Optimal taxation in a growth model with public consumption and home production

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Abstract

In a neoclassical growth model with public consumption, we show the following Pareto optimal tax rules. The government should tax leisure and private consumption at the same rate, and subsidize net investment at the same rate it taxes net capital income. Also, it should tax capital income more heavily than labor income. In an extension for home production, the additional rule is to tax investment for home production at the same rate of the tax on private market consumption. These tax and subsidy rates should be constant over time except the initial tax rate on capital income.

Keywords: Home production; Public consumption; Optimal taxation; Investment

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1. Introduction

A central question in public economics is how to collect tax revenue for public spending. The typical views are against capital income taxation except in the initial period and in favor of consumption taxation. On the one hand, the Ramsey tax system advocates a high tax on initial capital stock (or on capital income in the initial period) and a zero tax on capital income in future times; see, e.g., Judd (1985), Chamley (1986), and Chari, Christiano and Kehoe (1994). The Ramsey results hinge on the assumption that the government commitment is permanent. On the other hand, many studies argue that consumption taxes usually dominate either wage taxes or uniform income taxes in welfare terms; see, e.g., Summers (1981), Seidman (1984), Auerbach and Kotlikoff (1987), Pecorino (1993, 1994), Devereux and Love (1994), Turnovsky (2000), and Davies, Zeng and Zhang (2000). However, in the United States the capital income tax rate is higher than both the consumption tax rate and the wage income tax rate;[1] there are also sizable subsidies on investment.[2] The substantial gap between tax practice and tax theory motivates our present work on taxation.

In this paper, we use a neoclassical growth model and an extension for home production to investigate optimal taxation for the finance of public consumption that is valued in individuals' preferences. Unlike the Ramsey tax approach that typically focuses on the trade-off between labor and capital income taxes, we also consider consumption taxes and subsidies on net investment like Investment Tax Credits. The set of fiscal instruments in our model is sufficiently large such that the Pareto optimal allocation is achievable. The Pareto optimal

[1] There is no concensus on the effective tax rates in the United States. For details of the different views, see Feldstein, Dicks-Mireaux and Poterba (1983), Slemrod and Gordon (1988), Gomme, Kydland and Rupert (2001) and Gordon, Kalambokidis and Slemrod (2004).

[2] The subsidy rate can be inferred as the gap between statutory and effective tax rates. The US statutory corporate income tax rate had been 49.5% up until the 1986 tax reform that cut it to 38.3% along with the elimination of a 10% investment tax credit. According to Fullerton and Karayannis (1993), the effective tax rate that considers also investment allowances, including accelerated depreciation and tax credits, was 14.4% in 1980 and 24% in 1990. Thus, the gap was about 35 and 14 percentage points in 1980 and 1990, respectively. On the top of this gap, there are also tax credits for R&D expenditure in the US corporate tax system. Having all these combined, the overall subsidy rate may be as high as 30%-40%.

allocation will be characterized by the social planner allocation. With public consumption in the preferences, a key departure of the competitive equilibrium from the social planner allocation is that, when individuals cannot effectively provide public consumption, market labor becomes less meaningful to them. Consequently, leisure is expected to be above its first-best level and correspondingly market labor is below its first-best level, a key concern in the selection of taxes in addition to the concern of publicly providing an ideal level of public consumption.

We show that the Pareto optimal taxation possesses the following features in the neoclassical growth model with public consumption in the preferences. First, the government should tax leisure and private consumption at the same rate, by setting the consumption and labor income tax rates opposite to each other. Second, it should subsidize net investment at the same rate at which it taxes net capital income. Doing so not only removes investment distortions of capital income taxation but also generates a positive amount of net tax revenue that can be as high as over 10% of output. Third, the government should tax net capital income more heavily than labor income to raise market labor and reduce leisure. Finally, these tax and subsidy rates, though allowed to vary, should be constant over time to avoid intertemporal distortions, except that the tax rate on capital income in the initial period can differ from its later values.

Thus, our Pareto taxation approach may allow the government to tax the stock of, or the income from, the initial asset or wealth in the same way as the Ramsey taxation approach does. This tax may be efficient and contributes valuable tax revenue to the government as in the Ramsey taxation literature, as long as the government can commit on its tax promise permanently. As was well known in the literature, however, this permanent commitment is generally not credible and causes time inconsistency. In this regard, Auerbach and Hines (2002, P. 1407) point out "The time-varying nature of optimal capital taxation makes such a policy time-inconsistent, in that whatever profile of future taxes that is optimal as of year t

would not be optimal as of year $t+1$, and optimizing governments might therefore be tempted not to follow through on previously announced tax plans". This, among other factors, may help explain why in the real world tax systems differ from the Ramsey tax system. For this reason, we do not use the capital income tax or a capital levy in the initial period to finance future government spending.

