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Optimal Capital Taxation in a Neoclassical Growth Model

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Abstract

This paper studies the optimal factor tax incidence in a neoclassical growth model with a given share of government expenditure in output. In the Ramsey planner's optimization, the effect of next period's capital on government expenditure equals the given share of the marginal product of capital. Capital accumulation reduces the discounted net marginal product of next period's capital by way of increasing government expenditure. In order to internalize the distortion, it is optimal to tax capital income in the long run.

1. Introduction

Income taxes are the most important sources of the government revenue in most of the developed countries.[1] In particular, capital income taxes are a major source of the tax revenue across countries. For example, according to the Eurostat, total tax revenues as a percentage of the gross domestic product were 39.8% on average in 27 European countries in which over a quarter

[1] In the United States, for example, the income tax accounted for 50% of the federal revenue in 2009.

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(28.7%) came from capital tax revenues in 2007. While capital income includes corporate profits, capital gains, dividends, interest income and others, just taking the corporate income tax as an example, the top statutory tax rates on corporate income stayed as high as 43% in the United States, 41% in Japan, and 23.5% on average in 27 European countries in 2009.[2]

If the government can only use income taxes to maximize social welfare, early works by Judd (1985) and Chamley (1986) established that the government should tax only labor income and not capital income in the long run. The Chamley–Judd result was based on growth models in which physical capital is accumulated over time while the labor endowment is allocated between working and leisure. The reason is that capital income taxation slows down capital accumulation and leads to a dynamic efficiency loss that is higher than the static efficiency loss of labor income taxation.

Several studies have revisited the issue by relaxing key assumptions and proved the result to be robust. For example, using a one-sector growth model, Atkeson, Chari, and Kehoe (1999) relaxed Chamley's assumptions, one by one, to the environments with heterogeneous consumers, endogenous growth, and an open economy, and they found that Chamley's result is robust.[3] A number of authors studied the optimal capital tax in two-sector growth models with both physical and human capital and found that Chamley's result still holds (e.g., Lucas 1990; Jones, Manuelli, and Rossi 1993, 1997).

All aforementioned papers found a zero capital tax because their models involved no inherent distortions. A few authors have obtained positive optimal capital taxation by considering inherent distortions in their models. For example, Barro (1990), Guo and Lansing (1999), Cassou and Lansing (2006), and Chen (2007) uncovered positive capital taxes by incorporating distortions such as productive public capital, positive externalities, or imperfectly competitive product market into dynastic models. In a model with labor market frictions, Domeij (2005) found positive capital taxes when the worker of a match was compensated less than his contribution to the formation of the match.[4]

All these foregoing papers attained positive optimal capital tax by relying on inherent distortions. In this paper, we study the optimal capital tax in a neoclassical growth model without inherent distortions. In existing models of optimal capital taxation, the Ramsey planner treats government expenditure as fixed. The innovation of our paper is that the Ramsey planner treats

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[2] According to the Eurostat, the top corporate income tax rate ranged from the lowest 10% in Bulgaria to the highest 35% in the Netherlands in 2009, among which the rate was 29.8% in Germany, 34.4% in France, 31.4% in Italy, and 28% in the United Kingdom.

[3] See also Chari, Christiano, and Kehoe (1994) and Chari and Kehoe (1999).

[4] In overlapping generations models, an optimal positive capital tax rate was also obtained; see Imrohoroglu (1998) and Conesa, Kitao, and Krueger (2009) when borrowing constraints were tight and Peterman (2012) when human capital accumulation was age-specific.

government expenditure as a fixed share of output. We show that when the Ramsey planner fixes the share of government spending in output, it is optimal to tax capital income.

