{12}(\tau_1,\tau_2)]\,g_C(\tau_1,\tau_2)}{\Phi_1(\tau_1,\tau_2)-z_1(t)-n_{12}(\tau_1,\tau_2)z_2(t)}, \quad (30)$$

$$\frac{z_2(t+1)}{z_2(t)} = \frac{\eta\,[1+n_{21}(\tau_2,\tau_1)]\,g_C(\tau_1,\tau_2)}{\Phi_2(\tau_2,\tau_1)-z_2(t)-n_{21}(\tau_2,\tau_1)z_1(t)}, \quad (31)$$

where

$$\Phi_r(\tau_r,\tau_s) \equiv \tilde{A}(\phi)\tau_r^{\frac{\beta}{1-\beta}}\vartheta_r(n_{rs}(\tau_r,\tau_s))^{\frac{\alpha-\beta}{1-\beta}}\left\{1-(1-\alpha)\tau_r + [1-(1-\alpha)\tau_s]\frac{1-\tau_r}{1-\tau_s}n_{rs}(\tau_r,\tau_s)\right\}. \quad (32)$$

By (30) and (31), we arrive at the following proposition.

Proposition 1. *Suppose that*

$$\Phi_1(\tau_1,\tau_2) - \eta[1 + n_{12}(\tau_1,\tau_2)]g_C(\tau_1,\tau_2) > 0. \tag{33}$$

A unique steady state exists. In the steady state, $z_1(t)$ and $z_2(t)$ take the following constant values:

$$z_1^* = \frac{\Phi_1(\tau_1,\tau_2) - \eta[1 + n_{12}(\tau_1,\tau_2)]g_C(\tau_1,\tau_2)}{2} \tag{34}$$

$$z_2^* = \frac{\Phi_2(\tau_2,\tau_1) - \eta[1 + n_{21}(\tau_2,\tau_1)]g_C(\tau_1,\tau_2)}{2} \tag{35}$$

In the steady state, $C_1(t)$, $C_2(t)$, $N_1(t)$, $N_2(t)$, $Y_1(t)$, and $Y_2(t)$ grow at the same constant rate of $g_C(\tau_1,\tau_2)$, and $C_1(t) = C_2(t)$ holds. The economy jumps to the steady state initially.

Proof: See Appendix D.

The Ricardian households in both countries control their consumption by taking part in the global financial market. It leads to the same amount of consumption in both countries: $C_1(t) = C_2(t)$. Note that this relationship holds even in the absence of tax harmonization; $\tau_1 \neq \tau_2$. The effect of tax differences, if any, is neutralized by the common interest rate, which is brought about by the international knowledge spillover and free entry of firms. See the equilibrium world interest rate, (25). As mentioned below, this leads to the optimality of the CIT competition; Proposition 3.

3 Tax competition over CIT rates

Let us investigate the CIT competition between the two countries. We consider two alternative policies, the growth- and welfare-maximizing policies.

3.1 Growth-maximizing policy

Although our primary goal is to evaluate the welfare consequence of CIT competition, it is beneficial to explore the equilibrium under the growth-maximizing policy. Under the growth-maximizing policy, each country's government chooses a CIT rate that maximizes its country's growth rate, given the other country's CIT rate.

By (20), (21), (25), (26), and $\varphi(n_{rs}) \equiv \vartheta_r(n_{rs})/\vartheta_s(n_{rs}^{-1})$, we obtain

$$\frac{\partial g_C(\tau_r,\tau_s)}{\partial \tau_r} = \left[1 - \frac{\epsilon_r(n_{rs})}{\epsilon_r(n_{rs}) + \epsilon_s(n_{rs}^{-1})}\right] \frac{g_C(\tau_r,\tau_s)(\beta-\tau_r)}{\sigma(1-\tau_r)(1-\beta)\tau_r} \gtreqless 0, \quad \text{for} \quad \tau_r \lesseqgtr \beta, \tag{36}$$

where

$$\epsilon_r(n_{rs}) \equiv \frac{\vartheta_r'(n_{rs})n_{rs}}{\vartheta_r(n_{rs})} \quad \text{and} \quad \epsilon_s(n_{rs}^{-1}) \equiv \frac{\vartheta_s'(n_{rs}^{-1})n_{rs}^{-1}}{\vartheta_s(n_{rs}^{-1})}. \tag{37}$$

Appendix E provides the derivations of (36) and (37). We obtain the following proposition:

Proposition 2. *The growth-maximizing CIT rates are $\tau_1^{GM} = \tau_2^{GM} = \beta$, where τ_r^{GM} is the growth-maximizing CIT rate of country r. That is, Barro (1990)'s rule holds.*

As (36) shows, the effects of the growth and tax base externalities are maximized when each country's CIT rate equals the output elasticity of public services, β. The first term of the bracketed part in (36) corresponds to the growth externality, and the second term, to the tax base externality.

This result differs from Koethenbuerger and Lockwood (2010) and Hatfield (2015), both of which consider the capital tax competition. They show that the growth-maximizing tax rates deviate from the output elasticity of public services. The point is the difference in the tax bases. The tax base in our model is corporate income (a flow-based taxation), and capital stock (a stock-based taxation) in theirs. In our model, maximizing the net profits of the firms located in the home country is equivalent to maximizing the share of the firms; the CIT rate is set to β. In contrast, the tax base externality from the capital stock in Koethenbuerger and Lockwood (2010) and Hatfield (2015) is related to the growth externality from the capitalists' assets. Thus, the tax rate is set for optimal capital accumulation (Alesina and Rodrik 1994).

3.2 Welfare-maximizing policy

At first, we derive the indirect utility function of each country. Consumption per capita in country $r \in \{1,2\}$ is calculated as

$$\begin{aligned} C_r(t) &= \frac{z_r^* N_r(t)}{L_r(N_1(t)+N_2(t))}(N_1(t)+N_2(t)) \\ &= \frac{z_r^*(g_C(\tau_1,\tau_2)^t N_1(0) + g_C(\tau_1,\tau_2)^t N_2(0))}{L_r(1+n_{rs}(\tau_r,\tau_s))}, \quad \text{for} \quad r \neq s. \end{aligned}$$

Therefore, we obtain

$$C_1(t) = \frac{z_1^* g_C(\tau_1,\tau_2)^t}{L_1(1+n_{12}(\tau_1,\tau_2))}(N_1(0)+N_2(0)), \tag{38}$$

$$\begin{aligned} C_2(t) &= \frac{z_2^* g_C(\tau_1,\tau_2)^t}{L_2(1+n_{21}(\tau_2,\tau_1))}(N_1(0)+N_2(0)), \\ &\left(= \frac{n_{12}(\tau_1,\tau_2) z_2^* g_C(\tau_1,\tau_2)^t}{L_2(1+n_{12}(\tau_1,\tau_2))}(N_1(0)+N_2(0)) = \frac{z_1^* g_C(\tau_1,\tau_2)^t}{L_2(1+n_{12}(\tau_1,\tau_2))}(N_1(0)+N_2(0)) \right) \end{aligned} \tag{39}$$

where we normalize $N_r(0)+N_s(0)$ to be 1. Substituting (38) and (39) into (12) yields

$$\begin{aligned} U_1(0) &= \frac{(z_1^*/L_1)^{1-\sigma}\left[1/(1+n_{12}(\tau_1,\tau_2))\right]^{1-\sigma}}{(1-\sigma)\left[1-(1+\rho)^{-1} g_C(\tau_1,\tau_2)^{1-\sigma}\right]}, \\ U_2(0) &= \frac{(z_2^*/L_2)^{1-\sigma}\left[1/(1+n_{21}(\tau_2,\tau_1))\right]^{1-\sigma}}{(1-\sigma)\left[1-(1+\rho)^{-1} g_C(\tau_1,\tau_2)^{1-\sigma}\right]} \quad \left(= \frac{(z_1^*/L_2)^{1-\sigma}\left[1/(1+n_{12}(\tau_1,\tau_2))\right]^{1-\sigma}}{(1-\sigma)\left[1-(1+\rho)^{-1} g_C(\tau_1,\tau_2)^{1-\sigma}\right]} \right), \end{aligned} \tag{40}$$

where $1 > (1+\rho)^{-1} g_C(\tau_1,\tau_2)^{1-\sigma}$ holds by the transversality condition, (14).

3.2.1 Welfare-maximizing condition under tax harmonization (cooperative policy)

Next, we determine the welfare-maximizing condition under tax harmonization. Tax harmonization means that the two government commit to choose the same CIT rate; $\tau_1 = \tau_2 = \tau^h$. In this case, (i) $n_{12} = \varphi^{-1}(1)$ (from (20)) and (ii) $\vartheta_1(\varphi^{-1}(1)) = \vartheta_2(1/\varphi^{-1}(1))$ (from (19)) hold. Substituting (i) and (ii) into (25), (26), (32), (34), and (40), we obtain

$$L_1 U_1^h(0) + L_2 U_2^h(0) = \frac{(z_1^h)^{1-\sigma}\left[1/(1+\varphi^{-1}(1))\right]^{1-\sigma}(L_1^\sigma + L_2^\sigma)}{(1-\sigma)\left[1-(1+\rho)^{-1}(g^h)^{1-\sigma}\right]},$$

where

$$\begin{aligned} z_1^h \equiv z_1^*\left(\tau^h,\tau^h\right) &= \frac{\Phi_1\left(\tau^h,\tau^h\right) - \eta\left[1+\varphi^{-1}(1)\right] g^h}{2}, \\ \Phi_1\left(\tau^h,\tau^h\right) &= \tilde{A}(\phi)\left[1+\varphi^{-1}(1)\right]\left[1-(1-\alpha)\tau^h\right]\left(\tau^h\right)^{\frac{\beta}{1-\beta}} \vartheta_1\left(\varphi^{-1}(1)\right)^{\frac{\alpha-\beta}{1-\beta}}, \\ g^h \equiv g_C\left(\tau^h,\tau^h\right) &= \left[\frac{(1-\alpha)\tilde{A}(\phi)\left(1-\tau^h\right)\left(\tau^h\right)^{\frac{\beta}{1-\beta}} \vartheta_1\left(\varphi^{-1}(1)\right)^{\frac{\alpha-\beta}{1-\beta}}}{\eta(1+\rho)}\right]^{\frac{1}{\sigma}}. \end{aligned}$$