These tax rules survive the extension to include home production. The additional Pareto optimal tax rule with home production is that the government should tax home investment for home production at the same rate it taxes private market consumption so as to avoid distorting private consumption of the market and home goods at the margin. The consideration of the home sector may be highly relevant in comparing income taxation with consumption taxation for several reasons. First of all, the home sector is sizable in terms of output, capital stock, labor hours and investment as opposed to the market sector (see, e.g., Benhabib, Rogerson and Wright, 1991; Greenwood and Hercowitz, 1991; Gomme, Kydland and Rupert, 2001). Despite the existence of a large home sector, however, most studies on optimal taxation ignore it and focus only on the market sector. The ones with home production in their analysis of taxes include Lerner (1970), Boskin (1975), Sandmo (1990), Piggott and Whalley (1996), and Kleven, Richter and Birth (2000). They have examined various tax distortions and the optimal structure of tax systems in *static* models with home production. Differing from these studies, we focus on intertemporal optimal fiscal policy in a *dynamic* model with leisure and home production, and reach different results.[3]

Another reason to consider the home sector is that it is treated differently from the market sector in the real world tax system. In the market sector, factor incomes are typically taxed, and so are final goods and services, while investment is either exempted from taxes or

[3]Kolm (2000) and Engstrom, Holmlund and Kolm (2001) use wage bargaining/search models with home production to study the employment and welfare effects of labor income taxes. McGrattan, Rogerson and Wright (1997) investigate the effects of changes in taxes on output, investment and other variables in a dynamic model with home production. However, they do not consider optimal taxation.

subsidized. In the home sector, by contrast, income taxation does not apply, while investment in home production is usually taxed under consumption taxation. For example, investment for home renovation and maintenance is taxed at the stage of purchasing material inputs, but tax deductible if it is intended for commercial use. This asymmetric treatment of investment in the tax system across the two sectors casts doubt on the conventional view that favors consumption taxation over income taxation.

Our study is not the first one to challenge the conventional view that ranks consumption taxation over income taxation in welfare terms. In Krusell, Quadrini and Ríos-Rull (1996), capital income taxation may be better than consumption taxation because the former leads to less government transfers than does the latter in a political equilibrium.[4] In the present paper, we will focus on allocation efficiency alone, rather than redistributional income transfers.

The remainder of this paper proceeds as follows. Section 2 analyzes optimal taxation in the neoclassical model with public consumption in the preferences. Section 3 extends the analysis by considering the home sector. Section 4 concludes.

2. The neoclassical model with public consumption

Consider a production economy inhabited by many identical, infinitely lived consumers with a unit mass. In each period $t = 0, 1, ...,$ there are two goods: labor and a consumption-capital good. A constant-return-to-scale technology is available to transform labor L_t and capital K_t into output via the production function $F(K_t, L_t)$.[5] The output can be used for private consumption C_t, government consumption G_t, and new capital K_{t+1}. We shall assume that

[4] Jones, Manuelli and Rossi (1993, 97) identify upper limits on tax rates, revenue constraints, pure profits arising from productive government spending, or inclusion of capital in the social planner's (not households') preferences as reasons for income taxes to persist in the long run. Aiyagari (1995) shows that incomplete markets and borrowing constraints can produce the same result.

[5] We abstract from any external spillover from average or aggregate capital that may call for government subsidies on investment as shown in Devarajan, Xie and Zou (1998).

government consumption is a public good valued in individuals' preferences, and is thus endogenously determined in order to maximize social welfare. Feasibility in the economy requires that

$$C_t + G_t + K_{t+1} = F(K_t, L_t) + (1-\delta)K_t, \tag{1}$$

where $\delta \in (0,1)$ is the depreciation rate of capital. The preferences of each consumer are assumed as

$$\sum_{t=0}^{\infty} \beta^t U(C_t, L_t, G_t), \qquad 0 < \beta < 1, \tag{2}$$

where β is the discount factor and the period-utility function U is increasing in private and public consumption, decreasing in labor and strictly concave and satisfies the Inada conditions to ensure the existence and uniqueness of the solution.

We assume that the government finances public consumption by using proportional taxes on private consumption and on incomes from labor and capital net of depreciation, denoted by $\tau_{c,t}$, $\tau_{w,t}$ and $\tau_{k,t}$, respectively. In addition, the government can subsidize private net investment $K_{t+1} - K_t$ at a flat rate $s_{k,t}$, like investment tax credits that apply to new investment but exclude replacement for depreciated capital.

This model is the deterministic version of Chari, Christiano and Kehoe (1994), with several extensions such as public consumption in the preferences, the consumption tax and the investment subsidy. Since the government budget may not balance for any optimal tax policy in some periods of the transition, we will allow government debt to even out such possible imbalances over time.[6] We denote government debt per consumer as B_t with an after-tax return factor $R_{b,t}$.

The consumer budget constraint is $(1+\tau_{c,t})C_t + I_t - s_{k,t}(K_{t+1} - K_t) + B_{t+1} = R_{b,t}B_t + r_tK_t - \tau_{k,t}(r_t - \delta)K_t + (1-\tau_{w,t})w_tL_t$ where $I_t = K_{t+1} - (1-\delta)K_t$ is investment and r_t and w_t are

[6] However, we will not explore how an exogenous change in the scale of government debt serviced by distortionary taxes can affect the economy in this paper, which has been a subject by itself in the literature (e.g. Burbidge, 1983).

the before-tax rental rate of capital and the wage rate, respectively. The subsidy s_k applies to net investment $K_{t+1} - K_t$, while the tax τ_k applies to net capital income $(r_t - \delta)K_t$. Note that capital depreciation is not taxed in this model as in the literature. Nor is the replacement of depreciated capital subsidized. In this way of subsidization, all investment in the process of building up any particular level of capital K_t is subsidized once and only once.