The assumption of government expenditure as a fixed share of output is justified as follows. First, in reality, the government tends to maintain a stable share of government expenditure in output. For example, according to the Penn World Table (Heston, Summers, and Aten 2012), real government consumption per capita in the United States increased by 33% from $2,117 in 1973 to $2,821 in 1990, but the fraction of real government consumption in gross domestic product was around 9% in the same period. Next, a number of authors have assumed a fixed share of government expenditure in output in their studies. For example, in a two-sector, human-capital-based endogenous growth model, Jones, Manuelli, and Rossi (1993, Section IIB) obtained a zero capital tax by fixing the share of government spending on consumption in gross national product at the initial level. In a general equilibrium model, Lucas (2000, Section 4) surveyed research and offered new estimates about the welfare cost of inflation under the restriction that government consumption is a constant share in gross domestic product (GDP).[5]

By restricting government expenditure as a fixed share of output, as the Ramsey planner's optimization concerning the factor allocation changes government spending which is a proportion of variations in output, our model yields positive optimal capital taxes. To better understand underlying reasons, the household's tradeoffs between this period's consumption and next period's capital give an Euler equation such that the net marginal product of capital minus the time preference rate equals the capital tax rate times the net marginal product of capital in a steady state. Moreover, the Ramsey planner's choices of next period's capital is such that the shadow price of resources in this period equals the discounted net marginal product of capital minus the effect of capital on government expenditure in the next period. In a steady state, the Ramsey planner thus equates the net marginal product of capital minus the time preference rate to the effect of capital on government expenditure. In order for the Ramsey planner's choices of next period's capital to be consistent with the household's consumption Euler equation, it is clear that the capital tax rate times the net marginal product of capital must equal the effect of capital on government expenditure. This implies that the optimal capital tax rate is equal to the effect of capital on government expenditure divided by the net marginal product of capital. Under fixed government spending, the effect of capital on government expenditure is zero and thus the optimal capital tax rate is zero in the long run.

Conversely, when government expenditure is a fixed share of output, in the Ramsey planner's optimization of capital, the effect of capital on government expenditure is equal to a fixed share of the marginal product of

[5] Palivos and Yip (1995) and Ho, Zeng, and Zhang (2007) also assumed government consumption that is a constant share of GDP.

capital. As a result, the optimal capital tax rate is equal to a fixed share of the marginal product of capital divided by the net marginal product of capital. As the marginal product of capital is positive, the optimal capital tax is positive.

The result of a positive optimal capital tax is reasoned as follows. As government spending is a fixed share of output, capital accumulation generates a distortion on the amount of government expenditure that reduces the net marginal product of next period's capital. In order to internalize such a distortion, it is thus optimal to tax capital income in the long run.

We should note that this is not the first paper that yields positive optimal capital tax in a model without inherent distortions. To the best of our knowledge, Lansing (1999) and Chen and Lu (2013) obtained positive capital taxes in models with no inherent distortions. Our model is different from these two models. In a one-sector model, Lansing (1999) revisited the redistribution model considered by Judd (1985). He showed that the capital tax is generally nonzero when the capitalist's utility is logarithmic and the government cannot issue debt and thus faces a periodic balance-budget constraint. In a two-sector model with physical and human capital, Chen and Lu (2013) reexamined the model studied by Lucas (1990). They found positive capital taxes if agent's human capital is formed in the same way as it was by Lucas (1988) and Bond, Wang, and Yip (1996).

A roadmap for this paper is as follows. In Section 2, we set up a model and analyze individual's optimizations. In Section 3, we study the optimal tax incidence in the Ramsey second-best problem. Finally, concluding remarks are offered in Section 4.

2. The Basic Economic Environment

Our model is a discrete-time, Ramsey model with a continuum of identical infinitely-lived households (of measure one), a continuum of identical firms (of measure one), and a fiscal authority.

2.1. Households

The representative household has a unit of time endowment. In period t, a fraction l_t of the time endowment is allocated to work and the remaining fraction $1 - l_t$ is allocated to leisure. The household's preference is represented by

$$U = \sum\nolimits_{t=0}^{\infty} \left(\frac{1}{1+\rho}\right)^t u\,(c_t, 1 - l_t), \tag{1}$$

where c is consumption and $\rho > 0$ is the subjective rate of time preference. The utility u is strictly increasing in consumption and leisure and is strictly concave, and satisfies the standard Inada conditions.

In this economy, consumers own capital and rent it to firms. Denote by k the capital stock with δ its depreciation rate. Further, denote w and r the wage rate and the rental rate, respectively, and τ_l and τ_k their tax rate, respectively. The representative household's budget constraint is

$$k_{t+1} + p_t b_{t+1} = (1 - \tau_{lt})\, w_t l_t + R_t k_t + b_t - c_t, \quad k_0 \text{ and } b_0 \text{ given}, \tag{2}$$

where $R_t = [1 + (1 - \tau_{kt})(r_t - \delta)]$ is gross returns to capital after taxes and b_{t+1} is government bonds whose price is p_t.

