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Tax evasion and optimal corporate income tax rates in a growing economy

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Abstract

We explore how tax evasion by firms affects the growth- and welfare-maximizing rates of corporate income tax (CIT) in an endogenous growth model with productive public service. We show that the negative effect of CIT on growth is mitigated in the presence of tax evasion. This increases the benefit of raising the CIT rate for public service provision. Thus, in contrast to Barro [(1990) *Journal of Political Economy* 98, 103–125], the optimal tax rate is higher than the output elasticity of public service. Through numerical exercises, we demonstrate that the role of tax evasion by firms is quantitatively significant.

Keywords: Corporate income tax; tax evasion; growth; welfare

1. Introduction

Corporate income tax (hereafter, CIT) has detrimental effects on investment by firms. Modern prevailing opinions advocate that CIT should be cut to promote economic growth. Governments in developed countries have lowered the CIT rate in recent years: The average rate of CIT in OECD countries decreased from 32.5% to 24.2% between 2000 and 2017.¹ However, because CIT is an important tax basis for public finance, cutting the CIT rate reduces public investment in infrastructure (productive public services) and may lower the rate of economic growth (e.g., Barro (1990)).² Therefore, setting CIT rates involves a trade-off between private investment and the provision of productive public services for economic growth, and it is an important policy issue.

In addition, tax evasion by firms is a serious problem of CIT. There is large-scale tax evasion in real economies. For example, in the USA, from 2008 to 2010, the Internal Revenue Service (2016) reported an annual average of about 44 billion dollars in the estimated tax gaps of CIT (the amount of true tax liability that is not paid voluntarily and timely).³ Nonetheless, the actual audit coverage of taxed corporations is very limited, primarily because of fiscal tightness; only 1.0% of taxed returns were examined in the USA in 2016, and only 3.1% of all taxed corporations were audited in Japan in 2015.⁴

One of the most general ways of tax evasion is to under-declare income (e.g., Allingham and Sandmo (1972)). To under-declare corporate income, firms may understate their productivity and overstate their costs. There is institutional cause for such tax evasion behavior at the microeconomic level. The CIT systems in many countries have reduction and exemption measures; deficits of corporations can be carried forward and CITs of corporations with small income are reduced

or exempted. Such systems give corporations a loophole to under-declare their profit intentionally by overstating cost. These are neither unusual nor insignificant at the macroeconomic level. For example, the National Tax Agency (2016) reports that, on average, more than two-thirds of the ordinary corporations in Japan were loss-making corporations between 2011 and 2015. The reported losses amounted to 11.3 billion yen in 2015 and occupied a quarter of the reported total income in the corporate sector.

With these problems of CIT as motivation, this study investigates an optimal CIT policy in a growing economy with tax evasion by firms. The evaded tax payments are utilized for private investment, while a part of the tax revenue is lost. This affects the trade-off between private investment and the provision of productive public services. We are particularly interested in how CIT evasion by firms changes the optimal rate of CIT.

To tackle this problem, we construct a variety-expansion model of growth in which private firms invest to earn monopolistic profits and their investments sustain economic growth.⁵ A single final good is produced by using intermediate goods. Each intermediate good is produced by a monopolistically competitive firm. Each intermediate good firm invests to enter into business and pursues monopolistic profits. CIT discourages private investment because the monopolistic profits are subject to CIT. Meanwhile, productive public services have a positive effect on the monopolistic profits of intermediate good firms. Thus, CIT has a positive effect on private investment through productive public services financed by CIT.

In our model, facing CIT, firms have an incentive to evade tax payment by under-declaring their profits in the absence of a perfect tax enforcement system. Because each firm can avoid a part of tax payment, tax evasion weakens the discouraging effect of CIT on private investment. Simultaneously, tax evasion reduces the provision of productive public services. Thus, tax evasion by the corporate sector affects private investment, the provision of productive public services, and economic growth.

In a tractable model, we obtain a qualitative result that both the growth- and welfare-maximizing CIT rates are higher than the output-elasticity of public service. This contrasts with the familiar Barro's (1990) rule, which indicates that the tax rate should be set at the output elasticity of public services. The mechanism behind our result is as follows. When the government raises the CIT rate, the effective CIT rate and the tax revenue rise.⁶ This increases the provision of productive public services and promotes economic growth. Simultaneously, raising the CIT rate discourages private investment and has a detrimental effect on growth. However, this negative effect on growth is weakened by tax evasion. This is because, in response to a tax hike, firms attempt to secure profits by increasing tax evasion. It alleviates the reduction in private investment and the tax base of CIT. CIT evasion generates the benefits of raising the CIT rate for the provision of productive public services.

Next, we extend the model to obtain quantitative results. Our quantitative analyses show that tax evasion significantly raises the optimal CIT rate. In particular, the optimal tax rate is 40% for the benchmark case, which is much higher than the standard values of the output elasticity of public service, for example, 10%. This optimal CIT rate in our model, at 40%, is close to that in Aghion *et al.* (2016) mentioned below. Besides, we decompose the difference between the optimal tax rate and the output elasticity of public service into several parts including a part associated with the effect of CIT evasion. We find that the effect of CIT evasion occupies more than half of the total difference between the optimal tax rate and the output elasticity of public service for a wide range of reasonable parameter values. That is, even quantitatively, the effect of CIT evasion is the main source of the high optimal tax rate.

1.1 Related literature

Largely, our study is part of the literature starting with Barro (1990), which explores optimal taxation in an endogenous growth model with productive public service (capital) (e.g., Futagami *et al.*

(1993), Glomm and Ravikumar (1994), Turnovsky (1997)).⁷ These studies emphasize that the growth-maximizing income tax rate equals the output elasticity of public capital, and it coincides with the welfare-maximizing one in the balanced growth path. This is the so-called Barro rule.

More recent studies cast some doubts on the Barro rule. Some studies (e.g., Futagami et al. (1993), Ghosh and Roy (2004), Agénor (2008)) show that the welfare-maximizing tax rate is lower than the growth-maximizing one (output elasticity of public capital), while other studies (e.g., Kalaitzidakis and Kalyvitis (2004), Chang and Chang (2015)) show the opposite result.⁸ While these existing studies consider neither CIT nor tax evasion, our study investigates optimal taxation, theoretically and quantitatively, incorporating CIT evasion.⁹

Among the existing studies of tax evasion and growth, we should refer to Chen (2003) and Kafkalas et al. (2014).¹⁰ They investigate tax evasion by household-firms in Barro's (1990) type model, in which government incurs inspection expenditure to audit taxpayers. These authors focus on the trade-off between the government's inspection expenditure and public investment. Chen (2003) shows that the growth-maximizing announced tax rate is higher than the output elasticity of public service, under the assumption that inspection expenditure is proportional to output and household firms must incur tax evasion costs. Meanwhile, Kafkalas et al. (2014) assume that the government's inspection expenditure is proportional to tax revenues. They show that, even with tax evasion, the growth-(and utility-) maximizing effective tax rate equals the output elasticity of public capital, in line with Barro's rule.

In contrast to these studies, we do not focus on the role of inspection expenditure. Therefore, we adopt the same specification of inspection expenditure as Kafkalas et al. (2014), which does not affect Barro's rule. Thus, we can concentrate on the role of tax evasion behavior of firms with market power.

Although the findings on optimal tax rates from Chen (2003) and Kafkalas et al. (2014) are interesting, there are some reservations. First, they consider tax evasion by household-firms, where the firm is the same as a household. Since there is no difference between CIT and a household's income tax in their models, they do not consider the role of CIT evasion. Second, they assume a competitive goods market, and therefore, ignore tax evasion associated with profit maximization in an imperfectly competitive product market.¹¹ Thus, although tax evasion affects the aggregate economy through the government budget in their models, these studies do not consider the role of tax evasion in the production side directly.

Our study is also comparable to Aghion et al. (2016). They examine the relationship among corporate taxation, growth, and welfare, focusing on corruption. Aghion et al. (2016) construct an endogenous growth model in which public capital raises the expected returns to entrepreneurial efforts on R&D but tax revenue decreases due to the corruption of officers after tax collection. They suggest that the relationship between the CIT rate and growth is an inverted-U shape, and the welfare-maximizing CIT rate is 42% in the calibrated model. However, Aghion et al. (2016) do not consider tax evasion by firms but focus on the corruption between government and households. In this study, we incorporate corporate tax evasion in an endogenous growth model and suggest that the optimal CIT rate is as high as Aghion et al.'s (2016) estimate.

2. Model

Time is discrete and denoted by $t = 0, 1, \dots$. The economy is inhabited by the following four types of agents: producers of final outputs, producers of intermediate goods, a representative household, and government. An infinitely living representative household has perfect foresight and is endowed with L unit of labor. Labor moves freely across different production sectors. The intermediate goods sector is monopolistically competitive. The number of intermediate goods in period t is N_t . We assume $N_0 = 1$ without loss of generality. To operate in period t , each intermediate good producer invests in period $t - 1$. This investment increases the number of intermediate goods N_t over time. This is the growth engine of our model.

2.1 Producers of final good

A single final output is produced by perfectly competitive producers using the following technology:

$$Y_t = AL_{Y,t}^{1-\alpha} \int_0^{N_t} (G_t x_{i,t})^\alpha di, A > 0, 0 < \alpha < 1, \tag{1}$$

where Y_t is output, $L_{Y,t}$ is labor input in the final goods sector, and $x_{i,t}$ is the input of intermediate good i . Following Barro (1990), public services, G_t , increase the productivity of output. We take the final output as the numeraire. Although α encompasses both (i) the output elasticity of public services and (ii) the price elasticity of intermediate goods $1/(1 - \alpha)$, we examine the former in this simple model. In the extended model (Section 5), we separate (i) and (ii). We denote the price of intermediate good i and wage rate as $p_{i,t}$ and w_t , respectively. The profit maximization yields

$$w_t = (1 - \alpha)AL_{Y,t}^{-\alpha} \int_0^{N_t} (G_t x_{i,t})^\alpha di = (1 - \alpha) \frac{Y_t}{L_{Y,t}}, \tag{2}$$

$$p_{i,t} = \alpha AL_{Y,t}^{1-\alpha} G_t^\alpha x_{i,t}^{\alpha-1}. \tag{3}$$

Solving (2) and (3) with respect to $x_{i,t}$ yields the demand function for the product of firm i :

$$x(p_{i,t}) \equiv \frac{(1 - \alpha)Y_t}{w_t} \left(\frac{\alpha A G_t^\alpha}{p_{i,t}} \right)^{\frac{1}{1-\alpha}}. \tag{4}$$

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 $t - 1$. Firms finance the cost of this investment by borrowing from households. Because firms must incur investment costs in each period, the planning horizon of each firm is one period, as in Young (1998). When incurring investment costs, each firm draws its productivity $b > 0$ from distribution $F(b)$. We assume that (i) b is independent and identically distributed (iid) over time as well as across firms and (ii) b is private information. These two assumptions are useful in describing an environment where the true tax base of each firm cannot be observable without auditing firms, as we explain in Sections 2.2.2 and 2.2.3. Besides, heterogeneity among firms' productivity enables us to describe the realistic firm size distribution for the quantitative analysis in Section 5.

Let us denote the expected after-tax operating profit of a firm with productivity b in period t by $\pi_{i,t}^e$. $\pi_{i,t}^e$ depends on b . The next subsection discusses $\pi_{i,t}^e$ in detail. The objective of intermediate good firm i that invests in period $t - 1$ is given by

$$\Pi_{i,t-1} = \frac{1}{R_{t-1}} \int \pi_{i,t}^e dF(b) - \eta, \tag{5}$$

where R_{t-1} is the gross interest rate between periods $t - 1$ and t . Since b is iid across firms, all firms face the same Π_{t-1} in period $t - 1$. Free entry into the intermediate goods market implies

$$\int \pi_{i,t}^e dF(b) = R_{t-1}\eta. \tag{6}$$

2.2.2 Expected operating profits

We assume that the price of each intermediate good $p_{i,t}$ is public information. A firm with productivity b needs $1/b$ unit of labor to produce one unit of the intermediate good. The true operating profit of firm i is given by

$$\pi_{i,t} = \left(p_{i,t} - \frac{w_t}{b_i} \right) x(p_{i,t}). \tag{7}$$

We use the word “true” to distinguish the true operating profit from the operating profit that firm i declares, $\tilde{\pi}_{i,t}$, to the government. Because b is private information, the government cannot directly observe the true operating profit, $\pi_{i,t}$, and thus, cannot know whether the declared profit ($\tilde{\pi}_{i,t}$) is equal to the true profit ($\pi_{i,t}$) without conducting an audit.