Consumer purchases of capital are constrained to be nonnegative. We denote $R_{k,t} \equiv 1 - s_{k,t} + (1 - \tau_{k,t})r_t - \delta(1 - \tau_{k,t})$ and rewrite the consumer budget constraint as

$$(1 + \tau_{c,t})C_t + (1 - s_{k,t})K_{t+1} + B_{t+1} = R_{b,t}B_t + R_{k,t}K_t + (1 - \tau_{w,t})w_t L_t. \tag{3}$$

Note that $R_{k,t+1}/(1 - s_{k,t}) = [1 - s_{k,t+1} + (1 - \tau_{k,t+1})r_{t+1} - \delta(1 - \tau_{k,t+1})]/(1 - s_{k,t})$ corresponds to the gross rate of return on investment in period t. One may regard the case $\tau_{k,t} = s_{k,t}$ as one that has a zero net tax on capital income. However, it will become clear later that the net tax revenue with $\tau_{k,t} = s_{k,t}$ can be positive when the capital income tax base is greater than the investment subsidy base. Competitive pricing ensures that the before-tax returns on capital and labor equal their marginal products, that is

$$r_t = F_k(K_t, L_t), \tag{4}$$

$$w_t = F_l(K_t, L_t). \tag{5}$$

The government budget constraint is given as

$$B_{t+1} = R_{b,t}B_t + G_t + s_{k,t}(K_{t+1} - K_t) - \tau_{c,t}C_t - \tau_{w,t}w_t L_t - \tau_{k,t}(r_t - \delta)K_t. \tag{6}$$

Without uncertainty in the model, the sole purpose of government debt is to offset government deficits and surpluses over time in the transition such that it is possible for the government to set time invariant tax or subsidy rates. In the long run, the level of government debt can be set arbitrarily close to zero to concentrate on the finance of public consumption rather than the repayment of government debt.

In the rest of this section, we shall first determine the Pareto optimal allocation by investigating the social planner problem. We shall then investigate the tax and subsidy rates that can decentralize the Pareto optimal allocation into a competitive equilibrium allocation.

2.1. The social planner problem

The social planner problem is to maximize (2) subject to (1) by choosing the sequence (C_t, L_t, K_{t+1}, G_t), given the technology $F(K_t, L_t)$ and initial capital stock K_0. The first-order conditions are given below for $t \geq 0$.

$$K_{t+1}: \quad U_c(t) = \beta U_c(t+1)[1 + F_k(t+1) - \delta], \tag{7}$$

$$L_t: \quad -\frac{U_l(t)}{U_c(t)} = F_l(t), \tag{8}$$

$$G_t: \quad U_c(t) = U_g(t), \tag{9}$$

where $F_l(t) \equiv F_l(K_t, L_t)$ and $F_k(t) \equiv F_k(K_t, L_t)$, referring to the marginal products of labor and capital respectively; similarly, $U_j(t)$ is the marginal utility with respect to variable $j = C_t, L_t, G_t$. When time approaches infinity, the transversality condition is

$$\lim_{t \to \infty} \lambda_t K_t = 0, \tag{10}$$

where λ_t is the Lagrange multiplier associated with the feasibility constraint.

The system of equations (1), (7), (8) and (9) maps K into next K' and determines $(C(K), L(K), G(K))$ implicitly in a recursive structure, along with the transversality condition (10). Starting with any $K_0 > 0$, repeating this process over time can therefore implicitly determine the solution for the sequence (C_t, K_{t+1}, L_t, G_t).

2.2. The competitive equilibrium and government policy

In the decentralized economy, each consumer maximizes (2) subject to (3) by choosing a sequence (C_t, K_{t+1}, L_t) taking initial K_0 and government policy $(\tau_{c,t}, \tau_{k,t}, \tau_{w,t}, s_{k,t}, G_t)$ as given. Let p_t denote the Lagrange multiplier on the consumer budget constraint (3). The consumer problem is formulated as

$$\max \sum_{t=0}^{\infty} \big\{ \beta^t U(C_t, L_t, G_t) + p_t[R_{b,t}B_t + R_t K_t + (1-\tau_{w,t})w_t L_t - (1+\tau_{c,t})C_t - (1-s_{k,t})K_{t+1} - B_{t+1}] \big\}. \tag{11}$$

The first-order conditions for $t \geq 0$ are

$$B_{t+1}: \quad B_{t+1}[p_t - p_{t+1}R_{b,t+1}] = 0, \tag{12}$$

$$K_{t+1}: \quad K_{t+1}[(1-s_{k,t})p_t - p_{t+1}R_{t+1}] = 0, \tag{13}$$

$$C_t: \quad \beta^t U_c(t) = p_t(1+\tau_{c,t}), \tag{14}$$

$$L_t: \quad \beta^t U_l(t) = -p_t(1-\tau_{w,t})w_t. \tag{15}$$

The two transversality conditions associated with B_t and K_t are

$$\lim_{t\to\infty} p_t B_t = 0, \tag{16}$$

$$\lim_{t\to\infty} p_t K_t = 0. \tag{17}$$

The first-order conditions associated with B_{t+1} and K_{t+1} imply the no-arbitrage condition between these two variables:

$$R_{b,t+1} = R_{k,t+1}/(1-s_{k,t}). \tag{18}$$

The government chooses the level of public consumption G_t to maximize (2) subject to its constraint (6). Note that substituting the government budget constraint (6) into the consumer budget constraint (3) results in the feasibility constraint (1). Thus, the government chooses G in the same way as the social planner does, and therefore has the same first-order condition (9). In order to finance public consumption according to (6), the government chooses the rates of the taxes and the subsidy such that the first-order conditions of the consumer problem are the same as those in the social planner problem.

The optimal government policy is given below.