The household's dynamic programming problem is to choose $\{c_t, l_t, k_{t+1}, b_{t+1}\}_{t=0}^{\infty}$ in order to maximize the lifetime preference in (1) subject to constraint (2). Denote λ_t as the Lagrange multipliers on household's budget constraint (2). The necessary conditions with respect to c_t, l_t, k_{t+1} and b_{t+1} are, respectively,

$$u_c(c_t, 1 - l_t) = \lambda_t, \tag{3a}$$

$$u_{1-l}(c_t, 1 - l_t) = \lambda_t(1 - \tau_{lt}) w_t, \tag{3b}$$

$$\lambda_t = \frac{1}{1+\rho} \lambda_{t+1} R_{t+1}, \tag{3c}$$

$$\lambda_t p_t = \frac{1}{1+\rho} \lambda_{t+1}. \tag{3d}$$

To simplify these conditions, Equations (3a) and (3c) together yield the consumption Euler equation,

$$u_c(c_t, 1 - l_t) = \tfrac{1}{1+\rho} u_c(c_{t+1}, 1 - l_{t+1}) R_{t+1}. \tag{4a}$$

Next, combining Equations (3c) and (3d) gives the no-arbitrage condition between capital and bonds,

$$p_t = R_{t+1}^{-1}. \tag{4b}$$

Finally, Equations (3a) and (3b) jointly produce the consumption-leisure tradeoff condition as follows,

$$u_{1-l}(c_t, 1 - l_t) = u_c(c_t, 1 - l_t)\, (1 - \tau_{lt})\, w_t, \tag{4c}$$

which states in optimum, the marginal rate of substitution between leisure and consumption is equal to the posttax wage rate.

2.2. Firms

The representative firm rents capital and hires labor to produce a single final good y_t under the following neoclassical production function:

$$y_t = f(k_t, l_t). \tag{5a}$$

The function f is strictly increasing in capital and labor and is strictly concave, and satisfies the standard Inada conditions.

The firm's flow profit is

$$\pi_t = f(k_t, l_t) - w_t l_t - r_t k_t. \tag{5b}$$

The firm's optimal conditions for capital and labor are standard and are as follows.

$$f_k(k_t, l_t) = r_t, \tag{6a}$$

$$f_l(k_t, l_t) = w_t. \tag{6b}$$

2.3. The Government

The government finances expenditure by taxing factor income and issuing bonds. Denote G_t as the nonvalued government consumption, the government's flow budget constraint is

$$p_t b_{t+1} + \tau_{lt} w_t l_t + \tau_{kt}(r_t - \delta) k_t = G_t + b_t. \tag{7a}$$

With the help of Equation (4b), Equation (7a) can be rewritten as the intertemporal budget constraint as follows:

$$\begin{aligned} &\sum_{t=1}^{\infty} \prod_{i=1}^{t} R_i^{-1} [\tau_{lt} w_t l_t + \tau_{kt}(r_t - \delta) k_t] + \tau_{e0} w_0 e_0 \\ &+\tau_{k0}(r_0 - \delta) k_0 = \sum_{t=1}^{\infty} \prod_{i=1}^{t} R_i^{-1} G_t + G_0 + b_0. \end{aligned} \tag{7b}$$

2.4. Aggregate Resources and Equilibrium

All markets are perfectly competitive. The economy as a whole faces an aggregate goods market constraint, which using Equations (2), (5b), and (7a), is

$$c_t + k_{t+1} - (1 - \delta) k_t = f(k_t, l_t) - G_t. \tag{8}$$

Given a set of the government spending G_t and the tax policy τ_{kt} and τ_{lt}, the equilibrium is defined as follows. An equilibrium is household's choices $\{c_t, l_t, k_t, b_t\}$, firm's choices $\{l_t, k_t\}$, and prices $\{w_t, r_t\}$, such that: (i) the household optimizes, Equations (4a), (4b), and (4c); (ii) the firm optimizes, Equations (6a) and (6b); (iii) the government's intertemporal budget is balanced, Equation (7b); and (iv) the goods market clears, Equation (8).