Denote the announced CIT rate by $\tau \in (0, 1]$. The after-tax profit of each firm is given by $\pi_{i,t} - \tau \tilde{\pi}_{i,t}$, because CIT is imposed on declared profit $\tilde{\pi}_{i,t}$. We denote the probability of an audit by $\bar{q} \in [0, 1]$, and assume it is given exogenously. We impose a further assumption on \bar{q} later. Suppose that a firm is audited. If this firm under-declares its operating profit ($\tilde{\pi}_{i,t} < \pi_{i,t}$) to the government, it has to pay a penalty of $(1 + s)\tau(\pi_{i,t} - \tilde{\pi}_{i,t})$, where the exogenous parameter $s (\geq 0)$ is an additional tax rate. If the firm over-declares its operating profit ($\tilde{\pi}_{i,t} > \pi_{i,t}$), the overpayment, $\tau(\tilde{\pi}_{i,t} - \pi_{i,t})$, is refunded. The expected after-tax operating profit of firm i is given by

$$\pi_{i,t}^e = \pi_{i,t} - \tau \tilde{\pi}_{i,t} - \bar{q}(1 + s)\tau \cdot \max\{0, \pi_{i,t} - \tilde{\pi}_{i,t}\} + \bar{q}\tau \cdot \max\{0, \tilde{\pi}_{i,t} - \pi_{i,t}\}.$$

Given $\pi_{i,t}$, $\pi_{i,t}^e$ decreases with $\tilde{\pi}_{i,t}$ if $\tilde{\pi}_{i,t} > \pi_{i,t}$, and therefore no firms over-declare their operating profits, and the last term is equal to zero. Thus, $\tilde{\pi}_{i,t} \leq \pi_{i,t}$ must be satisfied in the following discussion. Then, the expected after-tax operating profit, $\pi_{i,t}^e$, for $\tilde{\pi}_{i,t} \leq \pi_{i,t}$, is

$$\pi_{i,t}^e = \pi_{i,t} - \tau \tilde{\pi}_{i,t} - \bar{q}(1 + s)\tau(\pi_{i,t} - \tilde{\pi}_{i,t}) = (1 - \tilde{\tau})\pi_{i,t}, \tag{8}$$

where $\tilde{\tau}$ is the effective CIT rate and defined as

$$\tilde{\tau} \equiv \left\{ [1 - \bar{q}(1 + s)] \frac{\tilde{\pi}_{i,t}}{\pi_{i,t}} + \bar{q}(1 + s) \right\} \tau. \tag{9}$$

2.2.3 Tax evasion and maximization of the expected operating profits

Firm i chooses $\tilde{\pi}_{i,t}$ and $p_{i,t}$ to maximize $\pi_{i,t}^e$. Our specification of tax evasion behavior is essentially similar to that of Allingham and Sandmo (1972), who consider tax evasion by a representative household, which evades income tax by choosing a declared income when its actual income is not directly known by the government. In our setting, each firm chooses its declared profit, $\tilde{\pi}_{i,t}$, by adjusting the price level when its actual profit, $\pi_{i,t}$, is not directly known by the government.

As a first step, we briefly discuss the case where the government can observe the true operating profits of each firm without any costs. We still assume that b is private information. Let us define the following function of p :

$$\Lambda(p) = (1 - \alpha)px(p), \tag{10}$$

where $x(p)$ is defined by (4). Since the government can observe the true operating profits, each firm declares its profits truthfully. We substitute $\tilde{\pi}_{i,t} = \pi_{i,t}$ into (8), which yields $\pi_{i,t}^e = (1 - \tau)\pi_{i,t}$. Thus, $\pi_{i,t}^e$ is maximized at $p_{i,t} = p_{i,t}^*$, where $p_{i,t}^*$ is defined as $p_{i,t}^* \equiv \frac{w_t}{\alpha b_i}$. The maximized operating profits is given by $\Lambda(p_{i,t}^*)$. Since firm i declares truthfully, the declared profit $\tilde{\pi}_{i,t}$ satisfies $\tilde{\pi}_{i,t} = \Lambda(p_{i,t}^*)$. The following points should be noted. First, function $\Lambda(p)$ does not depend on b . Thus, although b is not observable, the government knows the functional form of $\Lambda(p)$ as long as it knows the demand function, (4). Second, since b is private information, the government cannot directly observe whether the price set by firm i , $p_{i,t}$, is actually equal to $p_{i,t}^* = \frac{w_t}{\alpha b_i}$. Finally, the above result suggests that if firm i declares truthfully, the price set by the firm, $p_{i,t}$, and its declared profits, $\tilde{\pi}_{i,t}$, satisfy $\tilde{\pi}_{i,t} = \Lambda(p_{i,t})$. Conversely, if $p_{i,t}$ and $\tilde{\pi}_{i,t}$ do not satisfy $\tilde{\pi}_{i,t} = \Lambda(p_{i,t})$, firm i declares dishonestly.

We now consider the case where the government cannot observe the true operating profits of each firm without any costs. We consider two subcases. First, assume that $1 - \bar{q}(1 + s) < 0$. We rewrite (8) as

$$\pi_{i,t}^e = [1 - \bar{q}(1 + s)\tau]\pi_{i,t} - [1 - \bar{q}(1 + s)]\tau\tilde{\pi}_{i,t}. \tag{11}$$

If $1 - \bar{q}(1 + s) < 0$, firm i chooses $\tilde{\pi}_{i,t} = \pi_{i,t}$ because $\pi_{i,t}^e$ is increasing in $\tilde{\pi}_{i,t}$. Then, each firm declares its profit truthfully. Thus, each firm sets $p_{i,t} = p_{i,t}^*$. Furthermore, $\bar{\tau} = \tau$ by (9). Intuitively, if the expected additional tax rate is higher than the rate under honest declaration ($\bar{q}(1 + s)\tau > \tau$), firms have no incentive to under-declare profits because CIT does not affect $\tilde{\pi}_{i,t}$. Thus, they declare true profits ($\tilde{\pi}_{i,t} = \pi_{i,t}$), and tax evasion does not occur.

If $1 - \bar{q}(1 + s) = 0$, we obtain $\pi_{i,t}^e = (1 - \tau)\pi_{i,t}$ by (11). In this case, the expected after-tax profit does not depend on whether a firm declares its profit truthfully. The maximization of $\pi_{i,t}^e = (1 - \tau)\pi_{i,t}$ yields the same results as those of truth-telling firms. Summing up, we obtain the following.

Proposition 1. *If $1 - \bar{q}(1 + s) \leq 0$, then each firm i declares its true profit, $\tilde{\pi}_{i,t} = \pi_{i,t}$, and set its price level as $p_{i,t} = p_{i,t}^*$. The effective CIT rate coincides with the announced CIT rate, $\bar{\tau} = \tau$.*

Next, we assume that $1 - \bar{q}(1 + s) > 0$. Then, (11) shows that $\pi_{i,t}^e$ decreases with $\tilde{\pi}_{i,t}$. Thus, firm i has an incentive to under-declare its profits, $\tilde{\pi}_{i,t}^e < \pi_{i,t}^e$. Remember that the government can observe the price set by firm i , $p_{i,t}$, and its declared operating profits, $\tilde{\pi}_{i,t}$, but cannot observe b_i . This means that the government cannot observe whether firm i sets $p_{i,t}$ according to $p_{i,t} = \frac{w_t}{\alpha b_i}$. Suppose that $p_{i,t}$ and $\tilde{\pi}_{i,t}$ satisfy $\tilde{\pi}_{i,t} \neq \Lambda(p_{i,t})$, where function $\Lambda(\cdot)$ is defined by (10). From the discussion in the paragraph that includes (10), the government knows that the firm declares dishonestly. In contrast, suppose that $p_{i,t}$ and $\tilde{\pi}_{i,t}$ satisfy

$$\tilde{\pi}_{i,t} = \Lambda(p_{i,t}). \tag{12}$$

Remember that the government cannot know whether the price set by firm i , $p_{i,t}$, is equal to $p_{i,t}^* = \frac{w_t}{\alpha b_i}$. Thus, without auditing the firm, the government cannot know whether the firm declares truthfully. Given the discussion so far, we impose the following assumption.

Assumption 1. Consider a firm that sets the price at $p_{i,t}$. (i) If the firm’s declared profit satisfies $\tilde{\pi}_{i,t} \neq \Lambda(p_{i,t})$, the firm is audited with a probability of one; $\bar{q} = 1$. (ii) If the firm’s declared profit satisfies $\tilde{\pi}_{i,t} = \Lambda(p_{i,t})$, the firm is audited with a probability lower than one; $\bar{q} = q \in [0, 1)$. □

This assumption captures the idea that if a firm unnaturally declares its profits, the government audits the firm. Under this assumption, we first demonstrate how each firm declares its profits in the following lemma.

Lemma. Suppose that $1 - q(1 + s) > 0$ and that firm i sets $p_{i,t}$. Then, its declared profit satisfies $\tilde{\pi}_{i,t} = \Lambda(p_{i,t})$.

Proof. See Appendix A. □

Using Lemma, we consider firm i ’s choice of the price level, $p_{i,t}$.¹²

Suppose that $1 - q(1 + s) > 0$. Then, by (11), $\tilde{\pi}_{i,t} = \Lambda(p_{i,t})$, and $\bar{q} = q$, the problem of firm i is reduced to the problem to choose $p_{i,t}$ to maximize

$$\pi_{i,t}^e = [1 - q(1 + s)\tau] \left(p_{i,t} - \frac{w_t}{b_i} \right) x(p_{i,t}) - [1 - q(1 + s)]\tau \Lambda(p_{i,t}),$$

subject to $p_{i,t} \geq p_{i,t}^*$, which is from $\tilde{\pi}_{i,t} \leq \pi_{i,t}$.

The first-order condition is given by

$$\begin{aligned} \frac{\partial \pi_{i,t}^e}{\partial p_{i,t}} &= [1 - q(1 + s)\tau] \frac{\partial \pi_{i,t}}{\partial p_{i,t}} - [1 - q(1 + s)]\tau \Lambda'(p_{i,t}) \\ &= \frac{\alpha x(p_{i,t})}{p_{i,t}} \left\{ -\frac{1 - q(1 + s)\tau}{1 - \alpha} \left(p_{i,t} - \frac{w_t}{\alpha b_i} \right) + [1 - q(1 + s)]\tau p_{i,t} \right\} = 0, \end{aligned} \tag{13}$$

given that $\frac{\partial \pi_{i,t}}{\partial p_{i,t}} = -\alpha x(p_{i,t}) \left[\frac{p_{i,t} - w_t / (\alpha b_i)}{(1 - \alpha)p_{i,t}} \right]$ and $\Lambda'(p_{i,t}) = -\alpha x(p_{i,t})$. Because $1 - q(1 + s) > 0$ holds, we have that $0 < (1 - \alpha)[1 - q(1 + s)]\tau < [1 - q(1 + s)]\tau < 1 - q(1 + s)\tau$, which ensures the second-order condition. Solving (13) yields the following interior solution for $p_{i,t} > w_t / \alpha b_i$, which is denoted by $\tilde{p}_{i,t}$:

$$\tilde{p}_{i,t} \equiv \frac{w_t}{\alpha b_i} \Gamma(\tau), \text{ where } \Gamma(\tau) \equiv \frac{1 - q(1 + s)\tau}{1 - q(1 + s)\tau - (1 - \alpha)[1 - q(1 + s)]\tau} > 1. \tag{14}$$

Because $1 - q(1 + s) > 0$ and $(1 - \alpha)[1 - q(1 + s)]\tau < 1 - q(1 + s)\tau$, we have $\Gamma(\tau) > 1$ and, hence, $\tilde{p}_{i,t} > w_t / (\alpha b_i)$ is satisfied.

The following proposition summarizes firm i 's choice in which tax evasion occurs.

Proposition 2. *Suppose that $1 - q(1 + s) > 0$ and that Assumption 1 holds. Firms with productivity b_i set the price, $\tilde{p}_{i,t}$, as (14). The declared profit satisfies (12). The true profit and the expected after-tax operating profit are, respectively, given by*

$$\pi_{i,t} = (1 - \alpha \Gamma(\tau)^{-1}) \tilde{p}_{i,t} x(\tilde{p}_{i,t}) > \tilde{\pi}_{i,t}, \tag{15}$$

$$\pi_{i,t}^e = (1 - \tilde{\tau}) (1 - \alpha \Gamma(\tau)^{-1}) \tilde{p}_{i,t} x(\tilde{p}_{i,t}). \tag{16}$$

The inequality $\pi_{i,t} > \tilde{\pi}_{i,t}$ in (15) indicates that all firms under-declare their operating profits. The effective CIT rate, $\tilde{\tau} \in \left(0, \frac{1 + \alpha q(1 + s)}{1 + \alpha} \right)$, satisfies that $\tilde{\tau} < \tau$.

Proof. See the text and Appendix B. □

Proposition 2 states that if the expected additional tax rate is lower than the rate under honest declaration ($q(1 + s) < 1$), firms choose to evade CIT by under-declaring profits ($\tilde{\pi}_{i,t} < \pi_{i,t}$). This is captured by $\Gamma(\tau)$, which is the only difference between the honest and dishonest declaration. Because $\Lambda'(p_{i,t}) = -\alpha x(p_{i,t}) < 0$, a firm can under-declare its profit by raising its price level. When firms under-declare profits, they pretend to be less productive, which leads to a higher price setting ($\Gamma(\tau) > 1$), as represented by (14).

Notably, the CIT rate itself has a substantial effect on tax evasion through the term $\Gamma(\tau)$. From (9) and (15), we have $\text{sign}d(\tilde{\pi}_{i,t} / \pi_{i,t}) / d\tau = \text{sign}d(\tilde{\tau} / \tau) / d\tau = \text{sign}d(1 / \Gamma(\tau)) / d\tau < 0$.¹³ Thus, a rise in the CIT rate increases the difference between the true profit ($\pi_{i,t}$) and the declared profit ($\tilde{\pi}_{i,t}$) and encourages tax evasion.

