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Income Taxation Rules and Stability of a Small Open Economy☆

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ABSTRACT

This paper examines the stability of a small open economy under alternative income taxation rules. Using a one-sector real business cycle model with external increasing returns, we show that if the income tax schedule is linear, the small open economy will not generate equilibrium indeterminacy, but it exhibits a diverging behavior under certain conditions. In this case, an appropriate choice of nonlinear tax on the factor income may recover the saddle-point stability. We also reveal that if the taxation on the interest income on financial assets is regressive, then the small open economy may exhibit equilibrium indeterminacy. In this situation, a progressive tax rule on the interest income can contribute to eliminating sunspot-driven fluctuations.

1. Introduction

Does the income taxation rule act as a built-in stabilizer? This long-standing question has attracted a renewed interest in macroeconomics research, ever since Guo and Lansing (1998) revealed that progressive income taxation contributes to stabilizing an economy in the presence of sunspot-driven business fluctuations. Using a one-sector real business cycle model with external increasing returns, Guo and Lansing (1998) demonstrate that progressive income taxation narrows the parameter space in which equilibrium indeterminacy emerges. They also confirm that regressive income taxation enhances the possibility of equilibrium indeterminacy. Subsequent studies have reconsidered Guo and Lansing's finding in alternative settings such as two-sector real business cycle models, models with productive public investment, models with utility-enhancing public spending, and models of endogenous growth[1]. Those studies have shown that the taxation rule may play a decisive role in stabilizing the economy in various settings.

So far, the research on the stabilization effect of income taxation rules has focused on closed economies, and the role of taxation schemes for the stabilization effect in open economies has not yet been explored well. The purpose of this paper is to investigate the relationship between income tax schedules and the stability of a small open economy. We introduce the nonlinear taxation rule formulated by Guo and Lansing (1998) into a prototype model of a one-sector, small open economy with free capital mobility. Based on this analytical framework, we investigate which type of taxation rule contributes to stabilizing the small open economy.

We obtain two main findings. First, if the income taxation schedule is linear, then the small open economy will not yield

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[1] A sample includes Ben-Gad (2003), Chen et al. (2018), Chen and Guo (2013, 2016, 2017); Dromoel and Pintus (2007, 2008); Gokan (2013); Greiner (2006); Guo and Harrison (2001, 2015); Lloyd-Braga et al. (2008), and Zhang (2000).

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equilibrium indeterminacy. However, it is also shown that, under certain conditions, the equilibrium path of the economy diverges from the steady-state equilibrium, so that there is no feasible, perfect-foresight equilibrium. In this case, an appropriate choice of nonlinear tax schedule on the factor income may recover the saddle-point stability of the economy. Therefore, the income taxation rule stabilizes the economy in the old sense rather than in the modern sense, that is, ruling out sunspot-driven fluctuations.

Our second finding is that nonlinear taxation on the interest income on foreign bonds may generate equilibrium indeterminacy. In particular, our numerical analysis reveals that under plausible parameter values, sunspot-driven business cycles arise in the small open economy, if the tax schedule on the interest income is regressive, while progressive taxation may establish equilibrium determinacy. This means that, as far as the taxation on the interest income is concerned, progressive taxation would act as a built-in stabilizer in the sense that it may eliminate sunspot-driven fluctuations. Therefore, our paper shows that the main conclusion of Guo and Lansing (1998) generally holds in the open economy counterpart as well.

Related Studies

Besides the literature on the stabilization effect of taxation rule cited in Footnote 1, our paper is related to the early studies on indeterminacy in small open economies such as (Weder, 2001), and (Meng, 2003; Meng and Velasco, 2004)[2]. Weder (2001) opens up Benhabib and Farmer (1996) two-sector model with external increasing returns. Meng (2003); Meng and Velasco (2004) utilize Benhabib and Farmer (1998) two-sector model with social constant returns. In the closed economy models studied by Benhabib and Farmer (1996) and Benhabib and Farmer (1996), the presence of equilibrium indeterminacy needs not only specific conditions on the production technology but also a high degree of intertemporal substitutability of consumption. Weder (2001) and Meng (2003); Meng and Velasco (2004) reveal that under perfect international capital mobility, the small open economies may hold indeterminacy without imposing restrictions on the preference structure. Hence, those studies claim that small open economies tend to be more volatile than the closed economy counterparts, because indeterminacy may emerge in wider parameter spaces. As mentioned above, we find that such a conclusion does not hold in the one-sector, small open economy model that has been frequently used in the international macroeconomics[3].

We should point out that a few authors have examined the stabilization effect of fiscal policy rules in small open economies. Among others, Huang et al. (2017) introduce the balanced-budget rule á la Schmitt-Grohé and Uribe (1997) into a two-sector small open economy model with variable labor supply. Since Schmitt-Grohé and Uribe (1997) assume that the fiscal authority adjusts the tax rate to finance a fixed level of government spending, the rate of tax changes counter-cyclically. Hence, their fiscal scheme similar to the regressive tax in the context of Guo and Lansing (1998) taxation rule. Huang et al. (2017) find that the destabilizing effect of the balanced-budget rule emphasized by Schmitt-Grohé and Uribe (1997) does not necessarily hold in their small open economy. To the best of our knowledge, Zhang (2015) is the most closely related study to our paper. By use of a two-sector small open economy model in which capital goods are not internationally traded, Zhang (2015) examines the stabilization effect of Guo and Lansing (1998) taxation scheme. Zhang (2005) numerically confirms that regressive taxation may generate indeterminacy. Although the research concern of Huang et al. (2017) and Zhang (2015) overlaps with our paper, those authors do not analyze the role of the taxation rule on the interest income from financial assets. Therefore, those foregoing contributions and our study are complements rather than substitutes.