The welfare-maximizing CIT rate under tax harmonization is $\tau^h = \text{argmax}\left[L_1 U_1^h(0) + L_2 U_2^h(0)\right]$. The first order condition is given by

$$\frac{\partial \ln z^h}{\partial \tau^h} + \frac{(1+\rho)^{-1}(g^h)^{1-\sigma}}{1-(1+\rho)^{-1}(g^h)^{1-\sigma}} \frac{\partial \ln g^h}{\partial \tau^h} = 0, \tag{41}$$

where

$$\frac{\partial \ln z^h}{\partial \tau^h} = \frac{\tilde{A}(\phi)\left(\tau^h\right)^{\frac{\beta}{1-\beta}} \vartheta_1\left(\varphi^{-1}(1)\right)^{\frac{\alpha-\beta}{1-\beta}}\left[\frac{\beta}{1-\beta}\frac{1-(1-\alpha)\tau^h}{\tau^h} - (1-\alpha)\right] - \eta g^h \cdot \frac{\partial \ln g^h}{\partial \tau^h}}{\tilde{A}(\phi)\left(\tau^h\right)^{\frac{\beta}{1-\beta}} \vartheta_1\left(\varphi^{-1}(1)\right)^{\frac{\alpha-\beta}{1-\beta}}\left[1-(1-\alpha)\tau^h\right] - \eta g^h}, \tag{42}$$

$$\frac{\partial \ln g^h}{\partial \tau^h} = \frac{\beta - \tau^h}{\sigma(1-\beta)(1-\tau^h)\tau^h}. \tag{43}$$

Equations (41), (42), and (43) lead to the following remark.

Remark 2. *The welfare maximizing CIT rate exists between β and $\frac{\beta}{1-\alpha}$ (i.e., $\beta < \tau^h < \frac{\beta}{1-\alpha}$).*

This result is worth emphasizing. $\tau^h > \tau_r^{GM}$ suggests that growth-maximizing CIT competition does not attain the optimal allocation. Although the growth- and welfare-maximizing tax rates agree with the original model of household income taxation by Barro (1990), our model does not, due to CIT taxation. [6] Therefore, it is insufficient for governments to pursue economic growth in designing CIT policies.

3.2.2 Welfare-maximizing policy without tax harmonization (non-cooperative policy)

We address the welfare-maximizing condition under which each country's government chooses its CIT rate in (40), taking the other country's CIT rate as given.

A Nash equilibrium, denoted by $(\tau_1^{WM}, \tau_2^{WM})$, is an intersection of the best-response functions $\tau_1 = \mathcal{T}_1(\tau_2)$ and $\tau_2 = \mathcal{T}_2(\tau_1)$ defined by

$$\mathcal{T}_r(\tau_s) = \arg\max_{\tau_r} U_r(0) = \frac{(z_r^*/L_r)^{1-\sigma}\left[1/(1+n_{rs}(\tau_r,\tau_s))\right]^{1-\sigma}}{(1-\sigma)\left[1-(1+\rho)^{-1} g_C(\tau_r,\tau_s)^{1-\sigma}\right]},$$

[6] The difference between τ^h and β is owing to a feature of CIT. While a marginal increase in the CIT rate at β has no first-order effect on growth rate, it expands initial consumption. This is because the increase in productive government spending raises labor income, which is exempt from taxation. For more detail, see Proposition 5 and Appendix G of Hori et al. (2022).

$$\text{s.t.} \quad z_r^* = \frac{\Phi_r(\tau_r, \tau_s) - \eta[1 + n_{rs}(\tau_r, \tau_s)]g_C(\tau_r, \tau_s)}{2} \quad \text{and} \quad (20).$$

Thus, we arrive at the following proposition.

Proposition 3. *Suppose that the two countries have a symmetric spillover function (i.e., $\Theta_r = \Theta_s$).*[7] *Then, the CIT rate in the symmetric Nash equilibrium coincides with that under tax harmonization. That is, $\tau_1^{WM} = \tau_2^{WM} = \tau^h$ holds.*

Proof: See Appendix F.

Proposition 3 suggests that the symmetric Nash equilibrium under CIT competition between non-cooperative governments attains the second-best allocation. This result is surprising, considering the usual results in literature, which is that non-coordinated fiscal policies are generally inefficient. In fact, previous studies on dynamic capital tax competition over productive public goods indicate inefficiency. [8]

Consider the mechanism behind the result of Proposition 3. Intuitively, two sources of strategic interactions have opposing effects, and these offset each other. One is the tax base effect; an increase in the CIT rate of the home country induces firms to relocate to the foreign country, the CIT revenue decreases, and consequently, labor income decreases due to the reduction of productive public spending. In view of the tax base effect, non-cooperative governments seek to lower their own CIT rates to keep the firms and secure the CIT revenues.

The other source of strategic interaction is the spillover on productivity; an increase in the number of firms in one country raises the productivity of the other country. Such a positive spillover effect mitigates the opponent's loss due to the relatively high CIT rate. In other words, it dampens the advantage of decreasing the CIT rate.

As shown in Appendix F (the proof of Proposition 3), the two opposing effects offset each other. This stems from the Ricardian households' free trading in the global financial market. As mentioned after Proposition 1, a common world interest rate adjusted by international knowledge spillover and free entry of firms enable households to perfectly secure their consumption against tax changes, equalizing the impacts of the above-mentioned opposing effects.

[7] In this case, $\epsilon_r(n_{rs}) = \epsilon_s(n_{rs}^{-1})$ for all n_{rs}.

[8] Koethenbuerger and Lockwood (2010) show that average growth rate is always higher (lower) under decentralization with deterministic (stochastic) economies. Hatfield (2015) shows that growth rate is higher under a decentralized government.

4 Extension: Myopia and Inequality

In the baseline model, we show that consumption smoothing of Ricardian households makes CIT competition harmless. However, as widely known, myopic households, such as hand-to-mouth consumers, occupy a non-negligible ratio in actual economies. Thus, we can conjecture that CIT competition might have some effect on welfare when governments incorporate the presence of such myopic households.

Therefore, we introduce non-Ricardian (hand-to-mouth) consumers who do not have any financial assets; they just consume their current labor income (Campbell and Mankiw 1989; Mankiw 2000). [9] We assume that a fraction λ of all households are hand-to-mouth consumers (non-Ricardian households), and the rest are Ricardian households in both countries.

4.1 Characterization of the equilibrium

Let $C_r^{NR}(t)$ denote the non-Ricardian's consumption in country $r \in \{1, 2\}$. The other notations of variables and parameters, including Ricardian's consumption ($C_r(t)$), remain unchanged. From (24), aggregate non-Ricardian's consumption in each country is given by

$$C_r^{NR}(t)\lambda L_r (= w_r(t)\lambda L_r) = \lambda\alpha\tilde{A}\tau_r^{\frac{\beta}{1-\beta}}\vartheta_r(n_{rs}(\tau_r, \tau_s))^{\frac{\alpha-\beta}{1-\beta}}N_r(t), \tag{44}$$

while aggregate Ricardian households' budget constraint in two countries is given by

$$\begin{aligned}\sum_{r=1}^{2} W_r(t)(1-\lambda_r)L_r =& R(t-1)\sum_{r=1}^{2} W_r(t-1)(1-\lambda_r)L_r + \sum_{r=1}^{2} w_r(t)(1-\lambda_r)L_r \\ &- \sum_{r=1}^{2} C_r(t)(1-\lambda_r)L_r.\end{aligned} \tag{45}$$

The clearing condition of the asset market, which is (17) in the baseline model, changes into

$$W_1(t-1)(1-\lambda_1)L_1 + W_2(t-1)(1-\lambda_2)L_2 = \eta(N_1(t) + N_2(t)), \tag{46}$$

while (16), (18), (19), (20), (22), (24), (25), (26), (27), and (28) in Section 2.5 remain unchanged.

[9] Other interpretations for non-Ricardian consumers, following Galí et al. (2004), "*include myopia, lack of access to capital markets, fear of saving, ignorance of intertemporal trading opportunities, etc.*"

Therefore, (44) and (45), associated with, (5), (8), (16), (46), (25), (27), (28), and total expenditure of the final goods sector ($E(t) = (1-\alpha)(Y_1(t)+Y_2(t))$) satisfies the final good market clearing condition: $\eta(N_1(t+1)+N_2(t+1)) = Y_1(t)+Y_2(t)-E(t)-(G_1(t)+G_2(t)) - C_1(t)(1-\lambda_1)L_1 - C_1^{NR}(t)\lambda_1 L_1 - C_2(t)(1-\lambda_2)L_2 - C_2^{NR}(t)\lambda_2 L_2$. This is reduced to

$$
\begin{aligned}
\eta \sum_{r=1}^{2} N_r(t+1) = &\sum_{r,s=1,r\neq s}^{2} \tilde{A}(\phi)[(1-\tau_r)(1-\alpha)+(1-\lambda_r)\alpha]\tau_r^{\frac{\beta}{1-\beta}}\vartheta_r(n_{rs}(\tau_r,\tau_s))^{\frac{\alpha-\beta}{1-\beta}} N_r(t) \\
&-\sum_{r=1}^{2} C_r(t)(1-\lambda_2)L_r.
\end{aligned} \tag{47}
$$

Defined as $\tilde{z}_r(t) \equiv C_r(t)(1-\lambda_r)L_r/N_r(t)$ for $r \in \{1,2\}$ and using (19), (26), and (47), we obtain the following dynamic system:

$$
\frac{\tilde{z}_1(t+1)}{\tilde{z}_1(t)} = \frac{\eta\,[1+n_{12}(\tau_1,\tau_2)]\,g_C(\tau_1,\tau_2)}{\tilde{\Phi}_1(\tau_1,\tau_2)-\tilde{z}_1(t)-n_{12}(\tau_1,\tau_2)\tilde{z}_2(t)},
$$

$$
\frac{\tilde{z}_2(t+1)}{\tilde{z}_2(t)} = \frac{\eta\,[1+n_{21}(\tau_2,\tau_1)]\,g_C(\tau_1,\tau_2)}{\tilde{\Phi}_2(\tau_2,\tau_1)-\tilde{z}_2(t)-n_{21}(\tau_2,\tau_1)\tilde{z}_1(t)},
$$

where

$$
\begin{aligned}
\tilde{\Phi}_r(\tau_r,\tau_s) \equiv &\tilde{A}(\phi)\tau_r^{\frac{\beta}{1-\beta}}\vartheta_r(n_{rs}(\tau_r,\tau_s))^{\frac{\alpha-\beta}{1-\beta}}\Big\{[(1-\tau_r)(1-\alpha)+(1-\lambda_r)\alpha] \\
&+[(1-\tau_s)(1-\alpha)+(1-\lambda_s)\alpha]\frac{1-\tau_r}{1-\tau_s}n_{rs}(\tau_r,\tau_s)\Big\}.
\end{aligned}
$$

The extended model exhibits the same dynamic properties as the baseline model.