Tax evasion by firms may not be possible if we assume that the government incorporates the equilibrium behavior of firms (14) and, thus, can infer productivity b_i from $\tilde{p}_{i,t}$. Although recent literature on optimal taxation using the mechanism design approach includes this assumption, we do not. Instead, we assume that a government does not conduct such a perfect back calculation, as in Allingham and Sandmo (1972), because this simple setting allows us to provide interesting analyses on the macroeconomic consequences of CIT evasion in a tractable model.

REMARKS

The properties $d\tilde{\tau} / d\tau > 0$ and $d(\tilde{\tau} / \tau) / d\tau < 0$ are in line with Roubini and Sala-i-Martin (1995) and Kafkalas et al. (2014).¹⁴ However, the tax evasion considered in our model departs from these previous studies in the following respects.

First, tax evasion in our model is derived endogenously from the micro foundation of firms' tax evasion behavior, in contrast to the *ad-hoc* expression by Roubini and Sala-i-Martin (1995).

Second, Chen (2003) and Kafkalas et al. (2014) do not consider tax evasion associated with profit maximization in an imperfectly competitive product market. Thus, there is no relationship between the tax rates and the firms' choice of profits and declarations of profits in their models. In contrast, in our model, the CIT rate affects them substantially, as represented by $\Gamma(\tau) > 1$ and $\Gamma'(\tau) > 0$.

2.3 Household

The population size is constant at one. The utility function of a representative household is

$$U_0 = \sum_{t=0}^{\infty} \left(\frac{1}{1 + \rho} \right)^t u(C_t), u(C_t) = \frac{C_t^{1-\sigma}}{1-\sigma}, \sigma > 0. \tag{17}$$

$u(C_t) = \ln C_t$, when $\sigma = 1$. Here, C_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 L unit of labor inelastically. The household's budget constraint is given by $W_t = R_{t-1}W_{t-1} + w_tL - C_t$, where W_{t-1} is the assets at the end of period $t - 1$. The household's utility maximization yields

$$\frac{C_{t+1}}{C_t} = \left(\frac{R_t}{1 + \rho} \right)^{1/\sigma}, \tag{18}$$

and the transversality condition (TVC) is

$$\lim_{t \rightarrow \infty} \frac{C_t^{-\sigma} W_{t-1}}{(1 + \rho)^t} = 0. \tag{19}$$

2.4 Government

We assume that the government keeps a balanced budget in each period. From (8) and (9), the aggregate tax revenue of the government is $\int_0^{N_t} \int \{ \tau \tilde{\pi}_{i,t} + q(1 + s)\tau[\pi_{i,t} - \tilde{\pi}_{i,t}] \} dF(b) di = \tilde{\tau} \int_0^{N_t} \int \pi_{i,t} dF(b) di = \tilde{\tau} N_t \int \pi_{i,t} dF(b)$. Here, we use the fact that b is iid across firms. This revenue is allocated to productive government spending, G_t , and inspection expenditure to detect tax evasion, M_t . Thus, the budget constraint of the government is given by

$$\tilde{\tau} N_t \int \pi_{i,t} dF(b) = G_t + M_t. \tag{20}$$

The probability of a successful detection of tax evasion by a firm q occurs when we assume spending a constant fraction, Q , of government revenue on M_t .¹⁵ Therefore, the inspection expenditure is given by $M_t = Q\tilde{\tau}N_t \int \pi_{i,t} dF(b)$. This specification of M_t is in line with Kafkalas et al. (2014). Thus, (20) reduces to

$$G_t = (1 - Q)\tilde{\tau}N_t \int \pi_{i,t} dF(b). \tag{21}$$

As mentioned in the Introduction section, such a specification allows us to isolate the role of tax evasion by firms with market power for pursuing Barro's rule. This is because Kafkalas et al.'s (2014) result indicate that Barro's rule holds even with the tax evasion of perfectly competitive firms under inspection expenditure of the form in (21).

3. Equilibrium

An equilibrium is an allocation in which (i) all monopolistically competitive firms choose $[p_{i,t}, x_{i,t}]_{t=0}^{\infty}$, for $i \in [0, N_t]$, to maximize their after-tax operating profits; (ii) the evolution of the varieties of intermediate goods, $[N_t]_{t=0}^{\infty}$, is determined by free entry; (iii) the evolution of net interest and wage rates, $[R_{t-1}, w_t]_{t=0}^{\infty}$, satisfy market clearing; (iv) the evolution of aggregate consumption and investment, $[C_t, \eta N_{t+1}]_{t=0}^{\infty}$, is consistent with a household's utility maximization; and (v) the evolution of productive public expenditures and inspection expenditures, $[G_t, M_t]_{t=0}^{\infty}$, satisfy the budget constraint of the government, taking the announced CIT rate, additional tax rate, and the probability of an audit, (τ, s, q) , as given.

We begin with the labor market, which clears as

$$L = L_{Y,t} + N_t \int \frac{x_{i,t}}{b} dF(b). \tag{22}$$

The cost for entry into the intermediate good market η is financed by borrowing from households. Because N_{t+1} firms invest in period t , the asset market equilibrium condition is given by $W_t = \eta N_{t+1}$. The final good market clears as $Y_t = C_t + \eta N_{t+1} + G_t + M_t$.

We next characterize the dynamic system and the steady state of the economy. Appendix D shows that the dynamic system of the economy is characterized by the following single difference equation with respect to $z_t \equiv C_t/N_t$:

$$z_{t+1} = \frac{\eta^{1-\frac{1}{\sigma}} [(1-\tilde{\tau})(1-\alpha\Theta^{-1})\alpha\Omega(\tilde{\tau})/(1+\rho)]^{1/\sigma} z_t}{[1-\tilde{\tau}(1-\alpha\Theta^{-1})\alpha]\Omega(\tilde{\tau})-z_t}, \tag{23}$$

where

$$\Theta = \begin{cases} 1 & \text{if } 1-q(1+s) \leq 0 \\ \Gamma(\tau) & \text{if } 1-q(1+s) > 0, \end{cases}$$

and $\Omega(\tilde{\tau})$ in (23) is Y_t/N_t and is constant over time:

$$\begin{aligned} \frac{Y_t}{N_t} \left(= \frac{Y_{t+1}}{N_{t+1}} \right) &= \Omega(\tilde{\tau}) \equiv A^{\frac{1}{1-\alpha}} [(1-Q)\tilde{\tau}(1-\alpha\Theta^{-1})\alpha]^{\frac{\alpha}{1-\alpha}} (1-\alpha)\Theta\alpha^{\frac{2\alpha}{1-\alpha}} \\ &\times \left[\frac{L}{(1-\alpha)\Theta + \alpha^2} \right]^{\frac{1}{1-\alpha}} \left[\int b^{\frac{\alpha}{1-\alpha}} dF(b) \right]. \end{aligned} \tag{24}$$

Here, note that since Y_t/N_t is constant, $G_t x_{i,t}$ in (1) is also constant on the balanced growth path. Thus, because G_t/N_t is constant by (21), the growth rate of $x_{i,t}$ is $-\hat{g}$, where \hat{g} is the growth rate in the steady state defined in Proposition 3 below. So that the individual intermediate good firms' revenues and their profits do not grow at the balanced growth path. However, the economy grows by the expansion of varieties, the increase in N_t : See (1).

From (23), we arrive at the following proposition.

Proposition 3. *A unique steady state exists. In the steady state, z_t takes the following constant value:*

$$\hat{z} = [1-\tilde{\tau}(1-\alpha\Theta^{-1})\alpha]\Omega(\tilde{\tau}) - \eta [(1-\tilde{\tau})(1-\alpha\Theta^{-1})\alpha(1+\rho)^{-1}\eta^{-1}\Omega(\tilde{\tau})]^{1/\sigma} \in (0, \bar{z}), \tag{25}$$

where $\bar{z} \equiv [1-\tilde{\tau}(1-\alpha\Theta^{-1})\alpha]\Omega(\tilde{\tau})$. In the steady state, C_t , N_t , and Y_t grow at the same constant rate:

$$\hat{g} = [(1-\tilde{\tau})(1-\alpha\Theta^{-1})\alpha(1+\rho)^{-1}\eta^{-1}\Omega(\tilde{\tau})]^{1/\sigma}. \tag{26}$$

The economy jumps to the steady state initially.

Proof. See Appendix E. □

The labor allocated to the production of final and intermediate goods, $L_{Y,t}$ and $N_t \int \frac{x_{i,t}}{b} dF(b)$, are both constant over time during the steady state. In addition, Y_t , C_t , G_t , and M_t grow at the same rate as N_t . Again, note that the source of economic growth in our model is firms' investment in a new business (N_{t+1}), as in the standard expanding variety model, which becomes the fundamental source of perpetual growth. In addition, productive government service (G_t) has a growth effect. It amplifies the demand for intermediate goods, increases the expected profits of the intermediate good firms, promotes their entry, and raises the interest rate through the free entry condition: See (4) and (6). We investigate this growth effect in greater detail in the next section.

4. Optimal CIT rates

As mentioned in Section 2, the CIT rate substantially affects the tax evasion behavior of firms in the imperfectly competitive market. Therefore, we analyze the growth- and welfare-maximizing CIT rates under such CIT evasion.¹⁶

4.1 Growth-maximizing CIT rate

We obtain the following proposition.

Proposition 4. *Let us denote the growth-maximizing announced CIT rate and growth-maximizing effective CIT rate as τ^{GM} and $\tilde{\tau}^{GM}$, respectively.*

1. *When $1 - q(1 + s) \leq 0$ and each firm declares its true operating profit, $\tilde{\tau}^{GM} = \tau^{GM} = \alpha$ holds.*
2. *When $1 - q(1 + s) > 0$ and each firm under-declares its operating profit, $\tau^{GM} > \tilde{\tau}^{GM} > \alpha$ holds.*

Proof. See Appendix F. □

The first part of Proposition 4 is in line with Barro's (1990) rule, that is, the tax rate that maximizes long-run growth equals the output elasticity of public services, α . This result is also consistent with that of Kafkalas et al. (2014), indicating that even with government spending for detection, the growth-maximizing tax rate coincides with the output elasticity of public services.

Importantly, the mechanism behind this result is the same as that of Barro (1990). In Barro's model, the growth-maximizing rule is attributed to the following trade-off between income tax and growth. Meanwhile, an increase in income tax decreases the net interest rate ($(1 - \text{tax rate}) \times \text{interest rate}$) and hurts growth, and an increase in income tax boosts productive government spending and raises the interest rate. This has a positive effect on growth.

The interest rate in our model is determined through the free entry condition of intermediate goods firms as

$$R_{t-1} = \eta^{-1} \int \pi_{i,t}^e dF(b) = \eta^{-1} (1 - \tilde{\tau})(1 - \alpha\Theta^{-1})\alpha Y_t/N_t. \tag{27}$$

Here, Y_t/N_t , given in (24), is positively affected by¹⁷

$$G_t = (1 - Q)\tilde{\tau}N_t \int \pi_{i,t} dF(b) = (1 - Q)\tilde{\tau}(1 - \alpha\Theta^{-1})\alpha Y_t. \tag{28}$$

This induces essentially the same trade-off as Barro (1990). Thus, in the absence of tax evasion ($\Theta = 1$), we obtain the same result as Barro (1990).

The second part of Proposition 4 states that with under-declaration of profit, the growth-maximizing announced CIT rate is higher than the growth-maximizing effective CIT rate, $\tau^{GM} > \tilde{\tau}^{GM}$. Moreover, both are higher than the output elasticity of public services, α . That is, tax evasion

by firms increases the growth-maximizing tax rates, τ^{GM} and $\tilde{\tau}^{GM}$. $\tau^{GM} > \tilde{\tau}^{GM}$ stems simply from the evasion of CIT by firms. Then, we consider the intuition behind the result of $\tilde{\tau}^{GM} > \alpha$ here.

As we have seen after Proposition 2, in response to a tax hike, each intermediate good firm increases tax evasion. This secures the expected operating after-tax profit, $\pi_{i,t}^e$, and private investment. Because the true operating profit, $\pi_{i,t}$, is also secured, the tax base for public service provision ($= N_t \int \pi_{i,t} dF(b)$) is maintained.¹⁸ These are caused by the effect of CIT evasion associated with profit maximization in an imperfectly competitive product market, which are captured by the term $1 - \alpha\Theta^{-1}$ in (27) and (28), where $\Theta = \Gamma(\tau)$ and $\Gamma'(\tau) > 0$. Hereafter, we call this simply the effect of CIT evasion. The effect of CIT evasion mitigates the negative effect of CIT on growth and increases the benefit of raising the CIT rate for the provision of productive public services.¹⁹

Our result ($\tilde{\tau}^{GM} > \alpha$) is different from Kafkalas et al. (2014), who advocate that Barro’s rule holds ($\tilde{\tau}^{GM} = \alpha$) even in the economy with tax evasion. While tax evasion does not affect firms’ decision making in Kafkalas et al. (2014), our model includes the effect of CIT evasion as mentioned above, which causes $\tilde{\tau}^{GM} > \alpha$.²⁰

4.2 Welfare-maximizing CIT rate

Next, we analyze the welfare-maximizing CIT rate. Using the balanced growth rate, \hat{g} , the equilibrium path of consumption is given by $C_t = \hat{g}^t C_0 = \hat{g}^t \hat{z}$.²¹ Substituting it into the lifetime utility function of the representative household, (17), we obtain

$$U_0 = \frac{\hat{z}^{1-\sigma}}{(1-\sigma)[1-(1+\rho)^{-1}\hat{g}^{1-\sigma}]}, \tag{29}$$

where $1 > (1+\rho)^{-1}\hat{g}^{1-\sigma}$ holds by the TVC. The social welfare is determined by the initial level of consumption and the long-run growth rate, both of which depend on the announced CIT rate, τ . Let us denote the welfare-maximizing announced CIT rate by τ^{WM} .