The rest of the paper is organized as follows. The next section constructs the baseline model. Section 3 characterizes the equilibrium dynamics and explores the stabilization effect of alternative taxation rules. Section 4 concludes.

2. Model

In this paper, we use the one-sector real business cycle model with investment adjustment costs that has been frequently used in international macroeconomics[4]. We introduce production externalities and nonlinear taxation into the standard model.

2.1. Production and Consumption

The analytical framework of our study is a small open economy version of the model of Benhabib and Farmer (1994) which introduces production externalities into an otherwise standard baseline model of real business cycles. The home country and the rest of the world produce homogeneous goods. The aggregate production function of the home country is given by

$$Y_t = AK_t^a N_t^{1-a} \bar{K}_t^{\alpha-a} \bar{N}_t^{\beta-(1-a)} \quad A > 0, \quad 0 < a < 1, \quad a < \alpha \leq 1, \quad \beta > 1 - a,$$

where Y_t is output, K_t is capital, N_t is labor, and $\bar{K}_t$ and $\bar{N}_t$ represent country-specific, external effects associated with the aggregate levels of capital and labor. In our representative-agent economy, the mass of agents is normalized to one, and thus in equilibrium, $\bar{K}_t = K_t$ and $\bar{N}_t = N_t$ hold for all $t \geq 0$. Therefore, the social production function is written as

[2] Hu and Mino (2013) re-examine the findings by Meng (2003) and Meng and Velasco (2004) in a two-country model with free lending and borrowing. See also Lahiri (2001) for an early contribution to the study on equilibrium indeterminacy in open economies.

[3] See Chapter 6 in Mino (2017) for a detailed discussion on equilibrium indeterminacy in open economy models.

[4] See Chapter 3 in Schmitt-Grohé and Uribe (2017) for a detailed exposition on this prototype model in open economy macroeconomics.

$$Y_t = AK_t^{\alpha}N_t^{\beta}, \quad \alpha + \beta > 1. \tag{1}$$

The final good and factor markets are assumed to be competitive, and the factor prices are given by

$$r_t = aAK_t^{\alpha-1}N_t^{\beta}, \quad w_t = (1-a)AK_t^{\alpha}N_t^{\beta-1}, \tag{2}$$

where r_t is the rate of return to capital and w_t is the real wage rate.

Our formulation of a small open economy is the conventional one: domestic households freely lend to or borrow from foreign households, and international lending and borrowing are carried out by trading foreign bonds under a given world interest rate. The objective function of the representative household is the following lifetime utility:

$$U = \int_0^{\infty} e^{-\rho t}\log\left(C_t - \frac{N_t^{1+\gamma}}{1+\gamma}\right)dt, \quad \rho > 0, \quad \gamma > 0,$$

where ρ denotes a given time discount rate. In this paper, we assume that the representative household has the Greenwood–Hercowitz–Huffman (GHH) preferences (Greenwood et al., 1988). Under GHH preferences, there is no wealth effect on labor supply, so the labor supply solely depends on the real wage. As is well known, the emergence of equilibrium indeterminacy in the Benhabib-Farmer model stems from the wealth effect on labor supply, coupled with the presence of strong externality that makes the labor demand curve steeper than the Frisch labor supply curve. In this paper, we exclude the wealth effect to focus on income tax rules rather than on production and preference structures in discussing the equilibrium (in)determinacy problem.

The household's flow budget constraint is

$$\dot{B}_t = (1-\tau_{y,t})(r_tK_t + w_tN_t) + (1-\tau_{b,t})RB_t - \left[\frac{I_t}{K_t} + \frac{\theta}{2}\left(\frac{I_t}{K_t}\right)^2\right]K_t - C_t, \quad \theta > 0, \tag{3}$$

where B_t denotes the stock of foreign bond (net asset position) held by domestic households, R is a given world interest rate, $\tau_{b,t}$ is the rate of tax on interest income, $\tau_{y,t}$ is the rate of factor income tax, and I_t denotes gross investment on capital. Here, the term $(\theta/2)(I_t/K_t)^2K_t$ represents the adjustment costs of investment. In this paper. we assume that the home country is a lender to foreign households, so B_t has a positive value and the taxation on interest income is available. The capital stock changes according to

$$\dot{K}_t = I_t - \delta K_t, \quad 0 < \delta < 1, \tag{4}$$

where δ denotes the rate of the depreciation of capital.

The household maximizes the lifetime utility U by controlling C_t, N_t and I_t subject to (3) and (4) together with the initial condition on K_t and B_t as well as with the no-Ponzi-game condition:

$$\lim_{t\to\infty} e^{-(1-\tau_b)Rt}B_t \geq 0. \tag{5}$$

2.2. Taxation Rules

Following Guo and Lansing (1998), we assume that the fiscal authority adjusts each rate of income tax according to the following manner:

$$\tau_{y,t} = 1 - \eta_y\left(\frac{Y^*}{Y_t}\right)^{\phi_y}, \quad 0 < \eta_y < 1, \quad \underline{\phi}_y < \phi_y < 1, \quad \underline{\phi}_y < 0, \tag{6}$$

$$\tau_{b,t} = 1 - \eta_b\left(\frac{B^*}{B_t}\right)^{\phi_b}, \quad 0 < \eta_b < 1, \quad \underline{\phi}_b < \phi_b < 1, \quad \underline{\phi}_b < 0. \tag{7}$$

In the above, $Y_t = r_tK_t + w_tN_t$ denotes domestic factor income of the household in period t and Y^* is a reference level of factor income, which is represented by the steady-state level of the aggregate output. Similarly, the reference income in the case of the taxation on the interest income is its steady-state level, RB^*. Hence, the taxation rule is written as (7) on the interest income, RB_t. In the above, the restrictions on η_y and η_b mean that in the steady-state equilibrium where $Y_t = Y^*$ and $B_t = B^*$, the average tax rates are in between 0 and 1. In addition, $\underline{\phi}_y$ and $\underline{\phi}_b$ are defined as

$$\underline{\phi}_i = \frac{\eta_i - 1}{\eta_i}, \quad i = y, \ b.$$

In this taxation scheme, the rates of income tax are endogenously determined out of the steady state, but they become exogenously given flat rates, $1-\eta_y$ and $1-\eta_b$, at the steady state. The restriction on ϕ_i $(i = y, b)$ ensures that the marginal tax revenue of the government increases with households' incomes at the steady state even if $\phi_i < 0$[5].