Proposition 4. *Suppose that*

$$
\tilde{\Phi}_1(\tau_1,\tau_2)-\eta[1+n_{12}(\tau_1,\tau_2)]g_C(\tau_1,\tau_2) > 0.
$$

A unique steady state exists. In the steady state, $z_1(t)$ and $z_2(t)$ take the following constant values:

$$
\begin{aligned}
\tilde{z}_1^* &= \frac{\tilde{\Phi}_1(\tau_1,\tau_2)-\eta[1+n_{12}(\tau_1,\tau_2)]g_C(\tau_1,\tau_2)}{2} \\
\tilde{z}_2^* &= \frac{\tilde{\Phi}_2(\tau_2,\tau_1)-\eta[1+n_{21}(\tau_2,\tau_1)]g_C(\tau_1,\tau_2)}{2}
\end{aligned}
$$

In the steady state, $C_1(t)$, $C_2(t)$, $C_1^{NR}(t)$, $C_2^{NR}(t)$, $N_1(t)$, $N_2(t)$, $Y_1(t)$, and $Y_2(t)$ grow at the same constant rate of $g_C(\tau_1, \tau_2)$ and $C_1(t) = C_2(t)$ holds. The economy jumps to the steady state initially.

4.2 CIT policy by myopic governments

In this subsection, we analyze the welfare consequence of the CIT policies of myopic governments. In addition to considering the utility of non-Ricardian households, we consider another source of government myopia, the term of office. Regardless, non-Ricardian households play an essential role in the main result below.

Suppose that all governors have a finite term of office, T, and they choose a constant CIT rate during their governmental term. Since the system has a recursive structure without predetermined variables, policies in the last governmental term are continued to the next term in turn. Given that, consider the case where a governmental term starts at an initial period, $t = 0$. The objective of the government which begins at period υ and ends in $\upsilon + T$ is given by

$$\begin{aligned}\mathcal{W}_r(\upsilon) =& \lambda \sum_{t=\upsilon}^{\upsilon+T} \varrho^{t-\upsilon} \frac{C_r^{NR}(\upsilon)^{1-\sigma}}{1-\sigma} + (1-\lambda) \sum_{t=\upsilon}^{\upsilon+T} \varrho^{t-\upsilon} \frac{C_r(t)^{1-\sigma}}{1-\sigma} \\ =& \left\{ \lambda \left[\alpha \tilde{A} \tau_r^{\frac{\beta}{1-\beta}} \vartheta_r(n_{rs}(\tau_r, \tau_s))^{\frac{\alpha-\beta}{1-\beta}} \left(\frac{N_r(\upsilon)+N_s(\upsilon)}{1+n_{rs}(\tau_r,\tau_s)} \right) \right]^{1-\sigma} + (1-\lambda) \left[\frac{\tilde{z}_r^*(N_r(\upsilon)+N_s(\upsilon))}{1+n_{rs}(\tau_r,\tau_s)} \right]^{1-\sigma} \right\} \\ & \times \frac{1}{1-\sigma} \left[\frac{1 - \varrho g_C(\tau_r, \tau_s)^{1-\sigma} (\varrho g_C(\tau_r, \tau_s)^{1-\sigma})^T}{1 - \varrho g_C(\tau_r, \tau_s)^{1-\sigma}} \right], \end{aligned} \tag{48}$$

where $\varrho = \frac{1}{1+\rho}$ and recall that $1 > (1+\rho)^{-1} g_C(\tau_r, \tau_s)^{1-\sigma} = \varrho g_C(\tau_r, \tau_s)^{1-\sigma}$. The government take the total number of firms at the beginning of its governmental term, $N_r(\upsilon) + N_s(\upsilon)$, as given. We assume that $L_1 = L_2 = 1$, $\lambda_1 = \lambda_2 = \lambda$, and T is common to both countries.

4.2.1 The role of the non-Ricardian household

First, let us consider the limiting case of $T = +\infty$, the case of the infinite planning horizon. To gain the basic intuition for the main results (the numerical results in Section 4.2.3), we begin with a tractable case where the government only has interest in non-Ricardian households. [10] In

[10] This is interpreted as the case where the non-Ricardian households are the majority in the economies and the policies are chosen according to the median-voting scheme.

this case, the governments set $\lambda = 1$ in (48). In addition, we set $\sigma = 1$ for simplicity. Then, the objective function of the government is given by

$$U_0 = \sum_{t=0}^{+\infty} \varrho^t \ln (C_0^{NR} g_C^t) = (1-\varrho)^{-2} \left[(1-\varrho) \ln C_0^{NR} + \varrho \ln g_C \right], \tag{49}$$

$$\text{where} \qquad \ln C_0^{NR} = \frac{\beta}{1-\beta} \ln \tau_r + \frac{\alpha-\beta}{1-\beta} \ln \vartheta_r(n_{rs}(\tau_r, \tau_s)) - \ln (1 + n_{rs}(\tau_r, \tau_s)) + \text{const.}, \tag{50}$$

$$\ln g_C = \ln (1-\tau_r) + \frac{\beta}{1-\beta} \ln \tau_r + \frac{\alpha-\beta}{1-\beta} \ln \vartheta_r(n_{rs}(\tau_r, \tau_s)) + \text{const.} \tag{51}$$

Consider the policy regime of tax harmonization. That is, the two governments choose the same CIT rate, say, $\tau_r = \tau_s (= \tau^h)$. Then, the ratio n_{rs} sticks to 1, and the term of spillover, ϑ_r, is independent of the CIT rate. Using this fact, (50) and (51) are reduced to

$$\ln C_0^{NR} = \frac{\beta}{1-\beta} \ln \tau^h + \text{const.},$$
$$\ln g_C = \ln (1-\tau^h) + \frac{\beta}{1-\beta} \ln \tau^h + \text{const.}$$

Thus, substituting these into (49), the first-order condition for each government is

$$(1-\varrho) \frac{\beta}{1-\beta} \frac{1}{\tau^h} + \varrho \left(-\frac{1}{1-\tau^h} + \frac{\beta}{1-\beta} \frac{1}{\tau^h} \right) = 0, \tag{52}$$

which leads to $\tau^h = \frac{\beta}{\beta + \varrho(1-\beta)} > \beta$.

Next, consider the case of the CIT competition, where the government of country r maximizes (49) with respect to τ_r with τ_s given. The marginal effect of raising τ_r is

$$\begin{aligned} \frac{\partial U_0}{\partial \tau_r} = (1-\varrho) & \left(\frac{\beta}{1-\beta} \frac{1}{\tau_r} + \frac{\alpha-\beta}{1-\beta} \frac{\vartheta_r'}{\vartheta_r} \frac{\partial n_{rs}}{\partial \tau_r} - \frac{1}{1+n_{rs}} \frac{\partial n_{rs}}{\partial \tau_r} \right) \\ & + \varrho \left(-\frac{1}{1-\tau_r} + \frac{\beta}{1-\beta} \frac{1}{\tau_r} + \frac{\alpha-\beta}{1-\beta} \frac{\vartheta_r'}{\vartheta_r} \frac{\partial n_{rs}}{\partial \tau_r} \right). \end{aligned} \tag{53}$$

Equation (53) provides an important insight. The first order condition under harmonization policy, (52), tell us that the effect of the CIT competition is captured by the terms containing $\frac{\partial n_{rs}}{\partial \tau_r}$: Raising τ_r stimulates the firms to relocate to the foreign country, $\frac{\partial n_{rs}}{\partial \tau_r} > 0$, when $\tau_r > \beta$. An increase in the CIT rate has two opposing effects on the welfare of the home country, r. One is the positive spillover effect, $\frac{\alpha-\beta}{1-\beta}\frac{\vartheta_r'}{\vartheta_r}\frac{\partial n_{rs}}{\partial \tau_r} > 0$. That is, an increase in the number of the firms located at the foreign country raises the productivity of the home country through international spillover. The other is the tax base effect, $-\frac{1}{1+n_{rs}}\frac{\partial n_{rs}}{\partial \tau_r} < 0$. A decrease in the share of the firms reduces the tax revenue and, consequently, the productive government spending, which lowers labor income.

Evaluating (53) at $\tau_r = \tau_s = \tau^h$ and using (52), we obtain

$$\left.\frac{\partial U_0}{\partial \tau_r}\right|_{\tau_r=\tau_s=\tau^h} = \frac{\partial n_{rs}}{\partial \tau_r}\left(\frac{\alpha-\beta}{1-\beta}\frac{\vartheta_r'}{\vartheta_r} - \frac{1-\varrho}{2}\right),$$

where we use $n_{rs} = 1$ at $\tau_r = \tau_s = \tau^h$. Therefore, since $\frac{\partial n_{rs}}{\partial \tau_r} > 0$ by $\tau^h > \beta$, the government chooses a tax rate lower (higher) than τ_h in the Nash equilibrium if

$$\left.\frac{\vartheta_r'}{\vartheta_r}\right|_{n_{rs}=1} < (>)\frac{1-\varrho}{2}\frac{1-\beta}{\alpha-\beta}. \tag{54}$$

Inequality (54) suggests that if the elasticity of the spillover effect to n_{rs} is small, the governments choose a low CIT rate in equilibrium. Intuitively, this is because the contribution from cutting the CIT rate (the tax base effect) dominates the benefit of the international spillover.