Proposition 5.

1. When each firm declares its true operating profit, $1 - q(1 + s) \leq 0$, $\tau^{WM} > \tau^{GM} = \alpha$ holds. Therefore, the welfare-maximizing announced CIT rate, τ^{WM} , is higher than the growth-maximizing announced CIT rate, τ^{GM} .
2. Suppose that $1 - q(1 + s) > 0$ and $q = 0$. Then, each firm understates its operating profit and a marginal increase in the announced CIT rate at the growth-maximizing CIT rate improves social welfare.

Proof. See Appendix G. □

Proposition 5 shows that the welfare-maximizing CIT is higher than the growth-maximizing one.²² Meanwhile, a marginal increase in CIT from τ^{GM} does not affect the growth rate because the first-order effect vanishes at $\tau = \tau^{GM}$. In addition, it increases current consumption because labor income, which is exempt from taxation, is raised by increases in productive public services (see Appendix G). Therefore, the welfare-maximizing CIT rate is higher than the growth-maximizing one.

5. Quantitative analysis

Propositions 4 and 5 summarize that the following three effects make τ^{WM} larger than the output elasticity of public services with tax evasion by firms ($1 - q(1 + s) > 0$).

The first effect is represented by $\tau^{WM} > \tau^{GM}$; the welfare-maximizing announced tax rate is higher than the growth-maximizing one. This is because the tax base is CIT, and wage income is exempt from taxation as we have seen in Proposition 5. We call this *the tax base effect*. The

second effect is represented by $\tau^{GM} > \tilde{\tau}^{GM}$. This stems from the degree of tax evasion by firms, ($\tau > \tilde{\tau}$). We call this *the difference in tax rates*. The third effect is represented by $\tilde{\tau}^{GM} > \alpha$. This is attributable to *the effect of CIT evasion*, as mentioned in Section 4.1

The objective of this section is to investigate how high the welfare-maximizing CIT rate τ^{WM} is and which of the three effects contributes most to it. To solve these quantitative problems, we extend the above base model in this section.

5.1 Extended model

We start with a small revision of the model because the problematic restriction on the parameter lies in the previous form of production technology. The output-elasticity of public services α must be set at the price elasticity of intermediate good, $1/(1 - \alpha)$. To resolve this, we change production technology (1) into

$$Y_t = AL_{Y,t}^{1-\alpha} \int_0^{N_t} (a(G_t, N_t)x_{i,t})^\alpha di, \tag{30}$$

where

$$a(G_t, N_t) = G_t^\epsilon N_t^{1-\epsilon}, 0 < \epsilon < 1. \tag{31}$$

The composite externality (31) represents a combination of the role of knowledge spillover, as in Benassy (1998), together with productive public services, as in Barro (1990).

We adopt this form of composite externality for the following two reasons: First, as will become evident below and as stated by Chatterjee and Turnovsky (2012), it helps to provide a plausible calibration of the aggregate economy, something that is generically problematic in the conventional one-sector endogenous growth model.²³ Under (30) and (31), the output-elasticity of public services is $\beta \equiv \alpha\epsilon (< \alpha)$, which differentiates α from the output-elasticity of public services. Notice that the specification of (30) and (31) is consistent with the existence of the balanced growth by the expanding varieties. Similarly, to the explanation right before Proposition 3, $G_t^\epsilon N_t^{1-\epsilon} x_{i,t}$ in (30) is constant on the balanced growth path. This means that the engine of growth in this extended model is also the expansion of varieties. Second, as the following Remark shows, although we take an additional externality (the spillover of knowledge) into account, the basic property of the benchmark model is maintained.

Remark. The qualitative results do not change in the extended model. By replacing α with β , the same results as Propositions 4 and 5 hold.

Proof: See Appendix H. □

5.2 Calibration

To conduct numerical exercises, we set the baseline parameter value as in Table 1. Appendix I provides details of our calibration.

The distribution of firms’ productivity is determined to make the curvature of the distribution function of firm sizes in the model equal to that of the Pareto distribution estimated with US data by Axtell (2001). This requires $\psi = 1.059$. We choose $\alpha = 0.8620$ so that the markup rate of firms $\mu (= \Gamma(\tau)/\alpha - 1)$ takes 20%, which is a standard value of markup rate of firms (e.g., Rotemberg and Woodford (1999)).

We set the parameter to measure the knowledge spillover, ϵ , to 0.1160, so that the output elasticity of public services, β , equals 0.1. Although the estimates of the elasticity vary among some empirical studies, 0.1 is one of the reasonable values of β .²⁴

Table 1. Baseline parameter value

	Benchmark	Source
ψ	1.059	Axtell (2001)
α	0.8620	Markup rate = 0.2
ϵ	0.1160	$\partial \ln Y / \partial \ln G = 0.1$
τ	0.2706	Average CIT rate of OECD countries
q	0.096	Average audit rate of the majority class of the US large corporations
s	0.5	Fullerton and Karayannis (1994)
k	0.1667	$Q = kq$, enforcement budget and CIT revenue of the IRS
σ	1.5	Jones et al. (1993)
ρ	0.0204	Jones et al. (1993)
L	1	Normalization
$A^{1-\alpha\epsilon} / \eta$	34.2321	Growth rate = 0.02

In this subsection, we provide the baseline value of the announced CIT rate, $\tau = 0.2706$, to determine the baseline balanced growth rate because the balanced growth rate depends on τ in this model economy. This value of τ ($= 0.2706$) is the average CIT rate in OECD countries from 2000 to 2017.²⁵ We set the penalty tax rate, s , to 0.5, according to Fullerton and Karayannis (1994), who take this value as a normal rate in the USA.

We set the benchmark value of the audit rate, q , to 0.096. To obtain this value, we utilize the statistics provided by the Internal Revenue Service. Each *IRS Data Book* between 2000 and 2017 provides the actual ratio of the examined corporations to all corporations under a classification by firm size.²⁶ We choose the class of the smallest size of the large corporations.²⁷ This is because such a class occupies a significantly large part (about 60%) of the large corporations, which are corporations above a certain business size. Besides, the ratios of the audited corporations vary greatly across the classes and so does the number of corporations in the classes. This means that taking the average audit rate among the classes is unreasonable. Therefore, we set the audit rate in such a manner. Later, we confirm the robustness of our results for a range of q , including $q = 0.089$, the value adopted by Fullerton and Karayannis (1994).

The relationship between q and Q is specified by $Q = kq$, where k is a constant, to satisfy the natural properties: $\frac{dQ}{dq} > 0$, $Q \in [0, 1]$ for $q \in [0, 1]$, and $Q = 0$ for $q = 0$. We set $k = 0.167$ to make Q equal the ratio of inspection cost to the CIT revenue in the USA on average from 2000 to 2017.²⁸ However, not only the value but also the functional form does not change our results because the growth rate of our model is independent of them: see (26).

We set $\sigma = 1.5$ and $\rho = 0.0204$ according to Jones et al. (1993). These are the standard values used in quantifying growth models. We set $L = 1$ for normalization. Finally, we choose the scale parameter, A , and the cost of developing one intermediate good, η such that the balanced growth rate equals 2%.²⁹

The above benchmark parameter set realizes the case of tax evasion, $q(1 + s) - 1 < 0$.

5.3 Results

5.3.1 Main results

Table 2 provides the welfare-maximizing announced CIT rate, τ^{WM} , the growth-maximizing announced rate, τ^{GM} , and the growth-maximizing effective CIT rate, $\tilde{\tau}^{GM}$ for the benchmark case. We find that $\tau^{WM} = 0.4025$, $\tau^{GM} = 0.3921$, and $\tilde{\tau}^{GM} = 0.3133$. The value of the optimal CIT rate, 0.4025, is close to the estimated value of 42% by Aghion et al. (2016). As Propositions 4

Table 2. The welfare- and growth-maximizing tax rates and the contributions to $\tau^{WM} - \beta$ for the benchmark

τ^{WM}	0.4025
τ^{GM}	0.3921
$\tilde{\tau}^{GM}$	0.3133
β	0.1000
The tax base effect: $\tau^{WM} - \tau^{GM}$	0.0104
The difference in tax rates: $\tau^{GM} - \tilde{\tau}^{GM}$	0.0787
The effect of CIT evasion: $\tilde{\tau}^{GM} - \beta$	0.2133
Total effect: $\tau^{WM} - \beta$	0.3025

Table 3. The optimal CIT rates for alternative markup rates (benchmark: markup rate = 0.20)

Markup rate	0.10	0.20	0.30	0.40	0.50	0.75	1.00
τ^{WM}	0.5258	0.4025	0.3324	0.2868	0.2549	0.2058	0.1783
τ^{GM}	0.5077	0.3921	0.3248	0.2806	0.2493	0.2007	0.1733
$\tilde{\tau}^{GM}$	0.3761	0.3133	0.2718	0.2422	0.2201	0.1835	0.1617
$\tau^{WM} - \tau^{GM}$	0.0181	0.0104	0.0075	0.0062	0.0056	0.0050	0.0050
$\tau^{GM} - \tilde{\tau}^{GM}$	0.1315	0.0787	0.0529	0.0383	0.0291	0.0171	0.0116
$\tilde{\tau}^{GM} - \beta$	0.2761	0.2133	0.1718	0.1422	0.1201	0.0835	0.0617
$\tau^{WM} - \beta$	0.4258	0.3025	0.2324	0.1868	0.1549	0.1058	0.0783

and 5 indicate, τ^{WM} , τ^{GM} , and $\tilde{\tau}^{GM}$ are all larger than $\beta (= 0.1)$. Importantly, the difference between τ^{WM} and β is 0.3025, which is quite large.

The fifth, sixth, and seventh rows of Table 2 provide a decomposition of the total effect, $\tau^{WM} - \beta$. The effect of CIT evasion, $\tilde{\tau}^{GM} - \beta$, amounts to 0.2133 and is the largest of the three effects. Thus, the effect of CIT evasion is the primary source of the high optimal CIT rate quantitatively.

5.3.2 Robustness

The effect of CIT evasion depends on the markup rate $\mu (= \Gamma(\tau)/\alpha - 1)$ because it is related to their market power. Therefore, we calculate the optimal CIT rates for the various markup rates: see Table 3.³⁰

Around the benchmark value (e.g., the case of markup rate = 0.1, ..., 0.5), we find that both τ^{GM} and τ^{WM} are much higher than β . In particular, the effect of CIT evasion, $\tilde{\tau}^{GM} - \beta$, is significantly large for the alternative markup rates. This indicates that the effect of CIT evasion is the main source of the high optimal CIT rates.

Unsurprisingly, the level of the optimal CIT rate substantially changes according to the output elasticity of public services. However, we find that the impact of tax evasion remains relatively strong for the alternative values of β , the output elasticity of public services.³¹ In Table 4, we provide the ratio of the welfare-maximizing CIT rate to the output elasticity of public services, τ^{WM}/β . Remember that the criterion in the comparison with the Barro rule is β . Thus, for example, although $\tau^{WM} \approx 0.1$ in the case of $\beta = 0.025$, we can interpret this rate as a relatively large value. Because the ratios in Table 4 show that the optimal CIT rates are much higher than β , we can confirm the effect of tax evasion on the optimal CIT rate.

Table 4. We provide τ^{WM} , the ratio of τ^{WM} to β , and the shares of the effect of CIT evasion in the total effect for alternative output elasticities of public services (benchmark: $\beta = 0.10$)

β	0.025	0.05	0.10	0.15	0.20
τ^{WM}	0.0986	0.1980	0.4025	0.6188	0.8488
τ^{WM}/β	3.94	3.96	4.03	4.13	4.24
$\frac{\tilde{\tau}^{GM}-\beta}{\tau^{WM}-\beta}$	0.8833	0.8225	0.7025	0.6000	0.5084

Table 5. The optimal tax rates in the case of $q = 0.089$ for the benchmark

τ^{WM}	0.4162
τ^{GM}	0.4056
$\tilde{\tau}^{GM}$	0.3203
β	0.1000
The tax base effect: $\tau^{WM} - \tau^{GM}$	0.0105
The difference in tax rates: $\tau^{GM} - \tilde{\tau}^{GM}$	0.0853
The effect of CIT evasion: $\tilde{\tau}^{GM} - \beta$	0.2203
Total effect: $\tau^{WM} - \beta$	0.3162

Next, we calculate the share of the effect of CIT evasion in the total effect, $\frac{\tilde{\tau}^{GM}-\beta}{\tau^{WM}-\beta}$, for the alternative values of β . In the benchmark case, the share is 70%. For any other case, the effect of CIT evasion occupies more than half of the total effect. This ensures the robustness of the relative importance of the effect of CIT evasion.

Finally, we conduct a robustness check of the main result with respect to the audit rate q . Figure 1 illustrates the result. Indeed, the level of the optimal CIT rate changes according to q . However, for the various alternative values of q , we can confirm that the effect of CIT evasion is the dominant factor of the high optimal CIT rate relative to the output elasticity of public services.³²

6. Concluding remarks

This study investigates the optimal CIT in an endogenous growth model with productive public services, incorporating tax evasion by monopolistically competitive producers of intermediate goods.