[5] The government's revenue from factor income taxation is $T_y = \tau_{y,t}Y_t = \left[1 - \eta_y\left(\frac{Y^*}{Y_t}\right)^{\phi_y}\right]Y_t$. Thus $\frac{dT_y}{dY_t} = 1 - \eta_y(1-\phi_y)\left(\frac{Y^*}{Y_t}\right)^{\phi_y}$, which shows that the marginal tax revenue is positive at the steady state if $1 > (1-\phi_y)\eta_y$, which gives the minimum level of $\underline{\phi}_y$. The same argument is applied to the taxation on the interest income.

The tax schedule in (6) means that the marginal tax rate on the domestic income is given by

$$\frac{d}{dY_t}(\tau_{y,t}Y_t) = 1 - (1-\phi_y)\eta_y\left(\frac{Y^*}{Y_t}\right)^{\phi_y},$$

which is higher (lower) than the average tax rate, $\tau_{y,t}$ if $0 < \phi_y < 1$ ($\underline{\phi_y} < \phi_y < 0$). Thus, the taxation is progressive (regressive) if $0 < \phi_y < 1$ ($\underline{\phi_y} < \phi_y < 0$). The same argument holds for the taxation on the interest income. Note that under (6) and 7, the after-tax total income of the household is

$$(1-\tau_{y,t})Y_t + (1-\tau_{b,t})RB_t = \eta_y Y^{*\phi_y}(r_tK_t + w_tN_t)^{1-\phi_y} + \eta_b RB^{*\phi_b}B_t^{1-\phi_b}.$$

Denoting the government consumption as G_t, the flow budget constraint for the government is

$$G_t = \tau_{y,t}Y_t + \tau_{b,t}RB_t = \left[1 - \eta_y\left(\frac{Y^*}{Y_t}\right)^{\phi_y}\right]Y_t + \left[1 - \eta_b\left(\frac{B^*}{B_t}\right)^{\phi_b}\right]RB_t \tag{8}$$

We assume that the government simply consumes its tax revenue so that the government spending affects neither households' welfare nor firms' production activities.

2.3. The Optimal Conditions

To derive the optimization conditions for the household, we set up the following Hamiltonian function:

$$\begin{aligned} H_t &= \log\left(C_t - \frac{N_t^{1+\gamma}}{1+\gamma}\right) + q_t(I_t - \delta K_t) \\ &\quad + \lambda_t\left[\eta_y(Y^*)^{\phi y}(r_tK_t + w_tN_t)^{1-\phi_y} + \eta_b R(B^*)^{\phi_b}B_t^{1-\phi_b} - \left[\frac{I_t}{K_t} + \frac{\theta}{2}\left(\frac{I_t}{K_t}\right)^2\right]K_t - C_t\right], \end{aligned}$$

where q_t and λ_t respectively denote the utility prices of K_t and B_t.

Remember that when selecting C_t, N_t and I_t, the representative household takes sequences of $\{r_t,\ w_t\}_{t=0}^{\infty}$ as given. Therefore, noting that $r_tK_t + w_tN_t = Y_t$, we find that the first-order conditions for an optimum include the following:

$$\max_{C_t} H_t \Longrightarrow \left(C_t - \frac{N_t^{1+\gamma}}{1+\gamma}\right)^{-1} = \lambda_t, \tag{9a}$$

$$\max_{N_t} H_t \Longrightarrow \left(C_t - \frac{N_t^{1+\gamma}}{1+\gamma}\right)^{-1} N_t^{\gamma} = \lambda_t\eta_y(1-\phi_y)\left(\frac{Y^*}{Y_t}\right)^{\phi_y} w_t, \tag{9b}$$

$$\max_{I_t} H_t \Longrightarrow q_t = \lambda_t\left[1 + \theta\frac{I_t}{K_t}\right], \tag{9c}$$

$$\dot{q}_t = (\rho+\delta)q_t - \lambda_t\left[(1-\phi_y)\eta_y\left(\frac{Y^*}{Y_t}\right)^{\phi_y} r_t + \frac{\theta}{2}\left(\frac{I_t}{K_t}\right)^2\right], \tag{9d}$$

$$\dot{\lambda}_t = \lambda_t\left[\rho - (1-\phi_b)\eta_b\left(\frac{B^*}{B_t}\right)^{\phi_b} R\right], \tag{9e}$$

together with the transversality conditions: $\lim_{t\to\infty} e^{-\rho t}q_tK_t = 0$ and $\lim_{t\to\infty} e^{-\rho t}\lambda_tB_t = 0$.