Finally, we notice that the role of the Ricardian household in this extended model is similar to that in the baseline model. That is, when the non-Ricardian household is absent ($\lambda = 0$), the CIT rate set in the Nash equilibrium coincides with that in the harmonization, even if the governments' planning horizon is finite:

Remark 3. *If $\lambda = 0$, then $\tau^{WM} = \tau^h$ for any terms of office, T.*

Of course, this result also holds when the government is interested only in the welfare of the Ricardian household. This remark suggests that the source of the difference between τ^{WM} and τ^h in this extended model, which is numerically explored in Section 4.2.2, is the existence of the non-Ricardian household.

4.2.2 Calibration

For general cases of $\lambda \in (0, 1)$, we can obtain no analytical results. Therefore, we conduct some numerical exercises with a calibrated model.

Following Galí et al. (2004), we set $\lambda = 0.5$ for the benchmark case. The degree of relative risk aversion, σ, and the subjective discount rate, ρ, are set to 1.5 and $\frac{1}{0.95} - 1$, respectively, according to the standard calibration of growth models (Jones et al. 1993). The gross markup rate of intermediate good firms is $\frac{1}{\alpha}$. Thus, we set $\alpha = \frac{1}{1+0.2}$, adopting 20% as a standard value of the net markup rate (Rotemberg and Woodford 1999). Following some empirical works on productive government spending, the aggregate output elasticity of public service, β, is set to 0.1. See Bom and Ligthart (2014) and Calderón et al. (2015). The curvature of the production function of intermediate good firms, γ, is pinned down by the relationship $\beta = \alpha\gamma$.

Assuming the standard value of the growth rate to be 2%, we set the entry cost of intermediate good firms, η, as follows. Since the long-run growth rate depends on the CIT rate in this model as well as η, we have to choose a standard value for the CIT rate. We choose 0.27 for the standard CIT rate, because this is the average CIT rate across OECD countries from 1997 to 2021, according to *Corporate Tax Around the World* (2021), which is one of the widest databases on CIT rates. Normalizing the productivity of intermediate good firms to 1, we control the entry cost η such that the resulting growth rate on the balanced growth path is equal to 2%.

Finally, we specify the spillover function, Θ_r, by $\Theta_r(N_r, N_s) = B(N_r + \delta N_s)$, where $B > 0$ and $\delta \geq 0$ are given constants. Note that δ measures the strength of international knowledge spillover. In this case, we can find that $\varphi(n_{rs}) = \frac{n_{rs}-1+\sqrt{(n_{rs}-1)^2+4\delta^2 n_{rs}}}{2\delta}$ and $\epsilon_r(n_{rs}) = \frac{\delta n_{rs}}{1+\delta n_{rs}}$.

4.2.3 Numerical results

At first, focusing on the case of $T = +\infty$, we explore how the existence of rule-of-thumb households affect the result in Proposition 3; the symmetric Nash equilibrium under the CIT competition attains the second-best allocation. Figure 3 illustrates the result.

[Figure 3 is inserted here.]

The CIT rate in the Nash equilibrium, τ^{WM}, is higher than that under tax harmonization, τ^h, when rule-of-thumb households exist, $\lambda > 0$. This is because the gain from the positive spillover effect dominates the loss from the decrease in labor income due to the tax base effect in the calibrated model. See (54). Clearly, the larger the share of the rule-of-thumb household, the stronger this effect. Thus, the difference between τ^{WM} and τ^h increases in λ, as shown in Figure 3.

Next, we analyze the role of finite terms of office, $T < +\infty$. The qualitative results depend on

δ, the degree of spillover effect. Figure 4 shows the relationship between T and the equilibrium CIT rates under harmonization and Nash equilibrium when the spillover effect is weak ($\delta = 0.25$).

[Figure 4 is inserted here.]

In this case, τ^{WM} is lower than τ^h if the terms of office is short (T is small). In contrast, it is not true when the spillover effect is strong ($\delta = 1$), as illustrated in Figure 5. $\tau^{WM} > \tau^h$ holds for any T.

[Figure 5 is inserted here.]

Besides, when the spillover effect is extremely weak ($\delta = 0.05$), the inequality can be reversed as seen in Figure 6. $\tau^{WM} < \tau^h$ holds for any T. This result corresponds to one of the two cases in (54).

[Figure 6 is inserted here.]

These results seem initially complicated but are intuitively plausible. Setting a low CIT rate induces firms to remain located at the home country, and it enlarges the tax base for productive government spending. This increases the labor income of households in the home country; this is the tax base effect. Therefore, lowering the CIT rate is valuable when the international knowledge spillover is weak, i.e., δ is small. In particular, non-cooperative governments with a short planning horizon celebrate the short-run benefit from a rise in labor income and give priority to the tax base effect. This leads to a low equilibrium CIT rate with a small T under a weak spillover effect (Figure 4).

5 Concluding Remark

Using a two-country model of endogenous growth with international knowledge spillover, we show that the symmetric Nash equilibrium under the global CIT competition attains the second-best allocation by tax harmonization. This result stems from the international knowledge spillover and free trading by Ricardian households in the global financial market.

However, as widely known, many non-Ricardian households exist. Therefore, our results further suggest that in the presence of non-Ricardian households, CIT competition does not attain optimal allocation. Since the equilibrium CIT rate can be too high or low, depending on the elasticity of international knowledge spillover to firm locations, it is not so easy to evaluate the face value of the real CIT rates adopted globally. Even so, these results direct questions at the seemingly dominant view that global CIT competition will lead to excessively low CIT rates.

Appendix

A Derivation of (28)

Substituting (5), (16), (19), (27) (with $\beta \equiv \alpha\gamma$ and $\tilde{A}(\phi) \equiv \left\{(1+\phi^\alpha)^{1-\alpha} A^\alpha \alpha (1-\alpha)^\beta\right\}^{\frac{1}{1-\beta}}$) into (4) yields

$$
\begin{aligned}
x_{r,r}(t)^\alpha &= A^\alpha \left[\frac{G_r(t)^\gamma N_r(t)^{1-\gamma} \vartheta_r(n_{rs}(\tau_r,\tau_s))^{1-\gamma}}{(1+\phi^\alpha)N_r(t)}\right]^\alpha \\
&= (1+\phi^\alpha)^{-\alpha} A^\alpha \left(G_r(t)/N_r(t)\right)^\beta \vartheta\left(n_{rs}(\tau_r,\tau_s)\right)^{\alpha-\beta} \\
&= (1+\phi^\alpha)^{-\alpha} A^\alpha \left(\tau_r \pi_r(\tau_r,\tau_s)\right)^\beta \vartheta\left(n_{rs}(\tau_r,\tau_s)\right)^{\alpha-\beta} \\
&= (1-\alpha)^\beta (1+\phi^\alpha)^{-\alpha} A^\alpha \tilde{A}(\phi)^\beta \tau_r^{\frac{\beta}{1-\beta}} \vartheta_r(n_{rs}(\tau_r,\tau_s))^{\frac{\alpha-\beta}{1-\beta}} \\
&= \frac{\tilde{A}(\phi)}{(1+\phi^\alpha)\alpha} \tau_r^{\frac{\beta}{1-\beta}} \vartheta_r(n_{rs}(\tau_r,\tau_s))^{\frac{\alpha-\beta}{1-\beta}} \qquad \text{(A.1)}
\end{aligned}
$$

This combined with ($x_{r,s}(t) = \phi x_{r,r}(t)$) gives

$$
x_{r,s}(t)^\alpha = \frac{\phi^\alpha \tilde{A}(\phi)}{(1+\phi^\alpha)\alpha} \tau_r^{\frac{\beta}{1-\beta}} \vartheta_r(n_{rs}(\tau_r,\tau_s))^{\frac{\alpha-\beta}{1-\beta}}, \quad r \neq s. \qquad \text{(A.2)}
$$

Inserting (A.1) (A.2) into (1), we have

$$
\begin{aligned}
Y_1(t) &= N_1(t) x_{1,1}(t)^\alpha + N_2 x_{2,1}(t)^\alpha \\
&= \frac{\tilde{A}(\phi)}{(1+\phi^\alpha)\alpha} \left[\tau_1^{\frac{\beta}{1-\beta}} \vartheta_1(n_{12}(\tau_1,\tau_2))^{\frac{\alpha-\beta}{1-\beta}} N_1(t) + \phi^\alpha \tau_2^{\frac{\beta}{1-\beta}} \vartheta_2(n_{21}(\tau_2,\tau_1))^{\frac{\alpha-\beta}{1-\beta}} N_2(t)\right], \quad \text{(A.3)} \\
Y_2(t) &= \frac{\tilde{A}(\phi)}{(1+\phi^\alpha)\alpha} \left[\tau_2^{\frac{\beta}{1-\beta}} \vartheta_2(n_{21}(\tau_2,\tau_1))^{\frac{\alpha-\beta}{1-\beta}} N_2(t) + \phi^\alpha \tau_1^{\frac{\beta}{1-\beta}} \vartheta_1(n_{12}(\tau_1,\tau_2))^{\frac{\alpha-\beta}{1-\beta}} N_1(t)\right]. \quad \text{(A.4)}
\end{aligned}
$$

From (A.3) and (A.4), we obtain (28).