In equilibrium, by using the firm's optimal condition of capital in Equation (6a), the consumption Euler equation in Equation (4a) becomes

$$u_c\,(c_t, 1 - l_t)\,(1 + \rho) = u_c\,(c_{t+1}, 1 - l_{t+1})\,\{1 + (1 - \tau_{kt+1})\,[\,f_k(k_{t+1}, l_{t+1}) - \delta]\}. \quad (9)$$

Moreover, by using the firm's optimal condition of labor in Equation (6a), the household's consumption-leisure tradeoff condition in Equation (4c) becomes

$$u_{1-l}(c_t, 1 - l_t) = u_c(c_t, 1 - l_t)\,(1 - \tau_{lt})\,f_l(k_t, l_t). \quad (10)$$

Thus, we have simplified equilibrium conditions to Equations (8)–(10) in variables c_t, k_t, and l_t.

3. Ramsey Optimal Taxation

This section studies the Ramsey's optimal taxation. We follow the approach in Lucas (1990). To solve the Ramsey planner's problem, first we use the household's flow budget constraint in Equation (2) and the household's optimization condition (3a) to derive the following discounted sum of the household's lifetime budget constraint:[6]

$$\sum_{t=0}^{\infty}\left(\frac{1}{1+\rho}\right)^t u_c\,(c_t, 1 - l_t)\,[c_t - (1 - \tau_{lt})\,w_t l_t + k_{t+1} + p_t b_{t+1}]$$
$$= \sum_{t=0}^{\infty}\left(\frac{1}{1+\rho}\right)^t u_c\,(c_t, 1 - l_t)\,[R_t k_t + b_t]. \quad (11a)$$

If we use the simplified equilibrium conditions of Equations (9) and (10) and the household's optimization condition in Equation (4b), then Equation (11a) can be rewritten as the following implementability constraint:

$$\sum_{t=0}^{\infty}\left(\frac{1}{1+\rho}\right)^t [u_c(c_t, 1 - l_t)c_t - u_{1-l}(c_t, 1 - l_t)l_t]$$
$$= u_c(c_0, 1 - l_0)(R_0 k_0 + b_0). \quad (11b)$$

The Ramsey planner's problem is as follows. The planner chooses the allocation in order to maximize the representative household's welfare in Equation (1) subject to the implementability constraint (Equation (11b)), and the goods market clearance condition (Equation (8)).

[6] In deriving the discounted sum of the household's lifetime budget constraint, the shadow price of the flow budget in period t is λ_t, which is equal to $\lambda_t = u_c(c_t, 1 - l_t)$ according to Equation (3a).

3.1. The Steady-State Optimal Capital Tax Rate

The optimal capital tax can be determined by substituting the Ramsey allocation into the equilibrium conditions. The Ramsey planner's problem is to maximize the representative agent's lifetime utility (Equation (1)) subject to the resource constraint (Equation (8)) and the implementability constraint (Equation (11b)). In particular, the rate of optimal capital income taxes is determined by comparing the first-order condition of next period's capital (k_{t+1}) in the Ramsey planner's problem with the consumption Euler equation (9) in the household's problem.

It is easy to show that the first-order condition of next period's capital in the Ramsey planner's problem is

$$\varsigma_t = \frac{1}{1+\rho}\varsigma_{t+1}\left[1 + f_k\left(k_{t+1}, l_{t+1}\right) - \delta - \frac{dG_{t+1}}{dk_{t+1}}\right], \tag{12}$$

where ς_t is the Lagrange multiplier of the resource constraint in the economy (8). It is clear that the condition equates the shadow price of resources in this period to the discounted net marginal product of capital minus the effect of capital on government expenditure in the next period. Thus, if the effect of capital on government expenditure in the next period is positive, the net marginal product of capital from the social point of view in the next period is reduced.

In a steady state, Equation (12) is

$$f_k(k, l) - \delta - \rho = \frac{dG}{dk}, \tag{13a}$$

which requires that the net marginal product of capital minus the time preference rate equal the effect of capital on government expenditure in the long run.