2.4. Dynamic System

We find that, using (2), conditions (9a) and (9b) yield

$$N_t^{\gamma} = (1-\phi_y)\eta_y\left(\frac{Y^*}{Y_t}\right)^{\phi_y}(1-a)\frac{Y_t}{N_t}.$$

Substituting (1 into the above and solving it for N_t, we obtain

$$N_t = \Omega K_t^{\omega}, \tag{10}$$

where

$$\Omega = \left[(1-\phi_y)\eta_y(1-a)A^{1-\phi_y}Y^{*\phi_y}\right]^{\frac{1}{1+\gamma-\left(1-\phi_y\right)\beta}}, \qquad \omega = \frac{\alpha(1-\phi_y)}{1+\gamma-(1-\phi_y)\beta}. \tag{11}$$

Equation (10) gives the equilibrium level of hours worked. Substituting (10) into (1) presents a reduced form of the aggregate production function in such a way that

$$Y_t = A\Omega^{\beta}K_t^{\alpha+\beta\omega}. \tag{12}$$

As a result, the pre-tax real rate of return to capital is expressed as

$$r_t = a\frac{Y_t}{K_t} = aA\Omega^{\beta}K_t^{\alpha+\beta\omega-1}. \tag{13}$$

Equation (9a) gives

$$C_t = \frac{1}{\lambda_t} + \frac{N_t^{1+\gamma}}{1+\gamma}. \tag{14}$$

Using (9c), (9d) is written as follows:

$$\dot{K}_t = K_t\left[\frac{1}{\theta}\left(\frac{q_t}{\lambda_t} - 1\right) - \delta\right]. \tag{15}$$

Denoting $q_t/\lambda_t = v_t$ and using (9e), (3), (14), (15) and (9d), we obtain the following complete dynamic system with respect to B_t, v_t, K_t and λ_t:

$$\begin{aligned}\dot{B}_t &= \eta_y\left(\frac{Y^*}{A\Omega^{\beta}K_t^{\alpha+\beta\omega}}\right)^{\phi_y}A\Omega^{\beta}K_t^{\alpha+\beta\omega} + \eta_b\left(\frac{B^*}{B_t}\right)^{\phi_b}RB_t \\ &\quad - \left[\frac{1}{\theta}(v_t-1) + \frac{1}{2\theta}(v_t-1)^2\right]K_t - \frac{1}{\lambda_t} - \frac{(\Omega K_t^{\omega})^{1+\gamma}}{1+\gamma},\end{aligned} \tag{16a}$$

$$\begin{aligned}\dot{v}_t &= \delta v_t - \left[(1-\phi_y)\eta_y\left(\frac{Y^*}{A\Omega^{\beta}K_t^{\alpha+\beta\omega}}\right)^{\phi_y}aA\Omega^{\beta}K_t^{\alpha+\beta\omega-1} + \frac{1}{2\theta}(v_t-1)^2\right] \\ &\quad + (1-\phi_b)\eta_b\left(\frac{B^*}{B_t}\right)^{\phi_b}Rv_t,\end{aligned} \tag{16b}$$

$$\dot{K}_t = K_t\left[\frac{1}{\theta}(v_t-1) - \delta\right], \tag{16c}$$

$$\dot{\lambda}_t = \lambda_t\left[\rho - (1-\phi_b)\eta_b\left(\frac{B^*}{B_t}\right)^{\phi_b}R\right]. \tag{16d}$$

2.5. Steady-State Equilibrium

In the steady-state equilibrium, it holds that $Y_t = Y^*$ and $B_t = B^*$. In (16d), the steady-state condition, $\dot{\lambda}_t = 0$, holds if and only if

$$\rho = (1-\phi_b)\eta_b R. \tag{17}$$

We assume that (17) is fulfilled in order to define a feasible steady-state equilibrium. Hence, it holds that $\lambda_t = \bar{\lambda}$(=constant) for all $t \geq 0$. The steady-state condition for the aggregate capital stock, $\dot{K} = 0$ in (16c) gives the steady-state value of v_t as follows:

$$v^* = \theta\delta + 1, \tag{18}$$

which determines the steady-state level of relative utility price between the financial asset and the physical capital. Then the condition $\dot{v}_t = 0$ in (16b), together with (17) and (18), leads to

$$(\rho+\delta)(\theta\delta+1) = \eta_y(1-\phi_y)aA\Omega^{\beta}K^{*\alpha+\beta\omega-1} + \frac{\theta\delta^2}{2},$$

where K^* denotes the steady-state value of K_t. Note that $A\Omega^{\beta}(K^*)^{\alpha+\beta\omega-1} = Y^*/K^*$. Hence, the steady-state level of the output-capital ratio is determined by

$$\frac{Y^*}{K^*} = \frac{1}{a}\left[\frac{2(\rho+\delta)(\delta\theta+1) - \theta\delta^2}{2\eta_y(1-\phi_y)}\right]. \tag{19}$$

In view of (11), we see that the steady-state level of Y^* satisfies

$$Y^* = A\left[(1-\phi_y)\eta_y(1-a)A^{1-\phi_y}Y^{*\phi_y}\right]^{\frac{\beta}{1+\gamma-\left(1-\phi_y\right)\beta}}(K^*)^{\alpha+\beta\omega}.$$

This means that the relation between K^* and Y^* is given by

$$Y^* = A^{\frac{1+\gamma-\left(1-\phi_y\right)\beta}{1+\gamma-\beta}}\left[(1-\phi_y)\eta_y(1-a)A^{1-\phi_y}\right]^{\frac{\beta}{1+\gamma-\beta}}(K^*)^{\frac{1+\gamma-(1-\phi_y)\beta}{1+\gamma-\beta}(\alpha+\beta\omega)}. \tag{20}$$

Using (19) and (20), we can express the steady-state levels of K_t and Y_t in terms of the parameters involved in the model. When K^* is expressed as a function of the parameters, from (10) the steady-state level of hours worked is determined by $N^* = \Omega(K^*)^\beta$.