B Derivation of the final good market clearing condition and (29)

From (28), the aggregate final goods production in the two countries is given by

$$
Y_1(t) + Y_2(t) = \frac{\tilde{A}(\phi)}{\alpha} \left[\tau_1^{\frac{\beta}{1-\beta}} \vartheta_1(n_{12}(\tau_1,\tau_2))^{\frac{\alpha-\beta}{1-\beta}} N_1(t) + \tau_2^{\frac{\beta}{1-\beta}} \vartheta_2(n_{21}(\tau_2,\tau_1))^{\frac{\alpha-\beta}{1-\beta}} N_2(t)\right]. \quad \text{(B.1)}
$$

From (24) and (B.1), we have

$$w_1(t)L_1 + w_2(t)L_2 = \alpha \tilde{A}(\phi)\left[\tau_1^{\frac{\beta}{1-\beta}}\vartheta_1(n_{12}(\tau_1,\tau_2))^{\frac{\alpha-\beta}{1-\beta}}N_1(t) + \tau_2^{\frac{\beta}{1-\beta}}\vartheta_2(n_{21}(\tau_2,\tau_1))^{\frac{\alpha-\beta}{1-\beta}}N_2(t)\right]$$
$$= \alpha^2(Y_1(t) + Y_2(t)) \tag{B.2}$$

Equations (17) and (25) leads to

$$R(W_1(t-1)L_1 + W_2(t-1)L_2) = R\eta(N_1(t) + N_2(t)) = (1-\tau_1)\pi_1 N_1(t) + (1-\tau_2)\pi_2 N_2(t). \tag{B.3}$$

This equation (B.3) together with (15), (22), and (B.1) yields

$$R(W_1(t-1)L_1 + W_2(t-1)L_2)$$
$$= (1-\alpha)\tilde{A}(\phi)\left[\tau_1^{\frac{\beta}{1-\beta}}\vartheta_1(n_{12}(\tau_1,\tau_2))^{\frac{\alpha-\beta}{1-\beta}}N_1(t) + \tau_2^{\frac{\beta}{1-\beta}}\vartheta_2(n_{21}(\tau_2,\tau_1))^{\frac{\alpha-\beta}{1-\beta}}N_2(t)\right] - G_1(t) - G_2(t)$$
$$= (1-\alpha)\alpha(Y_1(t) + Y_2(t)) - (G_1(t) + G_2(t)) \tag{B.4}$$

Substituting (B.2), (B.4), and (17) into the sum of the total household budget constraint in the two countries, $W_1(t)L_1 + W_2(t)L_2 = R[W_1(t-1)L_1 + W_2(t-1)L_2] + w_1(t)L_1 + w_2(t)L_2 - C_1(t)L_1 - C_2(t)L_2$, we obtain

$$\eta(N_1(t+1) + N_2(t+1)) = \alpha(Y_1(t) + Y_2(t)) - (G_1(t) + G_2(t)) - C_1(t)L_1 - C_2(t)L_2$$
$$= Y_1(t) + Y_2(t) - E_1(t) - E_2(t) - (G_1(t) + G_2(t)) - C_1(t)L_1 - C_2(t)L_2,$$

where total sunk cost of final goods sector is $E_1(t) + E_2(t) = (1-\alpha)(Y_1(t) + Y_2(t))$. Thus, we obtain the final good market clearing condition:

$$\eta(N_1(t+1) + N_2(t+1)) = \alpha(Y_1(t) + Y_2(t)) - (G_1(t) + G_2(t)) - C_1(t)L_1 - C_2(t)L_2. \tag{B.5}$$

Using (28) and (27), (B.5) is rewritten into

$$\begin{aligned}
&\eta(N_1(t+1)+N_2(t+1)) \\
&= \tilde{A}(\phi)\left[[1-(1-\alpha)\tau_1]\tau_1^{\frac{\beta}{1-\beta}}\vartheta_1(n_{12}(\tau_1,\tau_2))^{\frac{\alpha-\beta}{1-\beta}}N_1(t)+[1-(1-\alpha)\tau_2]\tau_2^{\frac{\beta}{1-\beta}}\vartheta_2(n_{21}(\tau_2,\tau_1))^{\frac{\alpha-\beta}{1-\beta}}N_2(t)\right] \\
&\quad - C_1(t)L_1 - C_2(t)L_2.
\end{aligned}$$

Thus, we obtain (29).

C Derivation of the dynamic system (30) and (31)

Dividing (29) by $N_1(t)$ and using $z_1(t) \equiv \frac{C_1(t)L_1}{N_1(t)}$ and $\frac{C_2(t)L_2}{N_1(t)} = \frac{C_2(t)L_2}{N_2(t)} \cdot \frac{N_2(t)}{N_1(t)} = \frac{N_2(t)}{N_1(t)}z_2(t)$, we obtain

$$\begin{aligned}
&\eta\left[1+n_{12}(\tau_1,\tau_2)\right]\frac{N_1(t+1)}{N_1(t)} \\
&= \tilde{A}(\phi)\left[[1-(1-\alpha)\tau_1]\tau_1^{\frac{\beta}{1-\beta}}\vartheta_1(n_{12}(\tau_1,\tau_2))^{\frac{\alpha-\beta}{1-\beta}}+[1-(1-\alpha)\tau_2]\tau_2^{\frac{\beta}{1-\beta}}\vartheta_2(n_{21}(\tau_2,\tau_1))^{\frac{\alpha-\beta}{1-\beta}}n_{12}(\tau_1,\tau_2)\right] \\
&\quad - z_1(t) - n_{12}(\tau_1,\tau_2)z_2(t) \qquad \text{(C.1)}
\end{aligned}$$

Applying (19) to (C.1), we obtain

$$\frac{N_1(t+1)}{N_1(t)} = \frac{\Phi_1(\tau_1,\tau_2)-z_1(t)-n_{12}(\tau_1,\tau_2)z_2(t)}{\eta\left[1+n_{12}(\tau_1,\tau_2)\right]}. \qquad \text{(C.2)}$$

Next, dividing (29) by $N_2(t)$ and conducting the same calculation as for country 2, we obtain

$$\frac{N_2(t+1)}{N_2(t)} = \frac{\Phi_2(\tau_2,\tau_1)-z_2(t)-n_{21}(\tau_2,\tau_1)z_1(t)}{\eta\left[1+n_{21}(\tau_2,\tau_1)\right]} \qquad \text{(C.3)}$$

Using (C.2) and (C.3) together with (26), we obtain (30) and (31).

D Proof of Proposition 1

From (30) $z_1(t+1) = z_1(t)$ locus is given by

$$z_1(t) = \Phi_1(\tau_1,\tau_2) - \eta\left[1+n_{12}(\tau_1,\tau_2)\right]g_C(\tau_1,\tau_2) - n_{12}(\tau_1,\tau_2)z_2(t). \qquad \text{(D.1)}$$

From (31), $z_2(t+1) = z_2(t)$ locus is given by

$$z_2(t) = \Phi_2(\tau_2, \tau_1) - \eta\left[1 + n_{21}(\tau_2, \tau_1)\right] g_C(\tau_1, \tau_2) - n_{21}(\tau_2, \tau_1) z_1(t). \tag{D.2}$$

Here, we can show the following relationship:

$$\Phi_1(\tau_1, \tau_2) n_{21}(\tau_2, \tau_1) = \Phi_2(\tau_2, \tau_1) \quad (\Leftrightarrow \Phi_2(\tau_2, \tau_1) n_{12}(\tau_1, \tau_2) = \Phi_1(\tau_1, \tau_2)). \tag{D.3}$$

By using (32) and (19) with $n_{12}(\tau_1, \tau_2)^{-1} = n_{21}(\tau_1, \tau_2)$ (or $n_{21}(\tau_1, \tau_2)^{-1} = n_{12}(\tau_1, \tau_2)$), we can transform the left-hand side of (D.3) into

$$\begin{aligned}
&\Phi_1(\tau_1, \tau_2) n_{21}(\tau_2, \tau_1) \\
&= \tilde{A}(\phi) \tau_1^{\frac{\beta}{1-\beta}} \vartheta_1(n_{12}(\tau_1, \tau_2))^{\frac{\alpha-\beta}{1-\beta}} \left\{ 1 - (1-\alpha)\tau_1 + [1 - (1-\alpha)\tau_2] \frac{1-\tau_1}{1-\tau_2} n_{12}(\tau_1, \tau_2) \right\} n_{21}(\tau_2, \tau_1) \\
&= \tilde{A}(\phi) \tau_1^{\frac{\beta}{1-\beta}} \vartheta_1(n_{12}(\tau_1, \tau_2))^{\frac{\alpha-\beta}{1-\beta}} \left\{ [1 - (1-\alpha)\tau_1] n_{21}(\tau_2, \tau_1) + [1 - (1-\alpha)\tau_2] \frac{1-\tau_1}{1-\tau_2} \right\} \\
&= \tilde{A}(\phi) \tau_1^{\frac{\beta}{1-\beta}} \frac{1-\tau_2}{1-\tau_1} \left(\frac{\tau_2}{\tau_1} \right)^{\frac{\beta}{1-\beta}} \vartheta_2(n_{21}(\tau_1, \tau_2))^{\frac{\alpha-\beta}{1-\beta}} \left\{ [1 - (1-\alpha)\tau_1] n_{21}(\tau_2, \tau_1) + [1 - (1-\alpha)\tau_2] \frac{1-\tau_1}{1-\tau_2} \right\} \\
&= \tilde{A}(\phi) \tau_2^{\frac{\beta}{1-\beta}} \vartheta_2(n_{21}(\tau_1, \tau_2))^{\frac{\alpha-\beta}{1-\beta}} \left\{ [1 - (1-\alpha)\tau_1] \frac{1-\tau_2}{1-\tau_1} n_{21}(\tau_2, \tau_1) + 1 - (1-\alpha)\tau_2 \right\} \\
&= \Phi_2(\tau_2, \tau_1).
\end{aligned}$$

Thus, $z_1(t+1) = z_1(t)$ and $z_2(t+1) = z_2(t)$ loci are the lines with negative slope that take the following common values:

$$\begin{aligned}
z_1(t) &= \Phi_1(\tau_1, \tau_2) - \eta[1 + n_{12}(\tau_1, \tau_2)] g_C(\tau_1, \tau_2) \text{ when } z_2(t) = 0 \\
z_2(t) &= \Phi_2(\tau_2, \tau_1) - \eta[1 + n_{21}(\tau_2, \tau_1)] g_C(\tau_1, \tau_2) \text{ when } z_1(t) = 0.
\end{aligned}$$

Thus, $z_1(t+1) = z_1(t)$ locus and $z_2(t+1) = z_2(t)$ locus intersect in z_2-z_1 plane as depicted in Figure 2. Furthermore, from (D.1) and (D.2), associated with $n_{12}(\tau_1, \tau_2)^{-1} = n_{21}(\tau_1, \tau_2)$ ($n_{21}(\tau_1, \tau_2)^{-1} = n_{12}(\tau_1, \tau_2)$) and $\Phi_1(\tau_1, \tau_2) n_{21}(\tau_2, \tau_1) = \Phi_2(\tau_2, \tau_1)$ ($\Phi_2(\tau_2, \tau_1) n_{12}(\tau_1, \tau_2) = \Phi_1(\tau_1, \tau_2)$), we obtain the following relationship between $z_1(t)$ and $z_2(t)$ in the steady state:

$$z_1^* = n_{12}(\tau_1, \tau_2) z_2^* \qquad (\Leftrightarrow z_2^* = n_{21}(\tau_2, \tau_1) z_1^*) \tag{D.4}$$

Substituting (D.4) into (D.1) and (D.2), we obtain (34) and (35). Thus, $z_1^* > 0$ if and only if (33) hold. From (D.4), (33) also ensures $z_2^* > 0$.