Proposition 1: *For $t \geq 0$, the Pareto optimal government policy is characterized by $1 > \tau_{w,t} = -\tau_{c,t}$, $1 > s_{k,t} = \tau_{k,t+1}$, $U_c(t) = U_g(t)$ and $B_{t+1} = [1 - \delta + F_k(t)]B_t + G_t + s_{k,t}(K_{t+1} - K_t) - \tau_{c,t}C_t - \tau_{w,t}F_l(t)L_t - \tau_{k,t}(F_k(t) - \delta)K_t$. Also, $s_{k,t}$, $\tau_{k,t+1}$, $\tau_{c,t}$ and $\tau_{w,t}$ are constant over time for $t \geq 0$. In particular, $\tau_w < \tau_k$ for $t > 0$ if $B_\infty \geq 0$.*

Proof. First, it is obvious that the first-order condition (9) with respect to G_t holds true in both the social planner problem and the competitive equilibrium with the government choosing public consumption. Second, from the first-order conditions (14) and (15), we have $-U_l(t)/U_c(t) = (1 - \tau_{w,t})w_t/(1 + \tau_{c,t}) = (1 - \tau_{w,t})F_l(t)/(1 + \tau_{c,t})$. The relationship $\tau_{c,t} = -\tau_{w,t}$ removes the tax distortion from this optimal condition concerning the labor-leisure trade-off, and makes it the same as (8) in the social planner problem.

Third, from (13) and (14), we have

$$\frac{(1 - s_{k,t})}{1 + \tau_{c,t}} U_c(t) = \beta \frac{R_{k,t+1}}{1 + \tau_{c,t+1}} U_c(t + 1).$$

Removing tax distortions from this intertemporal optimal condition involves two rules. One is to set a time-invariant consumption tax rate, i.e. $\tau_{c,t} = \tau_{c,t+1}$ for $1 > s_{k,t}$ and $1 > \tau_{k,t+1}$. Since $\tau_{c,t} = -\tau_{w,t}$, the labor income tax rate must also be time invariant, i.e. $\tau_{w,t} = \tau_{w,t+1}$. The other rule is to set $s_{k,t} = \tau_{k,t+1}$ and $s_{k,t} = s_{k,t+1}$ that leads to $R_{k,t+1}/(1 - s_{k,t}) = 1 - \delta + F_k(t+1)$ by noting that $r_{t+1} = F_k(t+1)$ and $R_{k,t+1} = 1 - s_{k,t+1} + (1 - \tau_{k,t+1})(r_{t+1} - \delta)$. As a result, $\tau_{k,t+1}$ should also be constant over time for $t \geq 0$. Combining these two rules together makes the intertemporal optimal condition the same as (7) in the social planner problem.

Fourth, substituting the government budget constraint (6) into the consumer budget constraint (3) results in the feasibility constraint (1) as mentioned earlier. Also, this implies that the multiplier p_t in (11) should be the same as λ_t associated with feasibility in the social planner problem. Therefore, the transversality conditions (10) and (17) are the same. In a nutshell, the tax rules and the constraints result in the same system of four equations (1), (7), (8) and (9) that implicitly determines the allocation solution in a recursive structure as in the social planner problem, satisfying the same transversality condition.

Further, substituting $F_l = w$, $F_k = r$ and $R_b = R_k/(1-s_k) = 1-\delta+F_k$ into (6) gives $B_{t+1} = [1-\delta+F_k(t)]B_t + G_t + s_{k,t}(K_{t+1}-K_t) - \tau_{c,t}C_t - \tau_{w,t}F_l(t)L_t - \tau_{k,t}(F_k(t)-\delta)K_t$. This imposes an additional restriction on the decentralization of the social planner allocation into an equilibrium allocation through the tax policy, together with $\tau_w < 1$ and $\tau_k < 1$. Since the tax rates are constant over time, government debt will carry forward the remaining imbalance in the government budget in the transition toward the long run. We will then focus on the long-run restriction on government financing below.

Finally, in order to establish $\tau_k > \tau_w$ for $t > 0$, let us define $\tau_\Delta = \tau_k - \tau_w$ using the result that the tax rates and the subsidy rate are time invariant (except the initial tax rate $\tau_{k,0}$). Note also that in the steady state $I_t = \delta K_t$ with $B_{t+1} = B_t$ and $K_{t+1} = K_t$. Substituting $\tau_\Delta = \tau_k - \tau_w$, $s_k = \tau_k$ and $\tau_c = -\tau_w$ and the steady-state conditions into (6) yields

$$\begin{aligned} G_t &= -B_t(F_k(t)-\delta) - \tau_w C_t + \tau_w F_l(t)L_t + (\tau_w+\tau_\Delta)(F_k(t)-\delta)K_t \\ &= -B_t(F_k(t)-\delta) + \tau_w[F(K_t,L_t) - C_t - \delta K_t] + \tau_\Delta(F_k(t)-\delta)K_t. \end{aligned}$$

Since $G_t = F(K_t, L_t) - C_t - \delta K_t$ in the steady state, we rearrange the above equation as

$$G_t = \left(\frac{\tau_\Delta K_t - B_t}{1-\tau_w}\right)(F_k(t)-\delta). \tag{19}$$

Because $1 - \tau_w > 0$ and because $F_k(t) - \delta > 0$ for a meaningful problem for firms, we must have $\tau_\Delta > 0$ in the steady state in order to have positive public consumption if government debt in the steady state is positive or zero (i.e. $B_\infty \geq 0$). That is, $\tau_k > \tau_w$ in the steady state as long as government debt is positive or zero. Since these tax rates are time invariant outside the steady state as well with only one exception $\tau_{k,0}$, we must have $\tau_w < \tau_k$ for $t > 0$ as long as $B_\infty \geq 0$.