On the other hand, given (17), the constant value of $\bar{\lambda}$ is not determined by the steady-state conditions, $\dot{B}_t = \dot{v}_t = \dot{K}_t = 0$. As usual in the standard small-open economy model with free capital mobility, the steady-state levels of $\bar{\lambda}$ is pinned down by use of the intertemporal budget constraint for the household under given initial values of K_0 and B_0. We note that in the steady state (16a) gives

$$\eta_y A\Omega^\beta K^{*\alpha+\mu\omega} + \eta_b RB^* = \left[\delta + \frac{\delta^2\theta}{2}\right]K^* + C^*, \tag{21}$$

where $C^* = \frac{1}{\bar{\lambda}} + \frac{N^{*1+\gamma}}{1+\gamma}$. Since the magnitude of C^* depends on the initial levels of K_t and B_t, the steady-state level of asset holding, B^*, also depends on the initial conditions.

3. Stability under Alternative Tax Schedules

In this section, we examine the stabilization effect of taxation rules by specifying the values of ϕ_y and ϕ_b.

3.1. Linear Taxation on the Factor and Interest Incomes

When the fiscal authority adopts linear taxation rules. we set $\phi_y = \phi_b = 0$. In this case, the dynamic system reduces to (16c) and the following:

$$\dot{B}_t = \eta_y A\hat{\Omega}^\beta K_t^{\alpha+\beta\hat{\omega}} + \eta_b RB_t - \left[\frac{1}{\theta}(v_t-1) + \frac{1}{2\theta}(v_t-1)^2\right]K_t - \frac{1}{\lambda_t} - \frac{(\hat{\Omega}K_t^{\hat{\omega}})^{1+\gamma}}{1+\gamma}, \tag{22a}$$

$$\dot{v}_t = \delta v_t - \left[(1-\phi_y)\eta_y aA\Omega^\beta K_t^{\alpha+\beta\hat{\omega}-1} + \frac{1}{2\theta}(v_t-1)^2\right] + (1-\phi_b)\eta_b Rv_t, \tag{22b}$$

$$\dot{\lambda}_t = \lambda_t(\rho - \eta_b R). \tag{22c}$$

In the above,

$$\hat{\Omega} = \eta_y(1-a)A^{\frac{1}{1+\gamma-\beta}}, \qquad \hat{\omega} = \frac{\alpha}{1+\gamma-\beta}.$$

As before, we assume that $\eta_b R = \rho$ in order to define a meaningful steady state equilibrium. As a result, λ_t takes a constant value, $\bar{\lambda}$, for all $t \geq 0$. It is to be noted that (22b) and (16c) constitute a complete dynamic system with respect to v_t and K_t. Linearizing (22b) and (16c) at the steady state in which $\dot{v}_t = \dot{K}_t = 0$ holds. we obtain the following coefficient matrix:

$$J_1 = \begin{bmatrix} \rho & (\alpha+\beta\hat{\omega}-1)\hat{\Psi} \\ \frac{K^*}{\theta} & 0 \end{bmatrix},$$

where $\hat{\Psi} \equiv -\eta_y aA\hat{\Omega}^\beta(K^*)^{\alpha+\beta\hat{\omega}-2}$ is a negative constant. Hence, we see that

$$\text{sign}\det J_1 = \text{sign}\ (\alpha+\beta\hat{\omega}-1) = \text{sign}\left[\frac{\beta-(1-\alpha)(1+\gamma)}{1+\gamma-\beta}\right].$$

This means the following:

$$\det J_1 < 0 \text{ if } \beta < (1-\alpha)(1+\gamma) \text{ or } \beta > 1+\gamma, \tag{23}$$

$$\det J_1 > 0 \text{ if } (1-\alpha)(1+\gamma) < \beta < 1+\gamma. \tag{24}$$

If $\det J_1 < 0$, then (22b) and (16c) establish the local saddle stability. Denoting the stable arms on the (K_t, v_t) plane by $v_t = \xi(K_t)$, we can confirm that $\xi'(v_t) < 0$. Thus, the entire dynamic system is reduced to the following:

$$\begin{aligned}\dot{B}_t &= \eta_y A\Omega^\beta K_t^{\alpha+\mu\hat{\omega}} + \eta_b RB_t - \left[\frac{1}{\theta}(\xi(K_t)-1) + \frac{1}{2\theta}(\xi(K_t)-1)^2\right]K_t \\ &\quad - \frac{1}{\bar{\lambda}} - \frac{(\Omega K_t^{\hat{\omega}})^{1+\gamma}}{1+\gamma},\end{aligned} \tag{25a}$$

$$\dot{K}_t = K_t\left[\frac{1}{\theta}(\xi(K_t) - 1) - \delta\right]. \tag{25b}$$

Equation (25b) indicates that K_t exhibits a self-stabilizing behavior, and it converges to its steady-state level, K^*. When $K_t = K^*$, (25a) is written as

$$\dot{B}_t^* = \eta_y Y^* + \rho B_t^* - \delta\left(1 + \frac{\theta\delta}{2}\right)K^* - \frac{1}{\bar{\lambda}} - \frac{(N^*)^{1+\gamma}}{1+\gamma}, \tag{26}$$

where B_t^* denotes the level of B_t when $K_t = K^*$. In this case, the intertemporal budget constraint for the household held at the steady state is

$$B_0^* + \frac{1}{\rho}\eta_y Y^* = \frac{1}{\rho}\left[\frac{1}{\bar{\lambda}} + \frac{(N^*)^{1+\gamma}}{1+\gamma} + \delta\left(1 + \frac{\delta\theta}{2}\right)K^*\right]. \tag{27}$$

If $\bar{\lambda}$ is selected to satisfy (27), then(26) becomes

$$\dot{B}_t^* = \rho(B_t^* - B_0^*),$$

which means that $\dot{B}_0^* = 0$. As a result, an appropriate choice of $\bar{\lambda}$ fixes B_t at a steady-state level when K_t converges to K^*. Therefore, under the conditions in (23), the small open economy holds a unique stable equilibrium path that converges to the steady state.