We show that the growth- and welfare-maximizing CIT rates are higher than the output elasticity of productive public services. Thus, because of tax evasion by firms, the CIT rate should be higher than the output elasticity of public services. This is mainly because CIT evasion mitigates the negative effect of CIT on growth and increases the benefit of raising the CIT rate to provide productive public services. Under plausible parameter values, our numerical exercises show that the effect of CIT evasion is significant and that the optimal level of the CIT rate is much higher than the output elasticity of public services.

Next, we note the limitations of our theoretical framework and discuss directions for future research. First, we assume that the probability of audit (q) and the additional tax rate (s) are exogenous parameters. This is because, in addition to the theoretical simplicity, controlling these parameters would not prevent tax evasion in our framework, owing to actual budgetary constraints and its ineffectiveness as a penalty.³³ However, because of the budgetary problem faced by tax agencies, there is a trade-off between enlarging the audit system and keeping the tax revenue under reasonable (fiscal and/or legal) constraints. Therefore, it is worthwhile designing a corporate taxation scheme in which the probability of audit and the additional tax rate (q and s in the model) can be chosen.

The growth- and welfare-maximizing tax rates

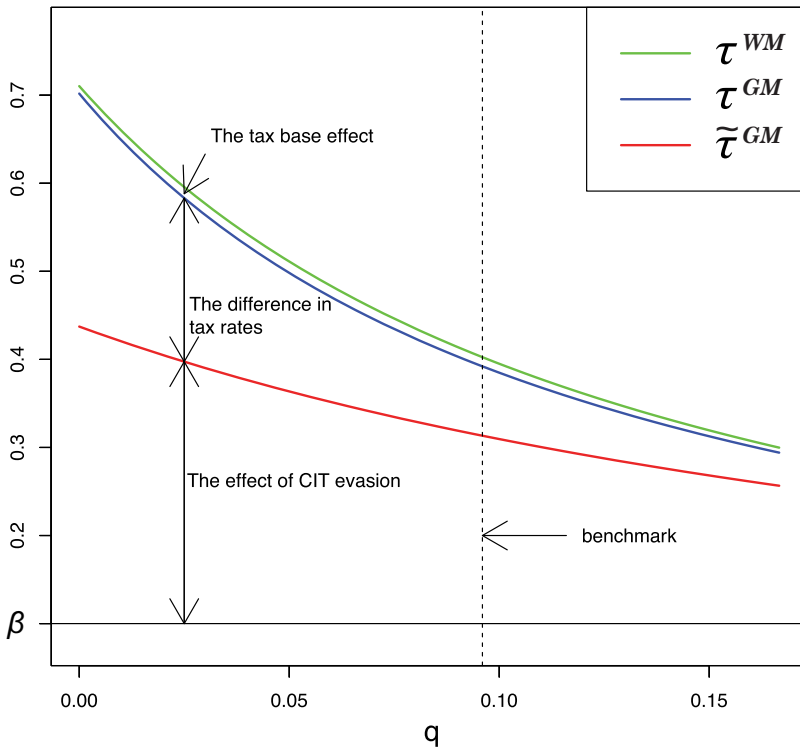


Figure 1. The growth- and welfare-maximizing tax rates (τ^{WM} , τ^{GM} , $\tilde{\tau}^{GM}$ and contributions to $\tau^{WM} > \beta$ for alternative values of q).

A further question is how the optimal CIT rates are affected by the presence of international tax competition. This model can be extended to open economies that incorporate tax competition in the locational choice of firms. With such an extension, reducing the CIT rate can have a growth-enhancing effect and play a crucial role in attracting foreign firms. However, a race to bottom with relation to CIT does not occur because it leads to a shortage of public infrastructure that attracts domestic investment (e.g., Dewit et al. (2017)). A positive CIT rate can exist in the game. This prediction might align with international negotiations over a minimum CIT rate, to be held in October 2021. Therefore, an empirical analysis is recommended for future studies.

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Notes

1 According to the policy stance of President Trump, the US government reduced the CIT rate to 21%. In Japan, the government plans to cut the CIT rate to about 20% gradually under some conditions.

2 In fact, CIT occupies a considerable fraction of the annual revenue of the public sector. For example, the Internal Revenue Service (2017) and the National Tax Agency (2017) report that the shares of CIT to total tax revenues were about 10% in the US in 2016 and 19% in Japan in 2015, respectively.

- 3 Here, the “tax gap” is the “gross tax gap” in the Internal Revenue Service’s survey. For details, see Internal Revenue Service (2016).
- 4 The sources of these facts are Internal Revenue Service (2017) and National Tax Agency (2016).
- 5 We follow Barro and Sala-i-Martin’s (2004) variety-expansion model.
- 6 Here, we mean that the effective tax rate is the ratio of the actually collected CIT revenue to the true profits of firms.
- 7 Some empirical studies suggest the importance of productive public expenditure for economic growth. Abiad et al. (2016) show that increases in public investment in infrastructure raise output in both the short and long run.
- 8 Futagami et al.’s (1993) finding works if the policy effects during the transition path caused by the accumulation of public capital are evaluated. Ghosh and Roy (2004) consider the composite output externality between the stock of public capital and the flow of public services. Kalaitzidakis and Kalyvitis (2004) consider the trade-off of public expenditure between new investment and the maintenance of existing public capital. Agénor (2008) considers public health capital in addition to general infrastructure. Chang and Chang (2015) consider an endogenous growth model with market imperfection both in goods and labor markets and show that welfare-maximizing productive government spending can be larger than growth-maximizing spending if it is financed by capital income taxes.
- 9 Agénor and Neanidis (2015) show empirically that public capital affects growth through productivity and innovation (R&D) capacity.
- 10 As explained above, firms’ tax evasion mitigates the negative effect of taxation. In this aspect, our study is related to Gillman and Kejak (2014), which explains the constant ratio of US government tax revenue to GDP along with the trend of declining US tax rates. Bethencourt and Kunze (in press) examine the relationship between capital income tax evasion and economic growth using a dynamic OLG model. They predict that poverty traps might arise when tax evasion induces a shortage of productive government service. Varvarigos (2017) shows that without productive government service, poverty traps can occur in a framework in which the agents evade labor income taxes. These studies neither consider CIT evasion nor the optimal tax level.
- 11 Some theoretical studies investigate the role of public capital on growth under an imperfectly competitive product market. Pereto (2007a) explores this issue in an R&D-based growth model where the market structure (entry and exit of firms) is endogenously determined. Pereto (2007b) shows that productive public capital is neutral to growth, and therefore, no optimal tax exists. Meanwhile, Chang and Chang (2015) advocate that infrastructure affects growth and optimal tax rates exist in an endogenous growth model, which includes monopolistic competition in the goods market and unionization in the labor market. The recent empirical study of Agénor and Neanidis (2015) may support the latter result.
- 12 Note that in the case of $1 - q(1 + s) \leq 0$, firm i declares its true profit, $\tilde{\pi}_{i,t} = \pi_{i,t}$, and sets $p_{i,t} = p_{i,t}^*$ as stated in Proposition 1.
- 13 see Appendix C for the details.
- 14 We obtain $d\bar{\tau}/d\tau > 0$, and $d(\bar{\tau}/\tau)/dq > 0$ as in Roubini and Sala-i-Martin (1995) and Kafkalas et al. (2014) (see Appendix C). Both studies assume that the difference between the announced and the effective tax rate increases with the announced tax rate τ and decreases with the detection probability q .
- 15 Since a functional form of Q with respect to q has no effect on the qualitative results below, we denote the fraction by Q . The numerical exercises conducted in Section 5.2 specify the strong relationship between q and Q .
- 16 Although we have assumed that q and s are exogenous (see Section 2.2.3), these parameters may be really endogenously selected by the governments in that the government controls tax enforcement and punishment against tax evasion. However, to concentrate on the choice of optimal CIT and keep the analyses simple, we ignore these policy dimensions and assume that they are exogenous parameters. This assumption is in line with Johansen (2010) who assumes that parameters related to tax enforcement and punishment against profit shifting by multinational firms are exogenous.
- 17 See Appendix D for the derivation of (27) and (28).
- 18 Indeed, the disparity between the announced and effective CIT rates is enlarged by the strong tax evasion due to the tax hike. At a glance, this is likely to damage public service provision. However, at the same time, such an increase in tax evasion holds the tax base, $N_t \int \pi_{i,t} dF(b) = (1 - \alpha\Theta^{-1})\alpha Y_t$.
- 19 Except for the effect of CIT evasion, there exist general equilibrium effects in our model. An increase in $p_{i,t}$ reduces the demands of intermediate good in the final good sector, $x(p_{i,t})$. This exerts the following opposite effects on R_{t-1} . Meanwhile, a fall in $x(p_{i,t})$ reduces $\pi_{i,t}^e$ and lowers R_{t-1} , and a fall in $x(p_{i,t})$ causes a labor shift from the intermediate to final good sector, which increases final output and raises R_{t-1} . However, we find that these general equilibrium effects are not the most important ones, as follows. By taking the logarithm of the growth rate (26) and differentiating it with respect to the effective tax rate $\bar{\tau}$, we find that the sum of the opposing general equilibrium effects is negative; the negative effect of a fall in $x(p_{i,t})$ dominates the positive effect of a rise in the final output by shifting labor to the final good sector. Therefore, the primary force of raising the growth-maximizing effective tax rate is the direct effect, which we mentioned in the text.
- 20 In Chen’s (2003) model, although the growth-maximizing announced tax rate is higher than the output elasticity of public service, it is ambiguous; so is the growth-maximizing effective tax rate. This is because the household-firms need to pay some tangible cost to evade tax and it is included in the definition of the effective tax rate of that model. Therefore, Chen’s (2003) result is not necessarily suitable for a rigorous comparison with those of Kafkalas et al. (2014) and this paper.

- 21 The economy jumps onto the balanced growth path in the initial period, as explained in Section 3. Remember that we assumed $N_0 = 1$.
- 22 In the case of an under-declaration of profits by firms ($1 - q(1 + s) > 0$), this statement no longer holds when $q \neq 0$. However, the only available limiting case in Part 2 (the case of $q = 0$) is a very persuasive one. This is because the result of $\tau^{WM} > \tau^{GM}$ is independent of tax evasion, as Part 1 shows, and the case of $q = 0$ is that in which the role of tax evasion is most strengthened. In fact, we could not find any counterexample for alternative values of q under the calibration in Section 5: See Figure 1. Thus, we conjecture that the assertion of $\tau^{WM} > \tau^{GM}$ may be true for the other values of q , even when $1 - q(1 + s) > 0$.
- 23 Chatterjee and Turnovsky (2012) consider the composite externality from physical capital, as in Romer (1986) and productive public spending or Barro (1990) and Futagami *et al.* (1993) and conduct numerical analyses, including growth and welfare effects. Our application of (31) is in line with Chatterjee and Turnovsky (2012) because, in our model, the stock of N_t replaces the role of physical capital and is both the engine of growth and the source of spillover and positive social returns to variety, as discussed in Romer (1986) and applied in R&D-based growth models as in Aghion and Howit (1998), Benassy (1998), Peretto (2007a), and others.
- 24 From an empirical point of view, the output elasticity of infrastructure (or productive public services) has been estimated and examined using data from many countries. Recent empirical studies (e.g., Röller and Waverman (2001), Shioji (2000), Esfahani and Ramirez (2003), Kamps (2006), Bom and Ligthart (2014)) indicate that the output elasticity of infrastructure (or productive public services) lies in the range of 0.1–0.2, on average. More recent studies by Bom and Ligthart (2014) and Caldeón *et al.* (2015) indicate that the output elasticity of infrastructure is around 0.1.
- 25 The value of τ does not strongly affect the levels of growth- and welfare-maximizing CIT rates. Therefore, the choice of the baseline value of τ makes little difference in the quantitative results of our numerical exercises.
- 26 We can collect the data from the archive of the prior year *IRS Data Books* in the Internal Revenue Service's website. These are downloadable at <https://www.irs.gov/statistics/soi-tax-stats-prior-year-irs-data-books>.
- 27 According to the definition by the Internal Revenue Service, large corporations are those with assets greater than 10 million dollars. The upper bound of the asset size of the smallest class is 50 million dollars.
- 28 The source is *IRS Data Book* between 2000 and 2017.
- 29 We do not eliminate the scale effect explicitly in this calibration because we obtain the same results in Section 5.3 if we do. Following the method in p. 302 of Barro and Sala-i-Martin (2004), we can eliminate the scale effect by imposing the relation $\eta = \mathcal{B}\alpha^{\frac{2\alpha}{1-\beta}} L^{\frac{1}{1-\beta}}$, where $\mathcal{B} > 0$. Given an arbitrary positive number \mathcal{B} , we set η satisfying the above equation. Given such η , we set the scale parameter A to fix the growth rate to 2%. This modification leads to the same quantities in Table 3. We can also adjust the value of η by varying \mathcal{B} .
- 30 We choose the values of α so that the markup rates take the values listed in Table 3. See also Appendix I for details of the calibration.
- 31 As we mentioned in the calibration section, the estimations of β lie at about 0.10 in existing empirical studies. Although the quantitative performance of the model heavily depends on β , the range considered here is sufficiently wide to keep the model quantitatively plausible.
- 32 In particular, consider $q = 0.089$. This is the value chosen in Fullerton and Karayannis (1994). Table 5 shows that the results do not change for the benchmark parameter (other than q).
- 33 For example, the operation cost of the IRS amounts to about 12 billion dollars, but the probability of auditing a firm in the representative class is less than 10% (IRS (2017)). In Japan, the National Tax Agency's budget was 700 billion yen in 2017, and the rate of audited firms was about 3% (NTA (2017)). Thus, to prevent tax evasion sufficiently, unrealistically high additional tax rates are required. Recall that the condition for a true declaration is $q(1 + s) > 1$.
- 34 The parameter restriction $q(1 + s) > \frac{\alpha(1+\alpha)-1}{\alpha}$ holds in a plausible parameter region because the valid range of α , the output elasticity of public service is around 0.1, according to empirical studies. See the calibration in Section 5.2. The corner point $\tau = 1$ can be optimal because the effective CIT rate is lower than 1 when firms evade CIT. If $q(1 + s)$ is small and α is large, the effective CIT rate becomes low, even though the growth-maximization CIT rate is high. Thus, the corner solution $\tau = 1$ is optimal in such a case.
- 35 When the tax system is household total income tax, as in Barro (1990) and Kafkalas *et al.* (2014), this effect vanishes. In fact, we find that the first term of \hat{z} is replaced by $(1 - \bar{\tau})\Omega(\bar{\tau})$, and hence, welfare-maximization is equivalent to growth-maximization; see (26).
- 36 An additional parameter restriction is $q(1 + s) > \frac{\beta(1+\alpha)-1}{\alpha}$. This is a quantitatively reasonable assumption, as we explain at the end of Appendix I.
- 37 Recall that the part of $\Omega(\tau)$ changes into $\hat{\Omega}(\bar{\tau})$.
- 38 For example, Rotemberg and Woodford (1999) adopt this value. However, because markup rate is a key parameter of our analysis, we conduct numerical exercises for alternative values. See Table 3.