According to (19), there is a trade-off between G and B in the long run. To finance public consumption, the government can set B_∞ arbitrarily close to zero in the steady state. The case $-\infty < B_\infty < 0$ is also possible when the government has built up an asset by a capital levy in the initial period as in the Ramsey taxation models. In particular, the initial tax on capital income in our model can be chosen to influence the time invariant tax rates such that government debt in the long run is close to zero through the intertemporal government budget constraint. As we explained earlier, we do not use the initial capital levy to be the source of tax revenue to finance public consumption in the long run (i.e. ruling out $B_\infty < 0$ by assumption). ■

Among the key features of the Pareto optimal government policy, the rule $\tau_{c,t} = -\tau_{w,t}$ means that private consumption and leisure should have the same tax rate. Otherwise, a higher tax rate on private consumption than that on leisure would make consumption more expensive and leisure less expensive, thereby encouraging consumers to spend more time on leisure and less income on private consumption, and vise versa. The time invariant feature of the consumption tax rate is necessary because taxing private consumption more or less at one time than at another would engender intertemporal distortions concerning investment at the margin. The rule $s_{k,t} = \tau_{k,t+1}$ means that the government should tax net capital income and subsidize net investment at the same rate so as to avoid distorting the decision on investment at the margin. The subsidy rate and the capital income tax rate should also be constant over time to avoid intertemporal distortions, except that the capital income tax rate in the initial period is independent of this restriction.

In fact, in the Pareto optimal tax system the capital income tax rate in the initial period $\tau_{k,0}$ can be chosen to run a balanced government budget in that period. If the government were to run a budget surplus then it would set a high initial capital income tax rate and build up an asset for future government spending as in the Ramsey taxation literature that typically finds a zero tax on capital income after a finite number of periods. Unlike the Ramsey taxation calling for a zero tax on capital income in the long run, the Pareto optimal taxation in our model can generate a positive amount of tax revenue from net capital income minus subsidies on net investment in all periods. This is because the net capital income tax base is usually greater than the net investment subsidy base. In the steady state, for example, net investment $K_{t+1} - K_t$ is equal to zero in this neoclassical growth model and hence the revenue from taxing net capital income less the investment subsidy is equal to $\tau_k(F_k(t) - \delta)K_t > 0$ because $F_k(t) - \delta > 0$ is necessary to cover a positive real interest rate on the capital rental market.

The result that net capital income should be taxed more heavily than labor income after the initial period ($\tau_k > \tau_w$) is consistent with the actual tax rate differential in the United States but is at odds with the results in the Ramsey taxation literature. One reason for this result arises from the fact that individual consumers cannot effectively provide the amount of public consumption without government provision. The government provision, on the other hand, is regarded as external by individual consumers. As a consequence, the private marginal rate of return on market labor to a consumer in the decentralized equilibrium is lower than the social rate in the social planner problem, implying that equilibrium leisure (labor) is above (below) its first-best level. Thus, taxing capital income more heavily than labor income is intended to tip the trade-off between labor and leisure toward the former. Another reason for the result is our use of investment tax credits. Without the investment subsidy as in the Ramsey tax literature, taxing capital income would reduce investment and hence become less attractive than taxing labor income in the long run.

The constancy of tax rates over time and the transitory nature of the capital income tax rate in the initial period are similar to those in Chari, Christiano and Kehoe (1994) whereby the capital income tax is roughly equal to zero after the initial transition period. However, neither the tax on private consumption spending nor the subsidy on investment is allowed in their model. In our model, setting the tax rate on consumption opposite to the tax rate on labor income leads to an equal tax rate on private consumption and leisure. In addition, setting an equal rate for the subsidy on net investment and for the tax on net capital income cancels out the investment distortion of capital income taxation and contributes a positive amount of net tax revenue at the same time. Furthermore, in our model as in Chari et al. (1994), government debt can absorb government deficits or surpluses so as to support constant tax rates over time in the transition. In the long run, however, the government can set the level of government debt arbitrarily close to zero so as to concentrate on the finance of public consumption. This can be achieved by selecting the initial tax on capital income and the Pareto optimal policy concerning the time invariant rates of taxes and subsidies. In doing so, a higher initial tax on capital income means lower tax rates in future times when targeting zero government debt in the long run.

It is also worth noting that the Pareto optimal taxation in our model permits a whole range of possible tax and subsidy combinations, as long as the rules established in Proposition 1 are followed. A special case of the Pareto optimal tax system is to set $\tau_w = \tau_c = 0$ and use $\tau_k = s_k$ for $t > 0$ alone. In the steady state, this exclusive capital income tax with the subsidy at the same rate may contribute an amount of net tax revenue over 10% of output for a large enough τ_k. In our model, the ratio of the capital income tax revenue to output in the steady state is equal to $\tau_k(F_k(t) - \delta)K_t/Y_t > 0$. If we use $\tau_k = 70\%$, $K_t/Y_t = 2.9$ and $F_k - \delta = 6\%$ (the real annual interest rate), then the ratio of the capital income tax revenue to output in the steady state is about 12%. In all periods including the transition, the ratio of the net capital income tax revenue to output is equal to $\tau_k[(F_k(t)-\delta)K_t-(K_{t+1}-K_t)]/Y_t = \tau_k[F_k(t)K_t - I_t]/Y_t$ with $s_k = \tau_k$. If we set the capital income tax rate at $\tau_k = 70\%$ and consider realistic figures of the capital income share in output at $F_k(t)K_t/Y_t = 35\%$ and the investment output ratio at 18%, then the ratio of the net capital income tax revenue to output is also about 12%.[7] This accounts for over 40% of the ratio of total government spending to GDP in the United States (28%). Obviously, if the preferences and technology are such that the ideal level of public consumption can be financed by the net capital income tax revenue net of investment subsidies, then the Pareto optimal tax rules can decentralize the social planner allocation into an equilibrium allocation.