On the other hand, if the conditions in (24) are satisfied, there is no equilibrium path that converges to (K^*, v^*). As shown in the next subsection, a nonlinear tax schedule may recover the saddle stability of our small open economy.

Proposition 1. *Under linear taxation rules, either if $\beta < (1-\alpha)(1+\gamma)$ or if $\beta > 1+\gamma$, then the equilibrium path of the small open economy is stable and determinate. If $(1-\alpha)(1+\gamma) < \beta < 1+\gamma$, then the economy exhibits diverging behavior so that there is no feasible equilibrium path of the economy that converges to the steady state.*

As is well known, in their analysis on the closed economy counterpart of our model, Benhabib and Farmer (1994) revealed that a necessary (but not sufficient) condition for equilibrium indeterminacy is that $\beta > 1+\gamma$, that is, the labor demand curve is steeper than the Frisch labor supply curve. In the small open economy in which the marginal utility of consumption stays constant over time under $\rho = (1-\tau_b)R$, the dynamic behavior of the economy hinges on the sign of $d\dot{v}_t/dK_t$, which is positive (resp. negative) if $\alpha + \beta\omega < 1$(resp. $\alpha + \beta\omega > 1$). If $\alpha + \beta\omega < 1$, the marginal product of capital of the social production function that involves external effects decreases with capital, which ensures saddle stability of the dynamic system of (K_t, v_t). Note that from Proposition 1, the saddle stability and equilibrium determinacy can be established under $\beta > 1+\gamma$, and thus the presence of strong external effects contributing to holding stability. In contrast, if the external effect associated with labor is sufficiently small to satisfy $(1-\alpha)(1+\gamma) < \beta < 1+\gamma$, then the small open economy is completely unstable, meaning that there is no feasible perfect-foresight equilibrium.

3.2. Nonlinear Taxation on the Factor Income

In this case, under (17), the dynamic system consists of (16c), (22c), and the following:

$$\dot{B}_t = \eta_y\left(\frac{Y^*}{A\Omega^\beta K_t^{\alpha+\beta\omega}}\right)^{\phi_y} A\Omega^\beta K_t^{\alpha+\beta\omega} + \eta_b R B_t - \left[\frac{1}{\theta}(v_t - 1) + \frac{1}{2\theta}(v_t-1)^2\right]K_t - \frac{1}{\bar{\lambda}} - \frac{(\Omega K_t^{\omega})^{1+\gamma}}{1+\gamma}, \tag{28a}$$

$$\dot{v}_t = \delta v_t - \left[(1-\phi_y)\eta_y\left(\frac{Y^*}{A\Omega^\beta K_t^{\alpha+\beta\omega}}\right)^{\phi_y} aA\Omega^\beta K_t^{\alpha+\beta\omega-1} + \frac{1}{2\theta}(v_t-1)^2\right] + \eta_b R v_t, \tag{28b}$$

where Ω and ω are defined in (11). Again, (16c) and(28b) constitute a complete system with respect K_t and v_t, and the coefficient matrix evaluated at the steady state values of K^* and v^* is given by

$$J_2 = \begin{bmatrix} \rho & [(\alpha+\beta\omega)(1-\phi_y) - 1]\Psi \\ \frac{K^*}{\theta} & 0 \end{bmatrix},$$

where $\Psi \equiv -(1-\phi_y)\eta_y aA\Omega^\beta (K^*)^{\alpha+\beta\omega-2}$ is a negative constant. Hence, we see that

$$\begin{aligned} \text{sign } \det J_2 &= \text{sign } [(\alpha+\beta\omega)(1-\phi_y) - 1] \\ &= \text{sign } \left[\frac{(1-\phi_y)\beta - (1-\alpha)(1+\gamma)}{1+\gamma-(1-\phi_y)\beta}\right]. \end{aligned}$$

Inspection of the dynamic system consisting of (16c) and (28b) leads to the following outcomes:

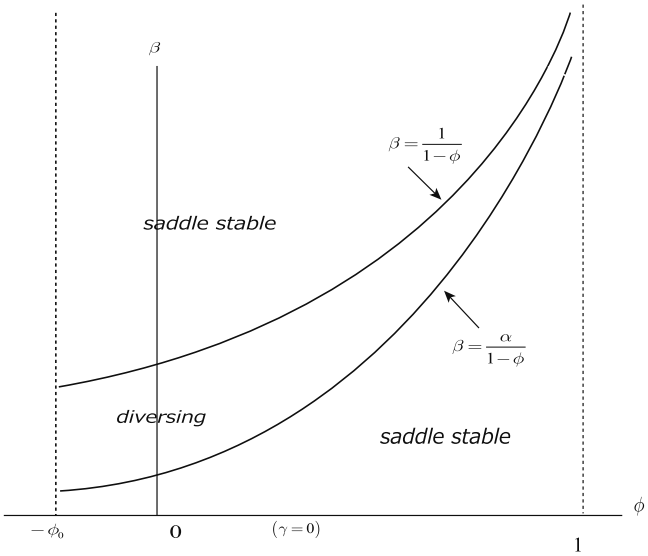

Fig. 1. Classification of (β, ϕ) space under exogenous growth ($\gamma = 0$)

Proposition 2. *The one-sector small open economy with exogenous growth and nonlinear income taxation holds saddle-point stability and equilibrium determinacy if one of the following conditions is satisfied:*

$$(1-\phi_y)\beta < (1-\alpha)(1+\gamma) \text{ or } (1-\phi_y)\beta > 1+\gamma. \tag{29}$$