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Appendix

A.1 Proof of lemma

We show that if $1 - q(1 + s) > 0$, the declared profit of the firm i , $\tilde{\pi}_{i,t}$, satisfies (12). To do so, we consider two types of dishonest firms: those that do not declare (12), and those that declare (12).

We begin with a firm of the first type that declares $\tilde{\pi}_{i,t}$, which is not equal to (12). In this case, this firm is audited with probability one; $\bar{q} = 1$. Thus, the expected after-tax profit of this firm is given by

$$\tilde{\pi}_{i,t}^e = \pi_{i,t} - \tau \tilde{\pi}_{i,t} - 1 \times (1 + s)\tau (\pi_{i,t} - \tilde{\pi}_{i,t}). \tag{A1}$$

We next consider a dishonest firm that declares (12). This firm is audited with a probability lower than one; $\bar{q} = q \in [0, 1)$, and the expected after-tax profit is given by

$$\tilde{\pi}_{i,t}^e = \pi_{i,t} - \tau \tilde{\pi}_{i,t} - q(1 + s)\tau (\pi_{i,t} - \tilde{\pi}_{i,t}). \tag{A2}$$

Suppose $\tilde{\pi}_{i,t}^e < \tilde{\pi}_{i,t}^e$ holds. This implies that a dishonest firm declares $\tilde{\tilde{\pi}}_{i,t}$, which is not equal to (12). Using (A1) and (A2), we rearrange $\tilde{\pi}_{i,t}^e < \tilde{\tilde{\pi}}_{i,t}^e$ as follows:

$$\begin{aligned} \pi_{i,t} - \tau \tilde{\pi}_{i,t} - q(1 + s)\tau (\pi_{i,t} - \tilde{\pi}_{i,t}) &< \pi_{i,t} - \tau \tilde{\tilde{\pi}}_{i,t} - (1 + s)\tau (\pi_{i,t} - \tilde{\tilde{\pi}}_{i,t}), \\ \Leftrightarrow (1 + s)(1 - q)\pi_{i,t} - [1 - q(1 + s)]\tilde{\pi}_{i,t} &< s\tilde{\tilde{\pi}}_{i,t}, \\ \Rightarrow (1 + s)(1 - q)\pi_{i,t} - [1 - q(1 + s)]\tilde{\pi}_{i,t} &< s\pi_{i,t}, \\ \Leftrightarrow [1 - q(1 + s)]\pi_{i,t} &< [1 - q(1 + s)]\tilde{\pi}_{i,t}. \end{aligned}$$

The third line uses the fact that $\tilde{\tilde{\pi}}_{i,t} \leq \pi_{i,t}$. If $1 - q(1 + s) > 0$, the inequality in the last line indicates that $\pi < \tilde{\pi}_{i,t}$, which contradicts $\tilde{\tilde{\pi}}_{i,t} \leq \pi_{i,t}$. Thus, dishonest firms declare (12). □

B. Derivations of the true profit: (15), the expected after-tax operating profit: (16), and the facts on the effective cit rate: $\tilde{\tau}$ when $1 - q(1 + s) > 0$

Substituting (14) into (7) yields (15). From $\pi_{i,t}^e = (1 - \tilde{\tau})\pi_{i,t}$ (see (8)) and (15) we obtain (16).

We move onto showing some facts on the effective tax rate when $1 - q(1 + s) > 0$. Here, let us define

$$\gamma(\tau) \equiv \Gamma(\tau)^{-1} = 1 - \frac{(1 - \alpha)[1 - q(1 + s)]\tau}{1 - q(1 + s)\tau} (< 1). \tag{B1}$$

Substituting (12) (evaluated at $p_{i,t} = \tilde{p}_{i,t}$) and (15) into (9), we have

$$\frac{\tilde{\tau}}{\tau} = [1 - q(1 + s)] \frac{1 - \alpha}{1 - \alpha\gamma(\tau)} + q(1 + s). \tag{B2}$$

First, we can easily show that $\tilde{\tau} < \tau$ because $[1 - q(1 + s)]\frac{1-\alpha}{1-\alpha\gamma(\tau)} + q(1 + s) - 1 = [1 - q(1 + s)]\left[\frac{1-\alpha}{1-\alpha\gamma(\tau)} - 1\right] < 0$, where $\gamma(\tau) < 1$ and $1 - q(1 + s) > 0$.

Second, from the definition of $\gamma(\tau)$ and (B2), $\lim_{\tau \rightarrow 0} \tilde{\tau} = 0$ and $\tilde{\tau}|_{\tau=1} = \frac{1 + \alpha q(1 + s)}{1 + \alpha}$ and, therefore, we have $\tilde{\tau} \in \left(0, \frac{1 + \alpha q(1 + s)}{1 + \alpha}\right]$. □

C. Relationship between $\tilde{\tau}$ and τ

From (B1), we obtain

$$\gamma'(\tau) = -\frac{(1 - \alpha)[1 - q(1 + s)]}{[1 - q(1 + s)\tau]^2} < 0, \tag{C1}$$

$$\frac{d\gamma(\tau)}{dq} = \frac{(1 - \alpha)(1 - \tau)\tau(1 + s)}{[1 - q(1 + s)\tau]^2} > 0, \tag{C2}$$

or both $\Gamma'(\tau) > 0$ and $d\Gamma(\tau)/dq < 0$. From (B2) and (B1), we obtain $d(\tilde{\tau}/\tau)/d\tau < 0$. From (B2), (C2), and $\gamma(\tau) < 1$, we obtain $d(\tilde{\tau}/\tau)/dq > 0$.

Finally, we prove $d\tilde{\tau}/d\tau > 0$. From (B2),

$$\frac{d\tilde{\tau}}{d\tau} = \frac{[1 - q(1 + s)](1 - \alpha)}{[1 - \alpha\gamma(\tau)]^2} [1 - \alpha\gamma(\tau) + \alpha\tau\gamma'(\tau)] + q(1 + s) \tag{C3}$$

Thus, we have $\frac{d\tilde{\tau}}{d\tau} > 0$, if and only if

$$1 - \alpha\gamma(\tau) + \alpha\tau\gamma'(\tau) > -\frac{[1 - \alpha\gamma(\tau)]^2 q(1 + s)}{[1 - q(1 + s)](1 - \alpha)} \tag{C4}$$

From $\gamma'(\tau) < 0$ and $\gamma''(\tau) < 0$, $\frac{d}{d\tau}[1 - \alpha\gamma(\tau) + \alpha\tau\gamma'(\tau)] = -\alpha\gamma''(\tau) + \alpha\tau\gamma''(\tau) < 0$ holds. This indicates that the LHS of (C4) is decreasing in τ . Furthermore, the RHS of (C4) is decreasing in τ because of $\gamma(\tau) < 1$ and $\gamma'(\tau) < 0$. Thus, $\frac{d\tilde{\tau}}{d\tau} > 0$ for any $\tau \in (0, 1)$ if the minimum value of the LHS of (C4), $1 - \alpha\gamma(1) + \alpha\tau\gamma'(1)$, is larger than the maximum value of the RHS, $-\frac{[1 - \alpha\gamma(0)]^2 q(1 + s)}{[1 - q(1 + s)](1 - \alpha)}$. Using $\gamma(0) = 1$, $\gamma(1) = \alpha$ and $\gamma'(1) = -\frac{1 - \alpha}{1 - q(1 + s)}$, we obtain

$$1 - \alpha\gamma(1) + \alpha\tau\gamma'(1) - \left\{ -\frac{[1 - \alpha\gamma(0)]^2 q(1 + s)}{[1 - q(1 + s)](1 - \alpha)} \right\} = \frac{(1 - \alpha)[1 - \alpha q(1 + s)]}{1 - q(1 + s)} > 0, \tag{C5}$$

and therefore, $\frac{d\tilde{\tau}}{d\tau} > 0$ for any $\tau \in (0, 1)$.

D. Derivation of equilibrium conditions

The price level of firm i and j whose productivity is b_i and b_j is $p_{i,t} = \frac{\Theta}{\alpha b_i} w_t$ and $p_{j,t} = \frac{\Theta}{\alpha b_j} w_t$, where $\Theta = 1(\Gamma(\tilde{\tau}))$ for $1 - q(1 + s) \leq (>) 0$. Combining these with (3) yields $\frac{p_{i,t}}{p_{j,t}} = \left(\frac{x_{i,t}}{x_{j,t}}\right)^{\alpha-1} = \frac{b_j}{b_i}$. Thus, we have $x_{i,t} = \left(\frac{b_j}{b_i}\right)^{\frac{1}{\alpha-1}} x_{j,t}$. This together with (1), (2), and (3) rewrites $p_{i,t} = \frac{\Theta}{\alpha b_i} w_t$ into

$$x_{i,t} = \frac{\alpha^2 L_{Y,t}}{(1 - \alpha)\Theta b_i^{\frac{1}{\alpha-1}} \int b \frac{\alpha}{1-\alpha} dF(b) N_t}. \tag{D1}$$

From (22) and (D1), we obtain labor employed in the final good sector as follows:

$$L_{Y,t} = \frac{(1 - \alpha)\Theta}{(1 - \alpha)\Theta + \alpha^2} L. \tag{D2}$$

Substituting (D2) into (D1) leads to

$$x(p_{i,t}) = \left[\frac{\alpha^2}{(1 - \alpha)\Theta + \alpha^2} \right] \frac{b_i^{\frac{1}{1-\alpha}}}{\int b_i^{\frac{\alpha}{1-\alpha}} dF(b)} \frac{L}{N_t}. \tag{D3}$$

From (1) and (3), we obtain $\int_0^{N_t} p_{i,t} x_{i,t} di = \alpha Y_t$. Combining $\int_0^{N_t} p_{i,t} x_{i,t} di = \alpha Y_t$ with $\pi_{i,t}^e = (1 - \tilde{\tau})(1 - \alpha\Theta^{-1}) p_{i,t} x(p_{i,t})$, we obtain the total expected after-tax operating profit, $N_t \int \pi_{i,t}^e dF(b) = (1 - \tilde{\tau})(1 - \alpha\Theta^{-1})\alpha Y_t$. By combining the total expected after-tax operating profit with (6), we obtain the gross interest rate

$$R_{t-1} = \frac{(1 - \tilde{\tau})(1 - \alpha\Theta^{-1})\alpha Y_t}{\eta N_t}. \tag{D4}$$

Combining $\pi_{i,t} = (1 - \alpha\Theta^{-1}) p_{i,t} x(p_{i,t})$ with $\int_0^{N_t} p_{i,t} x_{i,t} di = \alpha Y_t$, the budget constraint of the government (20) is rewritten into $G_t + M_t = \tilde{\tau}(1 - \alpha\Theta^{-1})\alpha Y_t$. Dividing both sides of the final good market clearing condition, $Y_t = C_t + \eta N_{t+1} + G_t + M_t$, by N_t and using $G_t + M_t = \tilde{\tau}(1 - \alpha\Theta^{-1})\alpha Y_t$ yield

$$\frac{N_{t+1}}{N_t} = \frac{1}{\eta} \left\{ [1 - \tilde{\tau}(1 - \alpha\Theta^{-1})\alpha] \frac{Y_t}{N_t} - \frac{C_t}{N_t} \right\}, \tag{D5}$$

and substituting (D4) into (18), we obtain

$$\frac{C_{t+1}}{C_t} = \left[\frac{(1 - \tilde{\tau})(1 - \alpha\Theta^{-1})\alpha Y_{t+1}}{(1 + \rho)\eta N_{t+1}} \right]^{1/\sigma}. \tag{D6}$$

Substituting $\pi_{i,t} = (1 - \alpha\Theta^{-1}) p_{i,t} x(p_{i,t})$ into (21) reduces to $G_t = (1 - Q)\tilde{\tau}(1 - \alpha\Theta^{-1})\alpha Y_t$. Combining it with (1), (D2), and (D3), we obtain $\frac{Y_t}{N_t} = \Omega(\tilde{\tau})$. Substituting $\frac{Y_t}{N_t} = \Omega(\tilde{\tau})$ into (D5) and (D6) and dividing (D6) by (D5) leads to (23).