[Figure 2 is inserted here.]

Next, we prove that the steady state (z_1^*, z_2^*) is unstable and the economy must be in the steady state (z_1^*, z_2^*) initially. From (30) and (31), $z_1(t+1)/z_1(t) \gtreqless 1$ if and only if

$$z_1(t) \gtreqless \Phi(\tau_1, \tau_2) - \eta\left[1 + n_{12}(\tau_1, \tau_2)\right] g_C(\tau_1, \tau_2) - n_{12}(\tau_1, \tau_2) z_2(t)$$

and $z_2(t+1)/z_2(t) \gtreqless 1$ if and only if

$$z_2(t) \gtreqless \Phi(\tau_2, \tau_1) - \eta\left[1 + n_{21}(\tau_2, \tau_1)\right] g_C(\tau_1, \tau_2) - n_{21}(\tau_2, \tau_1) z_1(t)$$

If $(z_1(t), z_2(t))$ is above the $z_1(t+1) = z_1(t)$ locus ($z_2(t+1) = z_2(t)$ locus), both $z_1(t)$ and $z_2(t)$ explode and both $N_1(t)$ and $N_2(t)$ eventually equal to zero from (C.2) and (C.3). When $N_1(t) = N_2(t) = 0$, both $Y_1(t) = Y_2(t) = 0$ and $C_1(t) = C_2(t) = 0$ occur, which violates the first-order conditions of the representative household. By contrast, if $(z_1(t), z_2(t))$ is below the $z_1(t+1) = z_1(t)$ locus ($z_2(t+1) = z_2(t)$ locus), both $z_1(t)$ and $z_2(t)$ eventually equals to zero. From $C_1(t) = z_1(t)N_1(t)/L_1$ and $C_2(t) = z_2(t)N_2(t)/L_2 = z_2(t)n_{12}(\tau_1, \tau_2)N_1(t)/L_2$, $z_1(t) = z_2(t) = 0$ leads to $C_1(t) = C_2(t) = 0$, which violate the first-order conditions of the representative household. Finally, any combinations of $(z_1(t), z_2(t))$ on the $z_1(t+1) = z_1(t)$ locus ($z_2(t+1) = z_2(t)$ locus) other than (z_1^*, z_2^*) do not satisfy the static equilibrium condition (D.4). Therefore, both $z_1(t)$ and $z_2(t)$ jump to the steady state values initially.

This fact, together with (D.4), shows that $C_1(t) = C_2(t)$ holds because $z_1^* = n_{12}(\tau_1, \tau_2) z_2^* \Leftrightarrow \frac{C_1(t)}{N_1(t)} = \frac{N_2(t)}{N_1(t)} \frac{C_2(t)}{N_2(t)} \Leftrightarrow C_1(t) = C_2(t)$.

E Derivation of (36)

From (25) and (26), we have

$$\frac{\partial g_C(\tau_r, \tau_s)}{\partial \tau_r} = \frac{g_C(\tau_r, \tau_s)}{\sigma(1-\beta)} \left[\frac{\beta - \tau_r}{(1-\tau_r)\tau_r} + (\alpha - \beta) \frac{\vartheta'(n_{rs})}{\vartheta(n_{rs})} \frac{\partial n_{rs}}{\partial \tau_r}\right]. \tag{E.1}$$

From (20), the derivative of n_{rs} with respect to τ_r is

$$\frac{\partial n_{rs}}{\partial \tau_r} = \frac{\varphi(n_{rs})}{\varphi'(n_{rs})}\frac{\tau_r - \beta}{(\alpha-\beta)\tau_r(1-\tau_r)}. \tag{E.2}$$

Substituting (E.2) into (E.1), we obtain

$$\frac{\partial g_C(\tau_r,\tau_s)}{\partial \tau_r} = \frac{g_C(\tau_r,\tau_s)}{\sigma(1-\beta)}\left[1-\frac{\varphi(n_{rs})\vartheta'(n_{rs})}{\varphi'(n_{rs})\vartheta(n_{rs})}\right]\frac{\beta-\tau_r}{(1-\tau_r)\tau_r}. \tag{E.3}$$

From (21) and $\varphi(n_{rs}) \equiv \vartheta_r(n_{rs})/\vartheta_s(n_{rs}^{-1})$, we obtain

$$\frac{\varphi(n_{rs})\vartheta'(n_{rs})}{\varphi'(n_{rs})\vartheta(n_{rs})} = \frac{\epsilon_r(n_{rs})}{\epsilon_r(n_{rs})+\epsilon_s(n_{rs}^{-1})}. \tag{E.4}$$

By (E.3) and (E.4), we obtain (36).

F Proof of Proposition 3

By $\frac{\partial U_r(0)}{\partial \tau_r} = U_r(0)\frac{\partial \ln U_r(0)}{\partial \tau_r}$, we have

$$\begin{aligned}\frac{\partial U_r(0)}{\partial \tau_r} =& \frac{(z_r^*/L_r)^{1-\sigma}\left[1/(1+n_{rs}(\tau_r,\tau_s))\right]^{1-\sigma}}{1-(1+\rho)^{-1}g_C(\tau_r,\tau_s)^{1-\sigma}} \\ &\times\left[\frac{\partial \ln z_r^*}{\partial \tau_r} - \frac{n_{rs}(\tau_r,\tau_s)}{1+n_{rs}(\tau_r,\tau_s)}\frac{\partial \ln n_{rs}}{\partial \tau_r} + \frac{(1+\rho)^{-1}g_C(\tau_r,\tau_s)^{1-\sigma}}{1-(1+\rho)^{-1}g_C(\tau_r,\tau_s)^{1-\sigma}}\frac{\partial \ln g_C}{\partial \tau_r}\right].\end{aligned}$$

Because of $1-(1+\rho)^{-1}g_C(\tau_r,\tau_s)^{1-\sigma} > 0$, we obtain

$$\text{sign}\frac{\partial U_r(0)}{\partial \tau_r} = \text{sign}\left[\frac{\partial \ln z_r^*}{\partial \tau_r} - \frac{n_{rs}(\tau_r,\tau_s)}{1+n_{rs}(\tau_r,\tau_s)}\frac{\partial \ln n_{rs}}{\partial \tau_r} + \frac{(1+\rho)^{-1}g_C(\tau_r,\tau_s)^{1-\sigma}}{1-(1+\rho)^{-1}g_C(\tau_r,\tau_s)^{1-\sigma}}\frac{\partial \ln g_C}{\partial \tau_r}\right], \tag{F.1}$$

where

$$\frac{\partial \ln z_r^*}{\partial \tau_r} = \frac{\frac{\partial \Phi_r(\tau_r,\tau_s)}{\partial \tau_r} - \eta g_C(\tau_r,\tau_s)\frac{\partial n_{rs}}{\partial \tau_r} - [1+n_{rs}(\tau_r,\tau_s)]\eta g_C(\tau_r,\tau_s)\frac{\partial \ln g_C}{\partial \tau_r}}{\Phi_r(\tau_r,\tau_s) - [1+n_{rs}(\tau_r,\tau_s)]\eta g_C(\tau_r,\tau_s)},$$

$$\begin{aligned}\frac{\partial \Phi_r}{\partial \tau_r} =& \tilde{A}(\phi)\tau_r^{\frac{\beta}{1-\beta}}\vartheta_r(n_{rs})^{\frac{\alpha-\beta}{1-\beta}}\left[\frac{\beta}{(1-\beta)\tau_r}+\frac{\alpha-\beta}{1-\beta}\frac{\vartheta_r'(n_{rs})}{\vartheta_r(n_{rs})}\frac{\partial n_{rs}}{\partial \tau_r}\right]\\ &\times\left\{1-(1-\alpha)\tau_r+[1-(1-\alpha)\tau_s]\frac{1-\tau_r}{1-\tau_s}n_{rs}\right\}+\tilde{A}(\phi)\tau_r^{\frac{\beta}{1-\beta}}\vartheta_r(n_{rs})^{\frac{\alpha-\beta}{1-\beta}}\\ &\times\left\{-(1-\alpha)-\frac{1-(1-\alpha)\tau_s}{1-\tau_s}n_{rs}+[1-(1-\alpha)\tau_s]\frac{1-\tau_r}{1-\tau_s}\frac{\partial n_{rs}}{\partial \tau_r}\right\}. \end{aligned} \tag{F.2}$$

By (E.2), the term $\frac{\alpha-\beta}{1-\beta}\frac{\vartheta_r'(n_{rs})}{\vartheta_r(n_{rs})}\frac{\partial n_{rs}}{\partial \tau_r}$ in (F.2) is reduced to $\frac{\varphi(n_{rs})\vartheta'(n_{rs})}{\varphi'(n_{rs})\vartheta(n_{rs})}\frac{\tau_r-\beta}{(1-\tau_r)\tau_r(1-\beta)}$. From (E.4), this term is rewritten by $\frac{\epsilon_r(n_{rs})}{\epsilon_r(n_{rs})+\epsilon_s(n_{rs}^{-1})}\frac{\tau_r-\beta}{(1-\tau_r)\tau_r(1-\beta)}=\frac{1}{2}\frac{\tau_r-\beta}{(1-\tau_r)\tau_r(1-\beta)}$ because of $\epsilon_r(n_{rs})=\epsilon_s(n_{rs}^{-1})$. Inserting it into (F.2) and evaluating (F.2) at the symmetric Nash equilibrium (i.e., $(\tau_1,\tau_2)=(\tau^*,\tau^*)$ and $n_{12}=n_{21}=1$) yields