The economy displays diverging behavior if and only if and only if

$$(1-\alpha)(1+\gamma) < (1-\phi_y)\beta < 1+\gamma. \tag{30}$$

We should note that in view of (29) if the fiscal authority sets the degree of the progressiveness of tax on the factor income, ϕ_y, to satisfy

$$\phi_y < 1 - \frac{1+\gamma}{\beta} \quad \text{or} \quad \phi_y > \frac{\beta - \alpha(1+\gamma)}{\beta + \alpha(1+\gamma)}, \tag{31}$$

then the economy can recover a unique, stable equilibrium. Figure 1classifies the (β, ϕ) space according to the dynamic behavior of the economy under given levels of α and γ. (For simplicity of exposition, in the figure we assume the case of indivisible labor, i.e. $\gamma = 0$). As the figure shows, if the external effect associated with aggregate labor is relatively small (so that β is relatively small), then a higher degree of tax progressiveness, (a higher ϕ) is useful to avoid diverging behavior of the economy. At the same time, it is easier to establish $(1-\phi_y)\beta > 1+\gamma$ in (29) under regressive taxation ($\phi_y < 0$). Therefore, unlike the closed economy model examined by Guo and Lansing (1998), a regressive tax scheme would contribute to hold the stability of the small open economy.

3.3. Nonlinear Taxation on Factor and Interest Incomes

Finally, let us inspect the general model constructed in Section 2. We linearize the dynamics system consisting of (16a), (16b), (16c) and (16d) at the steady-state equilibrium. The coefficient matrix evaluated at the steady state is given by

$$J_3 = \begin{bmatrix} \rho & -\left(\frac{1}{\theta}+\delta\right)K^* & S & \frac{1}{(\lambda^*)^2} \\ -\frac{\phi_b \rho v^*}{B^*} & \rho & T & 0 \\ 0 & \frac{K^*}{\theta} & 0 & 0 \\ \phi_b \frac{\rho}{B^*}\lambda^* & 0 & 0 & 0 \end{bmatrix}, \tag{32}$$

where

$$S = \left(\frac{\partial \dot{B}_t}{\partial K_t}\right)^* = \eta_y(1-\phi_y)(\alpha+\beta\omega)\frac{Y^*}{K^*} - \delta\left(1+\frac{\theta\delta}{2}\right) - \omega\Omega^{1+\gamma}(K^*)^{\omega(1+\gamma)-1},$$
$$T = \left(\frac{\partial \dot{v}_t}{\partial K_t}\right)^* = -a(1-\phi_y)\eta_y[(1-\phi_y)(\alpha+\beta\omega)-1]A\Omega^{\beta}(K^*)^{(\alpha+\beta\omega)-2}.$$

Let the eigenvalues of J be μ_i $(i = 1, 2, 3, 4)$. Then we find the following:

$$\mu_1 + \mu_2 + \mu_3 + \mu_4 = \text{trace } J_3 = 2\rho > 0, \tag{33}$$

$$\mu_1\mu_2\mu_3\mu_4 = \det J_3 = \phi_b \frac{\rho K^* T}{B^*\theta\lambda^*}. \tag{34}$$

Note that

$$\begin{aligned}\text{sign } \det J_3 &= \text{sign } \phi_b T = \text{sign } \phi_b[1-(1-\phi_y)(\alpha+\beta\omega)] \\ &= \text{sign } \phi_b\left[\frac{(1-\phi_y)\beta-(1-\alpha)(1+\gamma)}{1+\gamma-(1-\phi_y)\beta}\right].\end{aligned} \tag{35}$$

First, (33) shows that at least one of the eigenvalues is positive. Therefore, if $\det J_3 > 0$, then the linearized system has either two stable roots or no stable root. Since the system has two predetermined variables K_t and B_t, the former means equilibrium determinacy and the latter shows no stable equilibrium. On the other hand, if $\det J_3 < 0$, the system involves one or three stable roots. In the former case, there is no covering equilibrium path, while the latter case means equilibrium indeterminacy. Hence, inspecting (35), we find the following:

Proposition 3. *Suppose that one of the following conditions holds:*

$$(1-\phi_y)\beta < (1-\alpha)(1+\gamma) \text{ or } (1-\phi_y)\beta > 1+\gamma \tag{36}$$

Then the small open economy may hold determinacy (resp. indeterminacy) if taxation on the interest income is progressive (resp. regressive). *If it holds that*

$$(1-\alpha)(1+\gamma) < (1-\phi_y)\beta < 1+\gamma, \tag{37}$$

then the small open economy can yield determinacy (resp. indeterminacy) if taxation on the interest income is regressive (resp. progressive).

It should be pointed out that the analytical conditions in Proposition 3 do not exclude the possibility that the number of stable roots is one or zero. Since the analytical discussion does not provide further information about stability of our model, we examine numerical examples. We set the baseline parameter values (except for ϕ_b) in the following way:

$$\begin{aligned}\rho &= 0.02, \quad A = 1, \quad R = 0.03, .\delta = 0.1, \quad \theta = 1, \quad a = 0.35, \quad \alpha = 0.4, \quad \beta = 0.8, \\ \phi_y &= 0.3, \quad \eta_y = \eta_b = 0.7, \quad \gamma = 0.5.\end{aligned}$$

In the above, the magnitudes of ρ, δ, a and γ are conventional ones. To satisfy the first inequality in (36), we assume that there is a mild degree of externalities in aggregate production by setting $\alpha + \beta = 1.2$. Note that under our specifications, $\omega = 0.2978$ in (11) so $\alpha + \beta\omega = 0.638\,2$. Additionally, (19) yields $Y^*/K^* = 0.647$, which is not an unrealistic magnitude at least for the US economy. Then we can derive the steady-state values of K_t, Y_t, N_t and v_t as follows:

$$K^* = 0.9878, \quad Y^* = 0.5394, \quad N^* = 0.1959, \quad v^* = 1.1$$

We also find that $\Omega = 0.348$, $S = 0.1971$, and $T = 0.0346$. Since the steady-state levels of λ_t, C_t and B_t depend on the initial conditions, we assume that the initial levels of K_0 and B_0 are set to satisfy $C^* = 0.7Y^* = 0.376$, meaning that the income share of the private consumption is 0.7. Given this assumption, we find that $B^* = 3.171$ and $\frac{1}{\lambda^*} = C^* - \frac{(N^*)^{1+\gamma}}{1+\gamma} = 0.316$.