E. Proof of Proposition 3

Let us define the right-hand side (RHS) of (23) as $\vartheta(z_t) \equiv \frac{\eta^{1-\frac{1}{\sigma}} [(1-\tilde{\tau})(1-\alpha\Theta^{-1})\alpha\Omega(\tilde{\tau})/(1+\rho)]^{1/\sigma} z_t}{[1-\tilde{\tau}(1-\alpha\Theta^{-1})\alpha]\Omega(\tilde{\tau})-z_t}$. Here, note that the denominator of $\vartheta(z_t)$: $[1 - \tilde{\tau}(1 - \alpha\Theta^{-1})\alpha]\Omega(\tilde{\tau}) - z_t$ must be positive, that is, $z_t < \bar{z} \equiv [1 - \tilde{\tau}(1 - \alpha\Theta^{-1})\alpha]\Omega(\tilde{\tau})$, otherwise N_t eventually equals to zero from (D5): $\frac{N_{t+1}}{N_t} = \frac{1}{\eta} \left\{ [1 - \tilde{\tau}(1 - \alpha\Theta^{-1})\alpha] \Omega(\tilde{\tau}) - z_t \right\}$. When $N_t = 0$, both output and consumption equal to zero, which violates the first-order condition of the representative household.

The properties of $\vartheta(z_t)$ for $z_t \in [0, \bar{z})$ are as follows:

$$\begin{aligned} \vartheta(0) &= 0, \lim_{z_t \rightarrow \bar{z}} \vartheta(z_t) = +\infty, \\ \vartheta'(z_t) &= \frac{\eta^{1-\frac{1}{\sigma}} [(1-\tilde{\tau})(1-\alpha\Theta^{-1})\alpha\Omega(\tilde{\tau})/(1+\rho)]^{1/\sigma} [1-\tilde{\tau}(1-\alpha\Theta^{-1})\alpha]\Omega(\tilde{\tau})}{\{[1-\tilde{\tau}(1-\alpha\Theta^{-1})\alpha]\Omega(\tilde{\tau})-z_t\}^2} > 0, \\ \vartheta'(0) &= \frac{\eta [(1-\tilde{\tau})(1-\alpha\Theta^{-1})\alpha(1+\rho)^{-1}\eta^{-1}\Omega(\tilde{\tau})]^{1/\sigma}}{[1-\tilde{\tau}(1-\alpha\Theta^{-1})\alpha]\Omega(\tilde{\tau})}, \lim_{z_t \rightarrow \bar{z}} \vartheta'(z_t) = +\infty \\ \vartheta''(z_t) &= \frac{2\eta^{1-\frac{1}{\sigma}} [(1-\tilde{\tau})(1-\alpha\Theta^{-1})\alpha\Omega(\tilde{\tau})/(1+\rho)]^{1/\sigma} [1-\tilde{\tau}(1-\alpha\Theta^{-1})\alpha]\Omega(\tilde{\tau})}{\{[1-\tilde{\tau}(1-\alpha\Theta^{-1})\alpha]\Omega(\tilde{\tau})-z_t\}^3} > 0. \end{aligned} \tag{E1}$$

(E1) indicates that $\vartheta(z_t)$ is monotonically increasing and convex function of z_t and takes zero when $z_t = 0$.

Meanwhile, the left-hand side (LHS) of (23) represents 45° line. Thus, we find that a unique steady state $\hat{z} \in (0, \bar{z})$, which is unstable exists if and only if $\vartheta'(0) < 1$ holds. From (D5), (D6) and $Y_t/N_t = \Omega(\tau)$, C_t , N_t , and Y_t grow at the same constant rate, $C_{t+1}/C_t = N_{t+1}/N_t = Y_{t+1}/Y_t = \hat{g}$ in the steady state.

The rest of this appendix shows that the TVC (19) ensures $\vartheta'(0) < 1$. (26) and the asset market clearing condition, $W_t = \eta N_{t+1}$ together with the assumption $N_0 = 1$ transform the TVC (19) into $\lim_{t \rightarrow \infty} \frac{\hat{z}^{-\sigma} \hat{g}^{t(1-\sigma)}}{(1+\rho)^t} = 0$. To satisfy the TVC, $1 > (1+\rho)^{-1} \hat{g}^{1-\sigma}$ must holds. $1 > (1+\rho)^{-1} \hat{g}^{1-\sigma}$ and (26) together with $\frac{(1-\tilde{\tau})(1-\alpha\Theta^{-1})\alpha}{1-\tilde{\tau}(1-\alpha\Theta^{-1})\alpha} < 1$ lead to $\vartheta'(0) < 1$. □

F. Proof of Proposition 4

F.1 Proof of 1

In this case, since each firm does not evade CIT, $\Theta = 1$ and $\tilde{\tau} = \tau$. Then, by (24) and (26), we obtain $\tilde{\tau}^{GM} = \tau^{GM} = \alpha$ immediately.

F.2 Proof of 2

In the beginning, note that the decision of optimal announced CIT rate is equivalent to that of the optimal effective CIT rate. This is because $\tilde{\tau}$ is the function of τ from (B2), and $\tilde{\tau}$ is strictly increasing in τ , $d\tilde{\tau}/d\tau > 0$, for any $\tau \in (0, 1)$, as shown in Appendix C.

Because the growth rate converges to 0 as τ goes to 0 by the construction of the model, the growth rate is maximized at 1 or some interior point in (0, 1).

First, we prove that the growth-maximizing effective CIT is higher than α when it is an interior point in (0, 1). From the definition of $\Omega(\tilde{\tau})$ and (D6), growth maximization with respect to $\tilde{\tau}$ is equivalent to $\max_{\tilde{\tau}} f(\tilde{\tau}) = \ln(1-\tilde{\tau})\tilde{\tau}^{\frac{\alpha}{1-\alpha}} [1-\alpha\gamma(\tau)]^{\frac{1}{1-\alpha}} \gamma(\tau)^{\frac{\alpha}{1-\alpha}} [1-\alpha+\alpha^2\gamma(\tau)]^{-\frac{1}{1-\alpha}}$, subject to (B2): $\frac{\tilde{\tau}}{\tau} = [1-q(1+s)]^{\frac{1-\alpha}{1-\alpha\gamma(\tau)}} + q(1+s)$. The first derivative of $f(\tilde{\tau})$ is

$$f'(\tilde{\tau}) = \underbrace{\left[-\frac{1}{1-\tilde{\tau}} + \frac{\alpha}{1-\alpha} \frac{1}{\tilde{\tau}} \right]}_{\equiv \Psi_1(\tilde{\tau})} + \frac{\alpha}{1-\alpha} \frac{d\tau}{d\tilde{\tau}} \gamma'(\tau) \underbrace{\left[\frac{1}{\gamma(\tau)} - \frac{1}{1-\alpha\gamma(\tau)} - \frac{\alpha}{1-\alpha+\alpha^2\gamma(\tau)} \right]}_{\equiv \Psi_2(\tau)}. \tag{F1}$$

It is obvious that $\Psi_1(\tilde{\tau}) = -\frac{1}{1-\tilde{\tau}} + \frac{\alpha}{1-\alpha} \frac{1}{\tilde{\tau}} = \frac{\alpha-\tilde{\tau}}{(1-\tilde{\tau})(1-\alpha)\tilde{\tau}} \geq 0$ for $\tilde{\tau} \leq \alpha$. Next, we show that the sign of $\Psi_2(\tau)$ is negative for $\tilde{\tau} \leq \alpha$.

$$\begin{aligned} \text{sign}\Psi_2(\tau) &= [1 - \alpha\gamma(\tau)][1 - \alpha + \alpha^2\gamma(\tau)] - \gamma(\tau)[1 - \alpha + \alpha^2\gamma(\tau)] - \alpha\gamma(\tau)[1 - \alpha\gamma(\tau)] \\ &= -\alpha^3\gamma(\tau)^2 - (1 - \alpha)[(1 + 2\alpha)\gamma(\tau) - 1] \end{aligned} \tag{F2}$$

Here, $\text{sign}\Psi_2(\tau) < 0$ for $\gamma(\tau) > \frac{1}{1+2\alpha}$. Furthermore, (B1) and (B2) indicate that $\gamma(\tau)$ is increasing in $q(1+s)$ and when $q(1+s) = 0$, $\gamma(\tau) = 1 - (1-\alpha)\tau$, $\tau = \frac{\tilde{\tau}}{1-\alpha\tilde{\tau}}$ and $\gamma(\frac{\tilde{\tau}}{1-\alpha\tilde{\tau}}) = \frac{1-\tilde{\tau}}{1-\alpha\tilde{\tau}}$ hold. From $\frac{1-\tilde{\tau}}{1-\alpha\tilde{\tau}} - \frac{1}{1+2\alpha} = \frac{\alpha-\tilde{\tau}+\alpha(1-\tilde{\tau})}{(1-\alpha\tilde{\tau})(1+2\alpha)} > 0$, we obtain $\gamma(\frac{\tilde{\tau}}{1-\alpha\tilde{\tau}}) = \frac{1-\tilde{\tau}}{1-\alpha\tilde{\tau}} > \frac{1}{1+2\alpha}$ for $\tilde{\tau} \leq \alpha$. Thus, $\text{sign}\Psi_2(\tau) < 0$ for $\tilde{\tau} \leq \alpha$. Combining $\Psi_1(\tilde{\tau}) \geq 0$ and $\Psi_2(\tilde{\tau}) < 0$ for $\tilde{\tau} \leq \alpha$ with $\gamma'(\tau) < 0$ ((B2)) and $\frac{d\tilde{\tau}}{d\tau} > 0$, we obtain $f'(\tilde{\tau}) > 0$ for $\tilde{\tau} \leq \alpha$. From the discussion so far, we find that $\tilde{\tau}^{GM} > \alpha$ holds.

Next, we consider the case of the corner solution of growth-maximization: $\tau^{GM} = 1$. Assuming $q(1+s) > \frac{\alpha(1+\alpha)-1}{\alpha}$ additionally, we ensure that $\tilde{\tau}^{GM} > \alpha$ because $\tilde{\tau}|_{\tau=1} = \frac{1+\alpha q(1+s)}{1+\alpha}$.³⁴ □

G. Proof and intuition of Proposition 5

(i) PROOF OF 1

The maximization condition of social welfare is $\frac{\partial U}{\partial \tau} = 0$. By (29), this is equivalent to

$$\left[1 - (1 + \rho)^{-1}\hat{g}^{1-\sigma}\right] \frac{\partial \hat{z}}{\partial \tau} + (1 + \rho)^{-1}\hat{z}\hat{g}^{-\sigma} \frac{\partial \hat{g}}{\partial \tau} = 0. \tag{G1}$$

From (25) and (26), with $\Theta = 1$, we obtain $\hat{z} = \frac{1-\alpha(1-\alpha)\tau}{\eta^{-1}(1+\rho)^{-1}\alpha(1-\alpha)(1-\tau)}\hat{g}^\sigma - \eta\hat{g}$. Differentiating it with respect to τ yields $\frac{\partial \hat{z}}{\partial \tau} = \frac{\eta(1+\rho)}{\alpha(1-\alpha)} \left[\frac{1-\alpha(1-\alpha)}{(1-\tau)^2}\hat{g}^\sigma + \frac{1-\alpha(1-\alpha)\tau}{1-\tau}\sigma\hat{g}^{\sigma-1} \frac{\partial \hat{g}}{\partial \tau} \right] - \eta \frac{\partial \hat{g}}{\partial \tau}$. Substituting it into (G1) and rearranging it using $\hat{z} = \frac{1-\alpha(1-\alpha)\tau}{\eta^{-1}(1+\rho)^{-1}\alpha(1-\alpha)(1-\tau)}\hat{g}^\sigma - \eta\hat{g}$, we have

$$\frac{\partial \hat{g}}{\partial \tau} = - \frac{\left[1 - (1 + \rho)^{-1}\hat{g}^{1-\sigma}\right] \frac{(1+\rho)[1-\alpha(1-\alpha)]}{\alpha(1-\alpha)(1-\tau)^2}\hat{g}^\sigma}{K}, \tag{G2}$$

where $K = \left[1 - (1 + \rho)^{-1}\hat{g}^{1-\sigma}\right] \frac{(1+\rho)[1-\alpha(1-\alpha)\tau]}{\alpha(1-\alpha)(1-\tau)}\sigma\hat{g}^{\sigma-1} + \frac{1-\alpha(1-\alpha)}{\alpha(1-\alpha)(1-\tau)} > 0$. Therefore, by (G2), we find that $\frac{\partial \hat{g}}{\partial \tau}|_{\tau=\tau^{WM}} < 0$. This implies $\tau^{GM} < \tau^{WM}$ because \hat{g} is a single-peaked function of τ (see (26) and the definition of $\Omega(\tilde{\tau})$ with $\Theta = 1$).