$$\begin{aligned}\frac{\partial \Phi_r}{\partial \tau_r}|_{\tau_r=\tau^*} =& \tilde{A}(\phi)\,(\tau^*)^{\frac{\beta}{1-\beta}}\,\vartheta_r(1)^{\frac{\alpha-\beta}{1-\beta}}\left\{\frac{2\beta[1-(1-\alpha)\tau^*]}{(1-\beta)\tau^*}\left[1+\frac{1}{2\beta}\frac{\tau^*-\beta}{1-\tau^*}\right]-(1-\alpha)\right.\\ &\left.-\frac{1-(1-\alpha)\tau^*}{1-\tau^*}+[1-(1-\alpha)\tau^*]\frac{\partial n_{rs}}{\partial \tau_r}|_{\tau_r=\tau^*}\right\}\\ =& \tilde{A}(\phi)\,(\tau^*)^{\frac{\beta}{1-\beta}}\,\vartheta_r(1)^{\frac{\alpha-\beta}{1-\beta}}\left\{\frac{2\beta[1-(1-\alpha)\tau^*]}{(1-\beta)\tau^*}\frac{\beta(1-\tau^*)+\tau^*(1-\beta)}{2\beta(1-\tau^*)}-(1-\alpha)\right.\\ &\left.-\frac{1-(1-\alpha)\tau^*}{1-\tau^*}+[1-(1-\alpha)\tau^*]\frac{\partial n_{rs}}{\partial \tau_r}|_{\tau_r=\tau^*}\right\}\\ =& \tilde{A}(\phi)\,(\tau^*)^{\frac{\beta}{1-\beta}}\,\vartheta_r(1)^{\frac{\alpha-\beta}{1-\beta}}\left\{\frac{\beta}{1-\beta}\frac{1-(1-\alpha)\tau^*}{\tau^*}-(1-\alpha)\right.\\ &\left.+[1-(1-\alpha)\tau^*]\frac{\partial n_{rs}}{\partial \tau_r}|_{\tau_r=\tau^*}\right\} \end{aligned} \tag{F.3}$$

$$\begin{aligned}\frac{\partial \ln z_r^*}{\partial \tau_r}|_{\tau_r=\tau^*} &= \frac{\frac{\partial \Phi_r}{\partial \tau_r}|_{\tau_r=\tau^*}-\eta g_C(\tau^*,\tau^*)\frac{\partial n_{rs}}{\partial \tau_r}|_{\tau_r=\tau^*}-2\eta g_C(\tau^*,\tau^*)\frac{\partial \ln g_C}{\partial \tau_r}|_{\tau_r=\tau^*}}{\Phi_r(\tau^*,\tau^*)-2\eta g_C(\tau^*,\tau^*)}\\ &= \frac{\frac{\partial \Phi_r}{\partial \tau_r}|_{\tau_r=\tau^*}-\eta g_C(\tau^*,\tau^*)\frac{\partial n_{rs}}{\partial \tau_r}|_{\tau_r=\tau^*}-\eta g_C(\tau^*,\tau^*)\frac{\beta-\tau^*}{\sigma(1-\beta)(1-\tau^*)\tau^*}}{2\left\{\tilde{A}(\phi)\,(\tau^*)^{\frac{\beta}{1-\beta}}\,\vartheta_r(1)^{\frac{\alpha-\beta}{1-\beta}}[1-(1-\alpha)\tau^*]-\eta g_C(\tau^*,\tau^*)\right\}} \end{aligned} \tag{F.4}$$

where we have used

$$\frac{\partial \ln g_C}{\partial \tau_r}|_{\tau_r=\tau^*}=\frac{\beta-\tau^*}{2\sigma(1-\beta)(1-\tau^*)\tau^*}. \tag{F.5}$$

When $\Theta_r(N_r(t),N_s(t))$ and $\Theta_s(N_s(t),N_r(t))$ take the same form, the first-order condition for optimal tax harmonization, (41), is rewritten by

$$\frac{\tilde{A}(\phi)\left(\tau^h\right)^{\frac{\beta}{1-\beta}}\vartheta_1\left(1\right)^{\frac{\alpha-\beta}{1-\beta}}\left[\frac{\beta}{1-\beta}\frac{1-(1-\alpha)\tau^h}{\tau^h}-(1-\alpha)\right]-\eta g^h\cdot\frac{\beta-\tau^h}{\sigma(1-\beta)(1-\tau^h)\tau^h}}{\tilde{A}(\phi)\left(\tau^h\right)^{\frac{\beta}{1-\beta}}\vartheta_1\left(1\right)^{\frac{\alpha-\beta}{1-\beta}}\left[1-(1-\alpha)\tau^h\right]-\eta g^h} + \frac{(1+\rho)^{-1}(g^h)^{1-\sigma}}{1-(1+\rho)^{-1}(g^h)^{1-\sigma}}\cdot\frac{\beta-\tau^h}{\sigma(1-\beta)\left(1-\tau^h\right)\tau^h}=0. \tag{F.6}$$

Evaluating (F.1) together with (F.3), (F.4), and (F.5) at $\tau_r=\tau^*=\tau^h$, we obtain

$$\begin{aligned}
&\mathrm{sign}\frac{\partial U_r(0)}{\partial\tau_r}\\
&=\frac{\tilde{A}(\phi)\left(\tau^h\right)^{\frac{\beta}{1-\beta}}\vartheta_r(1)^{\frac{\alpha-\beta}{1-\beta}}\left\{\frac{\beta}{1-\beta}\frac{1-(1-\alpha)\tau^h}{\tau^h}-(1-\alpha)+\left[1-(1-\alpha)\tau^h\right]\frac{\partial n_{rs}}{\partial\tau_r}|_{\tau_r=\tau^h}\right\}}{2\left\{\tilde{A}(\phi)\left(\tau^h\right)^{\frac{\beta}{1-\beta}}\vartheta_r(1)^{\frac{\alpha-\beta}{1-\beta}}\left[1-(1-\alpha)\tau^h\right]-\eta g^h\right\}}\\
&\quad-\frac{\eta g^h\frac{\partial n_{rs}}{\partial\tau_r}|_{\tau_r=\tau^h}+\eta g^h\frac{\beta-\tau^h}{\sigma(1-\beta)(1-\tau^h)\tau^h}}{2\left\{\tilde{A}(\phi)\left(\tau^h\right)^{\frac{\beta}{1-\beta}}\vartheta_r(1)^{\frac{\alpha-\beta}{1-\beta}}\left[1-(1-\alpha)\tau^*\right]-\eta g^h\right\}}\\
&\quad+\frac{1}{2}\left[-\frac{\partial\ln n_{rs}}{\partial\tau_r}|_{\tau_r=\tau^h}+\frac{(1+\rho)^{-1}(g^h)^{1-\sigma}}{1-(1+\rho)^{-1}(g^h)^{1-\sigma}}\frac{\beta-\tau^h}{\sigma(1-\beta)\left(1-\tau^h\right)\tau^h}\right].
\end{aligned} \tag{F.7}$$

Substituting (F.6) into (F.7), we can rewrite (F.7) into

$$\begin{aligned}
\mathrm{sign}\frac{\partial U_r(0)}{\partial\tau_r}&=\frac{\left\{\tilde{A}(\phi)\left(\tau^h\right)^{\frac{\beta}{1-\beta}}\vartheta_r(1)^{\frac{\alpha-\beta}{1-\beta}}\left[1-(1-\alpha)\tau^*\right]-\eta g^h\right\}\frac{\partial\ln n_{rs}}{\partial\tau_r}|_{\tau_r=\tau^h}}{2\left\{\tilde{A}(\phi)\left(\tau^h\right)^{\frac{\beta}{1-\beta}}\vartheta_r(1)^{\frac{\alpha-\beta}{1-\beta}}\left[1-(1-\alpha)\tau^*\right]-\eta g^h\right\}}-\frac{1}{2}\frac{\partial\ln n_{rs}}{\partial\tau_r}|_{\tau_r=\tau^h}\\
&=\frac{1}{2}\frac{\partial\ln n_{rs}}{\partial\tau_r}|_{\tau_r=\tau^h}-\frac{1}{2}\frac{\partial\ln n_{rs}}{\partial\tau_r}|_{\tau_r=\tau^h}=0.
\end{aligned}$$

Thus, $\tau_1=\tau_2=\tau^h$ is a solution to welfare-maximization under CIT competition.

G Proof of Remark 3

From (48) and $\lambda=0$, we obtain

$$\begin{aligned}
\frac{\partial\mathcal{W}_r(\upsilon)}{\partial\tau_r}&=\left[\frac{\tilde{z}_1^*(N_r(\upsilon)+N_s(\upsilon))}{1+n_{rs}(\tau_r,\tau_s)}\right]^{1-\sigma}\left[\frac{1-\left[\varrho g_C(\tau_r,\tau_s)^{1-\sigma}\right]^{1+T}}{1-\varrho g_C(\tau_r,\tau_s)^{1-\sigma}}\right]\\
&\quad\times\left\{\frac{\partial\ln\tilde{z}_r^*}{\partial\tau_r}-\frac{n_{rs}(\tau_r,\tau_s)}{1+n_{rs}(\tau_r,\tau_s)}\frac{\partial\ln n_{rs}(\tau_r,\tau_s)}{\partial\tau_r}+\Omega(g_C,T)\frac{\partial\ln g_C(\tau_r,\tau_s)}{\partial\tau_r}\right\},
\end{aligned}$$

$$\Omega(g_C, T) \equiv \frac{\varrho g_C(\tau_r, \tau_s)^{1-\sigma}}{1 - \varrho g_C(\tau_r, \tau_s)^{1-\sigma}} - \frac{(1+T)\left[\varrho g_C(\tau_r, \tau_s)^{1-\sigma}\right]^{1+T}}{1 - \left[\varrho g_C(\tau_r, \tau_s)^{1-\sigma}\right]^{1+T}}.$$

Here, notice that $1 > \varrho g_C(\tau_r, \tau_s)^{1-\sigma}$ and that $\tilde{z}_1^* = z_1^*$ and $\tilde{z}_2^* = z_2^*$ hold because of $\lambda = 0$. Then, we obtain

$$\text{sign}\frac{\partial \mathcal{W}_r(\upsilon)}{\partial \tau_r} = \text{sign}\frac{\partial \ln z_r^*}{\partial \tau_r} - \frac{n_{rs}(\tau_r, \tau_s)}{1 + n_{rs}(\tau_r, \tau_s)}\frac{\partial \ln n_{rs}(\tau_r, \tau_s)}{\partial \tau_r} + \Omega(g_C, T)\frac{\partial \ln g_C(\tau_r, \tau_s)}{\partial \tau_r}. \tag{G.1}$$

It follows that (G.1) corresponds exactly with (F.1) in Appendix F when $\lim_{T\to\infty}\Omega(g_C, T) = \frac{\varrho g_C(\tau_r,\tau_s)^{1-\sigma}}{1-\varrho g_C(\tau_r,\tau_s)^{1-\sigma}}$ because $1 > \varrho g_C(\tau_r, \tau_s)^{1-\sigma}$.