If the ideal level of government spending exceeds the tax revenue from the Pareto optimal tax system, then one may have to consider to reduce subsidies on investment and leisure or increase taxes on private consumption spending and capital income. By Proposition 1 and the proof of it, a consumption tax alone without a matching subsidy on labor can only be a second best tax because it distorts the decision on private consumption and leisure at the margin. An improvement upon such a pure consumption tax without subsidies on labor for higher welfare may be achieved by adding a tax on net capital income with an investment subsidy to some extent, in the spirit of Proposition 1.

Next, we consider home production.

3. The extended model with home production

In this section, we use a relatively standard macro model with home production that has proved useful in a variety of other macro applications in, e.g., Greenwood and Hercowitz (1991), Greenwood, Rogerson and Wright (1995), McGrattan, Rogerson and Wright (1997), Einarsson and Marquis (1997) and Parente, Rogerson and Wright (2000).

[7] This figure 12% is consistent with the actual ratio of government consumption to GDP in the United States in the 1994 version of the data set by Barro and Lee. Also, see Barro (1990).

In this extended model, the home sector purchases an investment good $I_{h,t} = K_{h,t+1} - (1 - \delta_h)K_{h,t}$ from the market and uses home capital $K_{h,t}$ and home labor $L_{h,t}$ to produce a home consumption good $C_{h,t} = H(K_{h,t}, L_{h,t})$. The home-production technology $H(K_{h,t}, L_{h,t})$ is also assumed to be homogenous of degree one, like the technology used in the market sector that is now denoted as $F(K_{m,t}, L_{m,t})$ where the subscript m refers to the market sector. The depreciation rate of home capital is $\delta_h \in (0,1)$ and the depreciation rate of market capital is $\delta_m \in (0,1)$. Accordingly, $I_{m,t} = K_{m,t+1} - (1-\delta_m)K_{m,t}$.

Feasibility now requires that

$$C_{m,t} + G_t + K_{m,t+1} + K_{h,t+1} = F(K_{m,t}, L_{m,t}) + (1-\delta_m)K_{m,t} + (1-\delta_h)K_{h,t}. \tag{20}$$

The preferences are now defined over home consumption as well:

$$\sum_{t=0}^{\infty} \beta^t U(C_{m,t}, C_{h,t}, L_t, G_t), \tag{21}$$

where $L_t = L_{m,t} + L_{h,t}$. The consumer budget constraint is given as

$$\begin{aligned}(1+\tau_{c,t})C_{m,t} \; &+ \; (1+\tau_{h,t})[K_{h,t+1} - (1-\delta_h)K_{h,t}] + (1-s_{k,t})K_{m,t+1} + B_{t+1} \\ &= \; R_{b,t}B_t + R_{k,t}K_{m,t} + (1-\tau_{w,t})w_t L_{m,t},\end{aligned} \tag{22}$$

where $R_{k,t} \equiv 1 - s_{k,t} + (1-\tau_{k,t})(r_t - \delta_m)$ as in the previous section and $\tau_{h,t}$ is the tax rate on the purchase of home investment from the market. It is possible that this tax rate is equal to the tax rate on the purchase of private consumption C_m. It is interesting to explore whether this possibility becomes a tax rule in the Pareto tax system because taxing home investment may cause distortions on home and market activities. In particular, it may reduce home investment and may in turn reduce home labor by reducing the marginal gain of home labor (may therefore raise leisure and market labor). Here, $r_t = F_{k_m}(t)$ and $w_t = F_{l_m}(t)$ as in the previous section. The government budget constraint is

$$B_{t+1} \; = \; R_{b,t}B_t + G_t + s_{k,t}(K_{m,t+1} - K_{m,t}) - \tau_{c,t}\, C_{m,t} - \tau_{h,t}[K_{h,t+1} - (1-\delta_h)K_{h,t}]$$

$$-\tau_{k,t}\, K_{m,t}(r_t - \delta_m) - \tau_{w,t}\, w_t\, L_{m,t}. \tag{23}$$

In the remainder of this section, we investigate the social planner problem first and then the competitive equilibrium with the government providing public consumption via various taxes.

3.1. The social planner problem

The social planner maximizes (21) subject to (20) and $C_{h,t} = H(K_{h,t}, L_{h,t})$. The optimal conditions for $t \geq 0$ are

$$K_{m,t+1}: \quad U_{c_m}(t) = \beta U_{c_m}(t+1)[1 - \delta_m + F_{k_m}(t+1)], \tag{24}$$

$$K_{h,t+1}: \quad U_{c_m}(t) = \beta \left[U_{c_m}(t+1)(1-\delta_h) + U_{c_h}(t+1) H_{k_h}(t+1) \right], \tag{25}$$

$$L_{m,t}: \quad -\frac{U_l(t)}{U_{c_m}(t)} = F_{l_m}(t), \tag{26}$$

$$L_{h,t}: \quad -\frac{U_l(t)}{U_{c_h}(t)} = H_{l_h}(t), \tag{27}$$

$$G_t: \quad U_{c_m}(t) = U_g(t). \tag{28}$$

Here, $H_{k_h}(t) \equiv H_{k_h}(K_{h,t}, L_{h,t})$ and $H_{l_h}(t) \equiv H_{l_h}(K_{h,t}, L_{h,t})$, referring to the marginal products of home capital and home labor respectively. Among these conditions, (24), (26) and (28) are similar to their counterparts in the previous section without home production. The transversality conditions are

$$\lim_{t \to \infty} \lambda_t K_{h,t} = 0, \tag{29}$$

$$\lim_{t \to \infty} \lambda_t K_{m,t} = 0. \tag{30}$$

Again, the above equations determine the social planner allocation implicitly in a recursive structure.