(ii) PROOF OF 2

Since $\text{sign}\left\{\frac{dU}{d\tau}\Big|_{\tau=\tau^{GM}}\right\} = \text{sign}\left\{\frac{\partial \hat{z}}{\partial \tau}\Big|_{\tau=\tau^{GM}}\right\}$, we show $\frac{\partial \hat{z}}{\partial \tau}\Big|_{\tau=\tau^{GM}} > 0$ for $q = 0$. From (26) and (25), with $\Theta = \Gamma(\tau) = \gamma(\tau)^{-1}$, we obtain $\hat{z} = \frac{1-\alpha[1-\alpha\gamma(\tau)]\tilde{\tau}}{\eta^{-1}(1+\rho)^{-1}(1-\tilde{\tau})[1-\alpha\gamma(\tau)]\alpha}\hat{g}^\sigma - \eta\hat{g}$. Differentiating it with respect to τ , we obtain

$$\frac{\partial \hat{z}}{\partial \tau}\Big|_{\tau=\tau^{GM}} = \hat{g}^\sigma \frac{(1 - \alpha\gamma(\tau)) [1 - \alpha(1 - \alpha\gamma(\tau))] \frac{d\tilde{\tau}}{d\tau} + \alpha(1 - \tilde{\tau})\gamma'(\tau)}{\eta^{-1}(1 + \rho)^{-1}\alpha [(1 - \alpha\gamma(\tau))(1 - \tilde{\tau})]^2} \tag{G3}$$

Here, let us define the numerator of (G3) as J . Through simple algebra, we have $\gamma(\tau) = 1 - (1 - \alpha)\tau$ and $\tilde{\tau} = \left[\frac{1-\alpha}{1-\alpha\gamma(\tau)}\right]\tau$. Hence, utilizing these, we have

$$J = \frac{[1 - \alpha(1 - \alpha\gamma)](1 - \alpha)^3}{(1 - \alpha\gamma(\tau))[1 - \alpha(1 - \alpha)(1 - \alpha\tau)]} [1 - \alpha + \alpha(1 + \alpha)\tau]. \tag{G4}$$

Equation (G4) ensures that $J > 0$ for any $\tau \in (0, 1)$. This completes the proof. □

(iii) INTUITION OF Proposition 5

For an intuitive interpretation, we focus on the marginal effect of raising the tax rate on the growth-maximizing rate, τ^{GM} . By (29), the lifetime utility, U_0 , depends on the long-run growth rate, \hat{g} , and the initial consumption, \hat{z} . At $\tau = \tau^{GM}$, the marginal effect of raising τ on \hat{g} disappears. Then, the CIT rate affects welfare only through the effect on initial consumption: $\text{sign} \left\{ \frac{dU}{d\tau} \Big|_{\tau=\tau^{GM}} \right\} = \text{sign} \left\{ \frac{\partial \hat{z}}{\partial \tau} \Big|_{\tau=\tau^{GM}} \right\}$. Note that by (25) and (D4) in Appendix D, the initial consumption is decomposed into

$$\hat{z} = \underbrace{\left[1 - \tilde{\tau} (1 - \alpha \Theta^{-1}) \alpha \right] \Omega(\tilde{\tau})}_{\text{disposable income}} - \eta \underbrace{\left[(1 - \tilde{\tau}) (1 - \alpha \Theta^{-1}) \alpha (1 + \rho)^{-1} \eta^{-1} \Omega(\tilde{\tau}) \right]}_{=R/(1+\rho)}^{1/\sigma}.$$

Because the second term depends on the interest rate, this is a Slutsky decomposition of the initial consumption. Since the interest rate is also maximized at $\tau = \tau^{GM}$, the marginal effect on the second term disappears here. Consequently, the marginal effect of raising τ on \hat{z} at $\tau = \tau^{GM}$ equals that on the disposable income of household.

The disposable income of a household increases by raising τ from τ^{GM} marginally. Thus, $\tau^{GM} < \tau^{WM}$. Raising τ increases before tax income $\Omega(\tilde{\tau})$. While $\Omega(\tilde{\tau})$ includes both labor and asset income, CIT is imposed only on the source of asset income, that is, the firms’ profits. Thus, the disposable income of a household increases as a whole. It suggests that the break in the coincidence of growth- and welfare-maximization tax rates is because the tax base is CIT.³⁵

H. Proof of remark

We prove the counterpart of Proposition 4 in the Remark by modifying Appendix F as follows.

Under the production technology of the final goods, (30) and (31), the wage rate (2) and the price of intermediate goods (3) are rewritten as

$$w_t = (1 - \alpha) L_{Y,t}^{-\alpha} \int_0^{N_t} (a(G_t, N_t) x_{i,t})^\alpha di = (1 - \alpha) \frac{Y_t}{L_{Y,t}} \tag{H1}$$

and

$$p_{i,t} = \alpha A L_{Y,t}^{1-\alpha} a(G_t, N_t)^\alpha x_{i,t}^{\alpha-1}, \tag{H2}$$

respectively. These two equations yield the demand function for the product of firm i :

$$x(p_{i,t}) \equiv \frac{(1 - \alpha) Y_t}{w_t} \left(\frac{\alpha A a(G_t, N_t)^\alpha}{p_{i,t}} \right)^{\frac{1}{1-\alpha}}. \tag{H3}$$

Because the forms of true profit, (7), declared profit, (12), and the effective CIT rate, (9), remain unchanged, we confirm that $\frac{\partial \pi_{i,t}}{\partial p_{i,t}} = -\alpha x(p_{i,t}) \left[\frac{p_{i,t} - w_t / (\alpha b_i)}{(1 - \alpha) p_{i,t}} \right]$ and $\Lambda'(p_{i,t}) = -\alpha x(p_{i,t})$ also hold under (H3). Therefore, maximizing the expected after-tax operating profit of firm i , (8), yields the same results as those given in Proposition 2.

We obtain the equilibrium conditions ((D1), (D2), (D3), (D4) (D5), and (D6)) using the procedure given in Appendix D. To derive these equilibrium conditions, we use the (i) production of the final goods ((30) and (31)), (ii) wage rate (H1), (iii) demand function for the intermediate product (H3), (iv) free-entry condition (6), (v) Euler equation (18), (vi) government’s budget constraints ((20) and (21)), (vii) labor, asset, and final goods market clearing conditions ((22), $W_t = \eta N_{t+1}$, and $Y_t = C_t + \eta N_{t+1} + G_t + M_t$), and (viii) results of Proposition 2. Consequently, the dynamic system of the economy is characterized by the same form of difference equation as that in (23).

Note that the only difference between the baseline and the extended model is therefore given in (24). $Y_t/N_t (= Y_{t+1}/N_{t+1})$ changes to

$$\hat{\Omega}(\tilde{\tau}) \equiv A^{\frac{1}{1-\beta}} [(1-Q)\tilde{\tau}(1-\alpha\Theta^{-1})\alpha]^{\frac{\beta}{1-\beta}} [(1-\alpha)\Theta]^{\frac{1-\alpha}{1-\beta}} \alpha^{\frac{2\alpha}{1-\beta}} \left[\frac{L}{(1-\alpha)\Theta + \alpha^2} \right]^{\frac{1}{1-\beta}} \times \left[\int b^{\frac{\alpha}{1-\alpha}} dF(b) \right]^{\frac{1-\alpha}{1-\beta}}. \tag{H4}$$

The unique steady-state value of z_t in (25) and economic growth rate \hat{g} in (26) are modified by replacing $\Omega(\tilde{\tau})$ with $\hat{\Omega}(\tilde{\tau})$.

From the modified \hat{g} and (H4), we have $\tilde{\tau}^{GM} = \operatorname{argmax} (1-\tilde{\tau})\tilde{\tau}^{\frac{\beta}{1-\beta}}(1-\alpha\Theta^{-1})^{\frac{1}{1-\beta}}\Theta^{\frac{1-\alpha}{1-\beta}}\left(\frac{\Theta^{-1}}{1-\alpha+\alpha^2\Theta^{-1}}\right)^{\frac{1}{1-\beta}}$. (F1) changes as follows:

$$f'(\tilde{\tau}) = \underbrace{\left[-\frac{1}{1-\tilde{\tau}} + \frac{\beta}{1-\beta} \frac{1}{\tilde{\tau}} \right]}_{\equiv \tilde{\Psi}_1(\tilde{\tau})} + \frac{\alpha}{1-\beta} \frac{d\tau}{d\tilde{\tau}} \gamma'(\tau) \Psi_2(\tau). \tag{H5}$$

Immediately, we have $\tilde{\Psi}_1 = \frac{\beta-\tilde{\tau}}{(1-\tilde{\tau})(1-\alpha)\tilde{\tau}} \geq 0$, for $\tilde{\tau} \leq \beta$. As in Appendix F, sign $\Psi_2(\tau) < 0$ for $\tilde{\tau} \leq \beta$, because $\beta < \alpha$. This indicates that $\tilde{\tau}^{GM} \geq \beta$ for the interior solution. In addition, we discuss the corner solution ($\tau^{GM} = 1$) in the same way as in Appendix F.³⁶

The counterpart of Proposition 5 is proved in the same way as Proposition 5. This is because our calculations in Appendix G do not depend on the expression of the growth rate, \hat{g} , which is the unique difference between the baseline and extended model.³⁷ Immediately, it has the same property with respect to τ as the growth rate in the baseline model. As such, the calculations in Appendix G can be applied to the extended model. \square

I. Details of calibration

We seek to obtain quantitative implications for tax evasion in OECD countries.

- The distribution of productivity is set in such a way that the distribution of firm size is set to the Pareto distribution, which is estimated by Axtell (2001). By (D1) and (D2), letting $N_0 = 1$, we have

$$\frac{x_i}{b_i} = \underbrace{\left[\frac{\alpha^2}{(1-\alpha)\Gamma(\tau) + \alpha^2} \right]}_{\equiv B} \frac{L}{\int b^{\frac{\alpha}{1-\alpha}} dF(b)} b_i^{\frac{\alpha}{1-\alpha}},$$

where $\Gamma(\tau) = \frac{1-q(1+s)\tau}{1-q(1+s)\tau - (1-\alpha)[1-q(1+s)]\tau}$. This is the size of intermediate good firms. To

make its distribution a Pareto distribution, we set the distribution of $b^{\frac{\alpha}{1-\alpha}}$ to Pareto distribution with scale parameter $\phi > 0$ and shape parameter $\psi > 1$. Then, letting $\text{SCALE} = B\phi$, because $\int b^{\frac{\alpha}{1-\alpha}} dF(b) = \frac{\psi-1}{\psi} \phi$ in B , the distribution of firm size is the Pareto distribution with scale parameter

$$\text{SCALE} = \frac{\alpha^2}{(1-\alpha)\Gamma(\tau) + \alpha^2} \frac{\psi-1}{\psi} L, \tag{I1}$$

and shape parameter ψ . Since the shape parameter is the most important factor of firm distribution, we set $\psi = 1.059$ according to the estimate in Axtell (2001), which uses US data.

- Next, we control the markup rate of intermediate good firms. Letting the markup rate be μ , by (14),

$$\frac{\Gamma(\tau)}{\alpha} = 1 + \mu. \tag{I2}$$

As the benchmark value of μ , we adopt 0.2, a usual value of the macroeconomic model with imperfect competition.³⁸

- To determine the value of the remaining parameters, we set the benchmark value of τ , q , and s exogenously, as shown in Table 1. For their source, see Table 1 and the text.
- There are four undetermined parameters for (I1) and (I2), α , L , SCALE, and ϕ . Here, we put $L = \phi = 1$ and determine α and SCALE by (I1) and (I2). Note that productivity b follows the Pareto distribution with scale parameter $\phi^{\frac{\alpha}{1-\alpha}}$ and shape parameter $\frac{1-\alpha}{\alpha} \psi$, since we assume $b^{\frac{\alpha}{1-\alpha}}$ follows the Pareto distribution with scale parameter ϕ and shape parameter ψ . Because the scale of productivity may be arbitrarily fixed whenever the distribution of firm size is properly controlled, we set $\phi = 1$. We simply normalize $L = 1$. Since the number of the intermediate good firms is a continuum, the minimum of firm size among them does not have to correspond to the minimal number of employees in actual data (and only the shape of the distribution, the curvature of the density function, matters). Thus, we do not care about the magnitude of parameter SCALE, which is determined by (I1) for given α and the other parameters. Parameter α is pinned down by the condition of the markup rate, (I2).
- We explain the determination of α . Through long but straightforward algebra, (I2) can be rearranged as the quadratic equation with respect to α as follows: $\Phi_2 \alpha^2 + \Phi_1 \alpha + \Phi_0 = 0$, where $\Phi_2 = (1 + \mu)[1 - q(1 + s)]\tau$, $\Phi_1 = (1 + \mu)(1 - \tau)$, and $\Phi_0 = -[1 - q(1 + s)\tau]$. By $\Phi_2 > 0$ and $\Phi_1 > 0$, a necessary and sufficient condition for a unique solution in $(0, 1)$ is $\Phi_0 < 0$ and $\Phi_2 + \Phi_1 + \Phi_0 > 0$, which holds for any parameter set. The solution is given by $\alpha = \frac{-\Phi_1 + \sqrt{\Phi_1^2 - 4\Phi_2\Phi_0}}{2\Phi_2}$.
- Finally, by (26), we choose the value of $A^{\frac{1}{1-\alpha\epsilon}}/\eta$ to fix the long-run growth rate to 2%. This completes the parameter specification for conducting the numerical exercises.

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