Next, we consider the optimization problem under tax harmonization. The corresponding objective function is $\mathcal{W}_1(\upsilon) + \mathcal{W}_2(\upsilon)$ for $\lambda = 1$ with $\tau_1 = \tau_2 = \tau^h$ and is given by

$$\mathcal{W}_1(\upsilon) + \mathcal{W}_2(\upsilon) = \frac{1}{1-\sigma}\left[\frac{z_r^*(\tau^h, \tau^h)[N_r(\upsilon) + N_s(\upsilon)]}{1 + \varphi(1)}\right]^{1-\sigma}\left[\frac{1 - [\varrho g^h(\tau^h, \tau^h)^{1-\sigma}]^{1+T}}{1 - \varrho g^h(\tau^h, \tau^h)^{1-\sigma}}\right].$$

The first order condition with respect to τ_r is

$$\frac{\partial \ln z_r^*}{\partial \tau^h} + \Omega(g^h, T)\frac{\partial \ln g^h(\tau^h, \tau^h)}{\partial \tau^h} = 0, \tag{G.2}$$

where

$$\Omega(g^h, T) = \frac{\varrho g^h(\tau^h, \tau^h)^{1-\sigma}}{1 - \varrho g^h(\tau^h, \tau^h)^{1-\sigma}} - \frac{(1+T)\left[\varrho g^h(\tau^h, \tau^h)^{1-\sigma}\right]^{1+T}}{1 - \left[\varrho g^h(\tau^h, \tau^h)^{1-\sigma}\right]^{1+T}}.$$

The rest of the proof follows the same procedure as Appendix F; it suffices to use (G.1) and (G.2) with (F.3), (F.4), and (F.5), evaluating all at $\tau_r = \tau_s = \tau^* = \tau^h$.

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Figure 1: Regional average CIT rate in the world (Source: Corporate tax rates around the world 2021, Tax Foundation)

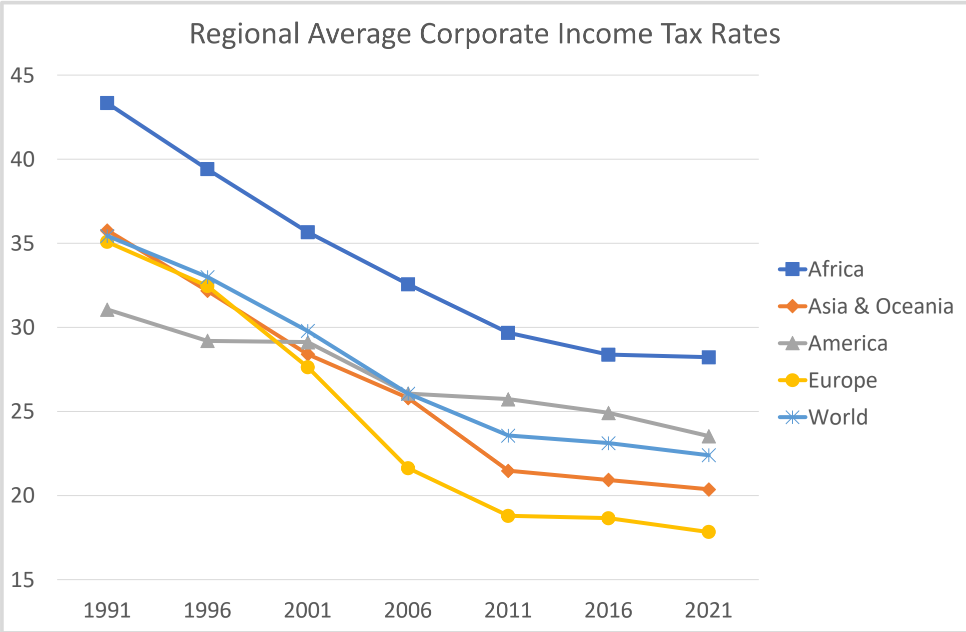

Figure 2: Phase diagram of $(z_1(t), z_2(t))$

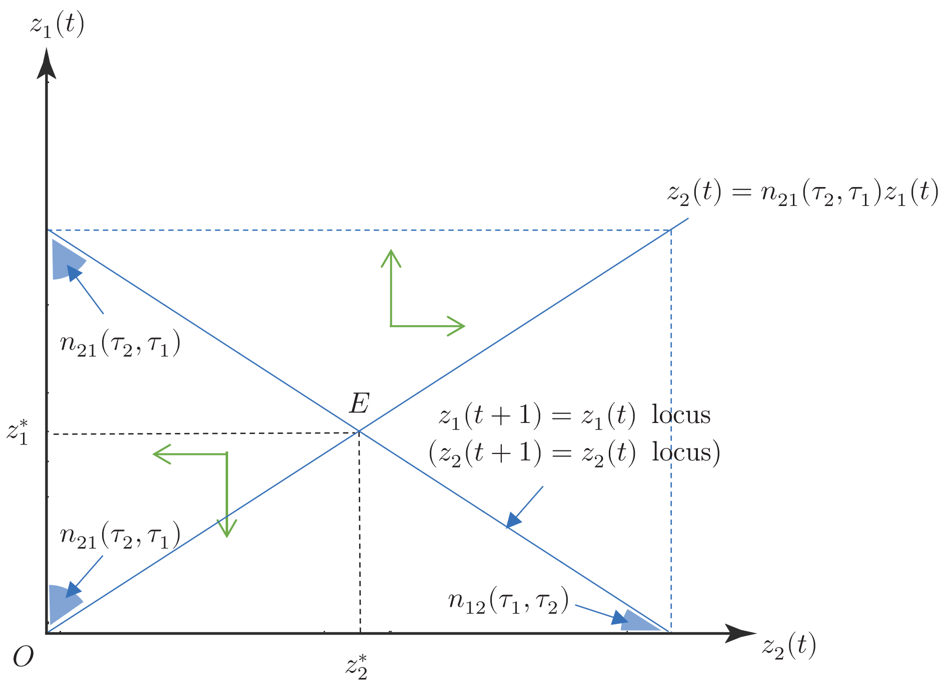

Figure 3: The share of rule-of-thumb households and the gap between equilibrium tax rates

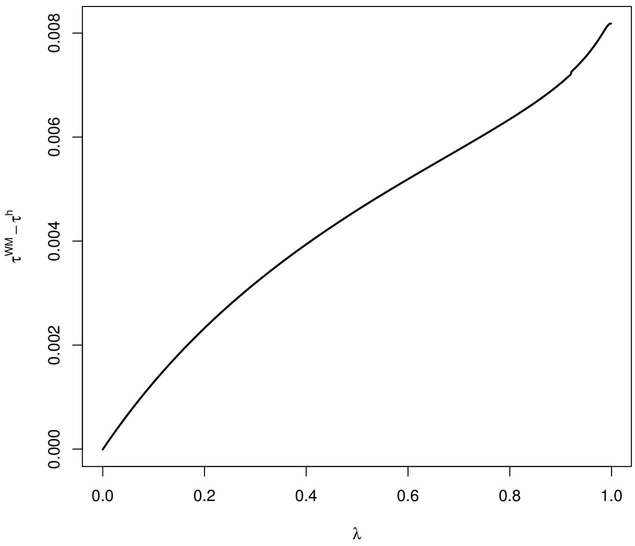

Figure 4: Terms of office and equilibrium tax rates with weak spillover ($\delta = 0.25$)

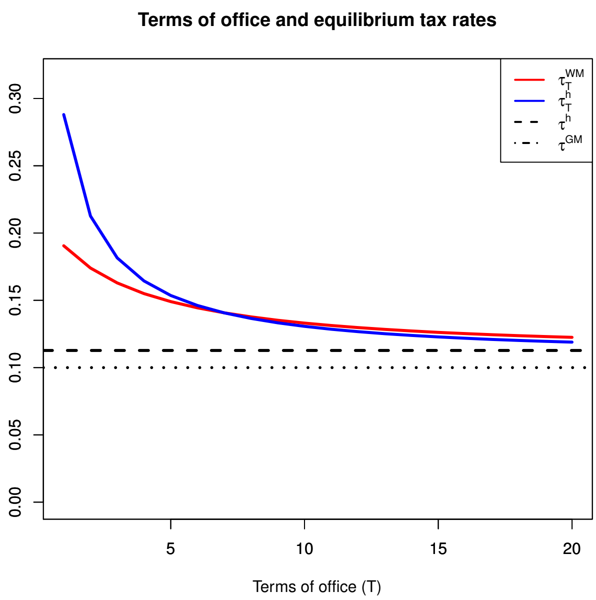

Figure 5: Terms of office and equilibrium tax rates with strong spillover ($\delta = 1$)

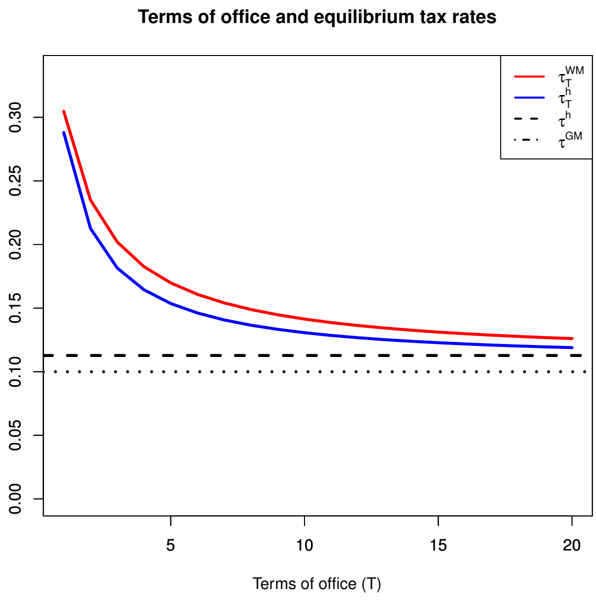

Figure 6: Terms of office and equilibrium tax rates with strong spillover ($\delta = 0.05$)