3.2. The competitive equilibrium and government policy

Each consumer maximizes (21) subject to the consumer budget constraint (22) and the home production technology $C_{h,t} = H(K_{h,t}, L_{h,t})$ by choosing a sequence of market and home activities $(C_{m,t}, C_{h,t}, K_{m,t+1}, K_{h,t+1}, L_{m,t}, L_{h,t})$, taking initial stocks $(K_{m,0}, K_{h,0})$ and government policy $(\tau_{c,t}, \tau_{h,t}, \tau_{w,t}, \tau_{k,t}, s_{k,t}, G_t)$ as given. Again, let p_t be the Lagrange multiplier on the consumer budget constraint. The optimal conditions are given below.

$$B_{t+1}: \quad B_{t+1}[p_t - p_{t+1}R_{b,t+1}] = 0, \tag{31}$$

$$K_{m,t+1}: \quad K_{m,t+1}[(1 - s_{k,t})p_t - p_{t+1}R_{k,t+1}] = 0, \tag{32}$$

$$K_{h,t+1}: \quad K_{h,t+1}\Big[(1 + \tau_{h,t})p_t - \beta^{t+1}U_{c_h}(t+1)H_{k_h}(t+1) - (1+\tau_{h,t+1})(1-\delta_h)p_{t+1}\Big] = 0, \tag{33}$$

$$C_{m,t}: \quad \beta^t U_{c_m}(t) = p_t(1 + \tau_{c,t}), \tag{34}$$

$$L_{m,t}: \quad \beta^t U_l(t) = -p_t(1 - \tau_{w,t})w_t, \tag{35}$$

$$L_{h,t}: \quad U_l(t) = -U_{c_h}(t)H_{l_h}(t). \tag{36}$$

As in Section 2, the government chooses the level of public consumption G_t to maximize social welfare (21) subject to the government budget constraint (23). Again, substituting the government budget constraint (23) into the consumer budget constraint (22) leads to the feasibility constraint (20). Thus, the first-order condition of the government choosing G_t is the same as (28) in the social planner problem. The transversality conditions are similar to those given earlier. The no-arbitrage condition between investments in government bonds B and in market capital K_m is the same as that in (18).

The optimal government policy with home production is given below.

Proposition 2: *For $t \geq 0$, the Pareto optimal government policy with home production is characterized by $1 > \tau_{w,t} = -\tau_{c,t}$, $\tau_{h,t} = \tau_{c,t}$, $1 > s_{k,t} = \tau_{k,t+1}$, $U_{c_m}(t) = U_g(t)$ and*

$B_{t+1} = [1-\delta_m + F_{k_m}(t)]B_t + G_t + s_{k,t}(K_{m,t+1} - K_{m,t}) - \tau_{c,t}C_{m,t} - \tau_{h,t}[K_{h,t+1} - (1-\delta_h)K_{h,t}] - \tau_{w,t}F_{l_m}(t)L_{m,t} - \tau_{k,t}(F_{k_m}(t) - \delta_m)K_{m,t}$. *Also,* $s_{k,t}$, $\tau_{k,t+1}$, $\tau_{c,t}$, $\tau_{h,t}$ *and* $\tau_{w,t}$ *are constant over time for* $t \geq 0$. *In particular,* $\tau_w < \tau_k$ *for* $t > 0$ *if* $B_\infty \geq 0$.

Proof. First, the first-order condition (28) with respect to G_t in the social planner problem is valid in the competitive equilibrium as mentioned earlier. Second, from the first-order conditions (34) and (35), we have $-U_l(t)/U_{c_m}(t) = (1-\tau_{w,t})w_t/(1+\tau_{c,t}) = (1-\tau_{w,t})F_{l_m}(t)/(1+\tau_{c,t})$. The relationship $\tau_{c,t} = -\tau_{w,t}$ removes the tax distortion from this optimal condition and makes it the same as (26) in the social planner problem in the same way as in the proof of Proposition 1.

Third, from (32) and (34), we have

$$\left(\frac{1-s_{k,t}}{1+\tau_{c,t}}\right) U_{c_m}(t) = \beta \left(\frac{R_{k,t+1}}{1+\tau_{c,t+1}}\right) U_{c_m}(t+1).$$

As in the proof of Proposition 1, removing tax distortions from this intertemporal optimal condition requires $\tau_{c,t} = \tau_{c,t+1}$, $s_{k,t} = \tau_{k,t+1}$ and $s_{k,t} = s_{k,t+1}$ for $1 > s_{k,t}$ and $1 > \tau_{k,t+1}$. This leads to $R_{k,t+1}/(1-s_{k,t}) = 1-\delta + F_{k_m}(t+1)$ by noting that $r_{t+1} = F_{k_m}(t+1)$ and $R_{k,t+1} = 1 - s_{k,t+1} + (1-\tau_{k,t+1})(r_{t+1} - \delta_m)$. Since $\tau_{c,t} = -\tau_{w,t}$, the constancy of the consumption tax over time means that the labor income tax rate must also be time invariant as well, i.e. $\tau_{w,t} = \tau_{w,t+1}$ for $t \geq 0$. Similarly, the relationship $s_{k,t} = \tau_{k,t+1}$ means that the constancy of $s_{k,t}$ over time carries on to $\tau_{k,t+1}$ for $t \geq 0$ as well. Combining these arguments all together leads to (24) in the social planner problem as we argued in the proof of Proposition 1.