Moreover, in a steady state, the household's consumption Euler equation (9) can be written as

$$f_k(k, l) - \delta - \rho = \tau_k[f_k(k, l) - \delta], \tag{13b}$$

which requires that the net marginal product of capital minus the time preference rate equal the capital tax rate times the net marginal product of capital in the long run.

In order for the Ramsey's planner's choices in Equation (13a) to be consistent with the household's choices in Equation (13b), it is clear that the rate of optimal capital income taxes is

$$\tau_k = \frac{dG/dk}{f_k(k, l) - \delta}. \tag{14}$$

Case 1: The fixed government expenditure

In this case, government expenditure is given at its initial value as was the setting in Judd (1985) and Chamley (1986). Thus, $G_t = G_0$ for all t, that is, $dG/dk = 0$. The optimal tax rate of capital income is always zero. Therefore, the government should only tax labor income and not capital income in the long run.

Case 2: The fixed share of government expenditure in output

In this case, let the share of government spending in output be fixed at $\beta \in (0,1)$.Thus, $\beta = G_t/f(k_t, l_t)$. As the Ramsey planner optimizes, the reallocation of k_t and l_t changes output and then G_t is changed according to $G_t = \beta f(k_t, l_t)$. Since $dG/dk = \beta f_k(k, l)$ is positive, the optimal tax rate of capital income is

$$\tau_k = \frac{\beta f_k(k, l)}{f_k(k, l) - \delta}, \tag{15}$$

which is positive.

Intuitively, when the government spending is a fixed fraction of output, capital accumulation reduces the discounted net marginal product of capital by increasing the government spending. In order to internalize the distortion, it is optimal to tax capital income in the long run. We should note that even if government expenditure is not a waste but is a lump-sum transfer to the representative household, the optimal capital tax is positive as capital accumulation distorts the amount of government expenditure through the effect on the net marginal product of capital but the effect of the lump-sum transfer is neutral. As the lump-sum transfer affects the household's budget constraint, the elasticity of substitution between consumption and leisure would affect the capital tax rate.

Moreover, when capital depreciates ($\delta > 0$), Equation (15) indicates $\tau_k > \beta$ and the rate of capital income taxes is larger than the share of government expenditure in output. The rate of taxes on capital income is increasing in the share of the government expenditure in output. Intuitively, a larger share of government expenditure in output indicates a larger effect of capital accumulation on government expenditure, which reduces more of the discounted net marginal product of capital. As a result, a larger rate on optimal capital income taxes is called for.

Finally, in the special case when $\delta = 0$, the rate of capital income taxes is reduced to $\tau_k = \beta$. In this case, the optimal capital income tax rate is equal to the share of government expenditure in output. Intuitively, as capital does not depreciate, less capital accumulation is needed, which generates less distortions on the discounted net marginal product of capital by way of increasing government expenditure. Therefore, a smaller rate of capital income taxes is optimal.

This special case of the capital income tax rate equal the share of government expenditure in output is reminiscent of the paper by Barro (1990).[7] In Barro (1990), with a given degree of externalities and with a variable share of government expenditure in output which equals the rate of taxes on capital income, the rate of optimal capital income taxes is determined by the given degree of externalities. In contrast, in our model, without externalities and with a given share of government expenditure in output, if capital does not depreciate, the rate of optimal capital income taxes is determined by the given share of government expenditure in output. In the determination of optimal capital taxation, a given share of government expenditure in output in our model plays a role like a given degree of externalities in Barro (1990).

3.2. Numerical Analysis

To offer quantitative results, we calibrate our model to match the U.S. quarterly data. The fraction of time allocated to work is around 25% according to Prescott (2006) and thus we set $l = 0.25$. Moreover, the average tax rates of the capital income and the labor income during 1960–2007 in the United States are around 0.3 and 0.2, respectively.[8] Thus, we choose initial tax rates at $\tau_k = 0.3$ and $\tau_l = 0.2$.