From (33) and (34), the intertemporal optimal condition concerning home capital investment is

$$\left(\frac{1+\tau_{h,t}}{1+\tau_{c,t}}\right) U_{c_m}(t) = \beta \left[\left(\frac{1+\tau_{h,t+1}}{1+\tau_{c,t+1}}\right) U_{c_m}(t+1)(1-\delta_h) + U_{c_h}(t+1)H_{k_h}(t+1)\right].$$

Setting $\tau_{c,t} = \tau_{h,t}$ can make this condition the same as (25) in the social planner problem. Since $\tau_{c,t}$ is constant over time, $\tau_{h,t}$ must be so as well. In addition, the first-order condition with respect to home labor (36) is the same as (27) in the social planner problem, that is there is no direct tax distortion in this optimal condition with respect to the trade-off between leisure and home labor. As mentioned earlier, substituting the government budget constraint (23) into the consumer budget constraint (22) leads to the feasibility constraint (20). As argued in the proof of Proposition 1, this leads to the same multiplier in the social planner problem and the competitive equilibrium and therefore leads to the same transversality conditions governing the long-run behavior of capital stocks $K_{h,\infty}$ and $K_{m,\infty}$. Now, we get the same system of equations as those in the social planner problem to implicitly determine the allocation solution in a recursive structure.

Finally, substituting $F_{l_m} = w$, $F_{k_m} = r$ and $R_b = R_{k_m}/(1 - s_k) = (1 - \delta_m + F_{k_m})$ into the government budget constraint (23) gives $B_{t+1} = [1 - \delta_m + F_{k_m}(t)]B_t + G_t + s_{k,t}(K_{m,t+1} - K_{m,t}) - \tau_{c,t}C_{m,t} - \tau_{h,t}[K_{h,t+1} - (1 - \delta_h)K_{h,t}] - \tau_{w,t}F_{l_m}(t)L_{m,t} - \tau_{k,t}(F_{k_m}(t) - \delta_m)K_{m,t}$. This imposes an addition restriction on the decentralization of the social planner allocation into an equilibrium allocation through the tax policy, together with $\tau_{w,t} < 1$ and $\tau_{k,t} < 1$. The rest of the proof is similar to the counterpart in the proof of Proposition 1. ■

With home production, the Pareto optimal tax rules in Proposition 1 are still valid, except that the government budget balance now includes a tax (or a subsidy if $\tau_{h,t} < 0$) on home-investment spending. The new findings with home production are as follows. The tax (or subsidy) rate on home investment should be equal to the tax (or subsidy) rate on private consumption spending; and it should be time invariant.

The intuitions for these new insights are as follows. The time invariant feature of this tax on home investment spending avoids intertemporal distortions. Setting the tax rate on home investment spending at the same rate as that on private consumption spending is somewhat surprising, as the traditional view is typically against taxes on investment spending. It turns out that a tax on home investment spending is essentially a tax on private consumption of a non-market good despite home labor is also used in home production. Thus, equalizing the tax rates on the two private consumption goods helps to remove distortions between them at the margin, as long as leisure is taxed at the same rate under $\tau_c = \tau_h = -\tau_w$ to offset the expected negative effect of τ_c and τ_h on market labor and home labor, respectively. Specifically, $-U_l(t)/U_{c_m}(t) = [(1-\tau_w)/(1+\tau_c)]F_{l_m}(t)$ and $-U_l(t)/U_{c_h}(t) = H_{l_h}(t)$ under $\tau_c = -\tau_w$ imply a socially optimal trade-off $U_{c_m}(t)/U_{c_h}(t) = H_{l_h}(t)/F_{l_m}(t)$. This optimal trade-off means that the marginal rate of substitution between the two private consumption goods should be equal to the marginal rate of substitution of labor between these two sectors. Putting it differently, it means that the marginal utility of home labor $U_{c_h}(t)H_{l_h}(t)$ should be equal to the marginal utility of market labor $U_{c_m}(t)F_{l_m}(t)$.

4. Conclusion

In this paper, we have used a neoclassical growth model and an extension for home production to investigate optimal taxation. We have assumed public consumption in the preferences of the population and allowed for a sufficiently large set of fiscal instruments such that the Pareto optimal allocation is achievable. We have found that the Pareto optimal taxation should have the following features. First, the government should tax leisure and private consumption at the same rate. Second, it should subsidize net investment at the same rate at which it taxes net capital income. Doing so not only removes investment distortions of capital income taxation but also generates a positive amount of net tax revenue that can be as high as over 10% of output. Third, the government should tax capital income more heavily than labor income to raise market labor and reduce leisure, because otherwise public consumption in individuals's preferences would cause leisure to be above its first-best level. Fourth, all these tax rates and the subsidy rate should be constant over time to avoid intertemporal distortions, with one exception that the capital income tax rate in the initial period may differ from its later values.

These Pareto optimal tax rules are valid in the extended version of the neoclassical growth model with home production. The additional insight with home production is that the government should tax home investment for home consumption at the same rate at which it taxes private market consumption. Again, these tax rates should be constant over time to avoid intertemporal distortions.

Since the Pareto optimal taxation faces an upper limit on the revenue it can generate relative to output, it may not be possible to decentralize the social planner allocation into an equilibrium allocation when the preference over public consumption is sufficiently strong. Interestingly, the attainable revenue as a fraction of output by the Pareto optimal taxation may be consistent with the realistic ratio of government consumption to GDP in the United States. A more complete analysis of optimal taxation that also considers other components of government spending, such as welfare transfer payments, awaits future research.

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