We use the separable utility function $u(c_t, 1 - l_t) = \log c_t + \kappa \frac{(1-l_t)^{1-\varphi}-1}{1-\varphi}$, which is consistent with steady-state growth in a deterministic version of the RBC model (cf. King and Rebelo 1999). The parameter $\kappa > 0$ is the share of leisure relative to consumption in utility and $\phi > 0$ is a coefficient related to the intertemporal elasticity of substitution (hereafter IES) for labor which is $\text{IES} = (1 - l)/(\phi l)$. The IES for labor ranges from close to 0 (MaCurdy 1981) to 3.8 (Imai and Keane 2004). Following Hansen and Imrohoroglu (2009), we choose a middle value at 2, which implies $\phi = 1.5$.

We use the Cobb–Douglas production function: $y_t = Ak_t^{\alpha} l_t^{1-\alpha}$. We choose the share of capital at $\alpha = 0.3$ and normalize $A = 1$. The annual time preference rate used by Kydland and Prescott (1991) is 4%, so we set $\rho = 1\%$ as a quarterly rate. According to Cooley (1995), the quarterly capital-output ratio is around 12.1. By using the foregoing parameter values, we utilize the steady-state version of Equation (13b) and the Cobb–Douglas production function to calibrate the depreciation rate of capital at $\delta = 1.05\%$, and the rental rate at $r = 0.0248$. Thus, the capital stock, output and the wage rate are $k = 8.8060$, $y = 0.7278$, and $w = 2.0377$, respectively.

[7] Barro (1990) is a one-sector endogenous growth model with inelastic labor and with only capital income taxes, and thus the share of government expenditure in output is equal to the rate of capital income taxes. By assuming a positive degree of externalities of public capital to private production, Barro (1990) finds that the rate of optimal capital income taxes is equal to the degree of externalities which pins down the share of government expenditure in output.

[8] Data is from McDaniel (2007) who calculated a series of average tax rates on consumption, investment, labor and capital using national account statistics in 15 OECD countries.

In the benchmark parameterization, we set $b_0 = 0$ and assume that the government's budget is balanced in the initial steady state. We use Equation (7a) to calculate the initial government spending $G_0 = 0.1396$. Thus, the share of the initial government spending in output is at $g = 0.1919$. Furthermore, using the equilibrium condition (8), we obtain consumption $c = 0.4956$. Finally, using (10), we calibrate $\kappa = 2.1365$. We are now ready to quantify the Ramsey optimal factor tax rates. When government expenditure is fixed at its initial value, the optimal tax rates of capital income and labor income are $(\tau_k, \tau_l) = (0\%, 21.36\%)$ that features a zero capital tax rate in the long run. Conversely, when the share of government expenditure in GDP is fixed at its initial value, the optimal tax rates of capital income and labor income are $(\tau_k, \tau_l) = (32.74\%, 19.66\%)$ that features a positive capital tax rate in the long run.

Finally, the IES of the labor supply equal 2 may be at the high side. If we lower the IES to 0.5 with the implied $\phi = 6$, the optimal tax rates of capital income and labor income are still $(\tau_k, \tau_l) = (32.74\%, 19.66\%)$ that features a positive capital tax rate in the long run.

4. Concluding Remarks

Early works by Judd (1985), Chamley (1986), and others established zero optimal capital taxation in the long run. In existing models that yield a zero optimal capital tax, the Ramsey planner treats government expenditure as fixed. This paper revisits the issue of optimal capital taxation by allowing the Ramsey planner to treat government expenditure as a fixed share in output.

In the model, the household's tradeoffs between this period's consumption and next period's capital give an Euler equation such that the net marginal product of capital minus the time preference rate equals the capital tax rate times the net marginal product of capital in a steady state. The Ramsey planner's choices of next period's capital is such that in a steady state, the net marginal product of capital minus the time preference rate is equal to the effect of next period's capital on government expenditure. In order for the Ramsey planner's choices to be consistent with the household's choices, the capital tax rate times the net marginal product of capital must equal the effect of next period's capital on government expenditure, thereby implying that the optimal capital tax rate equals the effect of next period's capital on government expenditure divided by the net marginal product of capital. With a given share of government spending in output, in the Ramsey planner's optimization, the effect of next period's capital on government expenditure is the given share times the marginal product of capital. Thus, capital accumulation generates a negative distortion on government spending through affecting the marginal product of capital. In order to internalize the distortion, it is thus optimal to tax capital income in the long run.

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