We first assume that the taxation on the interest income is progressive by setting $\phi_b = 0.3$. Then we evaluate J_3 based on the numerical values derived so far. We find that J_3 has two posi tive and two negative real eigenvalues[6]. We change ϕ_b between 0.1 and 0.4 to see that the number of stable root remains the same[7]. Therefore, if a progressive taxation rule is applied to the interest income, the small open economy tends to hold equilibrium determinacy around the steady-state equilibrium.

Next, we set $\phi_b = -0.3$, that is, the tax schedule on the interest income is regressive. In this case, we find that J_3 has one positive and one negative real eigenvalue. In addition, J_3 also has conjugate complex eigenvalues with negative real parts[8]. Consequently, under a regressive tax schedule on the interest income, the economy exhibits local indeterminacy of equilibrium. We change ϕ_b

[6] In this specific example, the eigenvalues are: 0.252 49, 0.04, 823, −0.008 923, −0.159 83.

[7] We also adjust η_b to hold $(1-\phi_b)\eta bR = \rho$.

[8] Specifically, the eigenvalues are:

$$0.241\,07,\ -0.02\,865\,1,\ -0.04.\ 910\,1 + 0.010\,19i,\ -0.04\,910\,1 - 0.010\,19i.$$

between − 0.1 and − 0.4 and obtain the same outcome. However, we also find that if the taxation on the interest income is too regressive, for example, $\phi_b = -0.6$, then J has one positive and one negative eigenvalue, together with conjugate complex eigenvalues with positive real parts. In this case, the small open autonomy shows a diverging behavior, unless the economy stays at the steady state at the outset.

Finally, let us set $\phi_y = -0.1$. If other parameters have the same values shown above, it holds that $(1-\alpha)(1+\gamma) < (1-\phi_y)\beta < 1+\gamma$, so that in view of Proposition 2, the economy displays diverging behavior if the taxation rule on the interest income is linear ($\phi_b = 0$). In this case, our numerical analysis reveals that J_3 has four unstable roots if $\phi_b > 0$, and it has three unstable roots if $\phi_b < 0$. Hence, under plausible parameter specifications, the second half of Proposition 3 is unlikely to hold. Consequently, it is safe to conclude that sunspot-driven fluctuations in the small open economy can be observed, only when the tax schedule on the interest income is regressive under the conditions given in (36).

The intuition behind the fact that regressive taxation on the interest income may cause equilibrium indeterminacy is the following. Suppose that the small open economy stays at the steady state in the initial period. Suppose further that a positive sunspot shock raises the household's expected permanent income and the household increases consumption. This leads to a negative current account, so the net asset position of the household, B_t, starts declining. Since the tax scheme on the interest income is regressive, a lower B_t decreases the marginal after-tax interest income, $\eta_b(1-\phi_b)\left(\frac{B^*}{Bt}\right)^{\phi_b}R$, and thus, from (16d), the utility price of the financial asset, λ_t, starts rising. Hence, consumption, C_t, decreases, by which the level of B_t will return to the original steady-state equilibrium. Such a self-stabilizing behavior of the economy allows the presence of sunspot equilibria.

3.4. Remarks

In this subsection, we present additional remarks on the main outcomes derived so far.

The Two-Sector Economy

Following the standard modeling of the one-sector small open economy, we have assumed that the real investment is associated with adjustment costs. In the one-good economy without adjustment costs of investment, capital and foreign bonds are perfectly substitute each other, and, hence, the households' portfolio choice between real and financial assets becomes indeterminate. Alternatively, we may consider a two-sector economy in which consumption goods and investment goods are produced by use of different technologies. In addition, if the investment goods are not internationally traded, capital accumulation is determined by the market equilibrium condition of investment goods in the domestic market. In this setting, the relative price of investment goods in terms of consumption goods corresponds to $v_t(=q_t/\lambda_t)$ in our one-sector model. As mentioned in Section 1, Zhang (2015) introduces the Guo-Lansing taxation scheme into a two-sector model. Assuming that the investment good sector employes a more capital intensive technology than the consumption good sector, Zhang (2015) shows that regressive taxation on factor income may give rise to indeterminacy, whereas progressive taxation may generate determinacy. Judging from our analysis in Section 3.3, it is easy to anticipate that the two-sector economy would hold intermediacy under a regressive tax scheme on the interest income, even though the taxation is progressive on the factor income.

The Zero-Root Problem

As we have assumed in this paper, most of the small open economy models with perfect capital mobility assume that the time discount rate of the representative household equals the world interest rate in order to keep the marginal utility of consumption constant over time. As a result, if the equilibrium path is determinate, the steady-state level of the foreign bonds depends on the initial conditions on bonds and capital. This means that if the equilibrium path is indeterminate, the steady-state level of foreign bonds is indeterminate as well. A simple way to resolve this problem in our model is to ignore the reference level of the stock of foreign bond, B^*, in the taxation rule on the interest income. For example, if the tax schedule on the interest income is given by $\tau_b(B_t) = 1 - \eta_b(B_t)^{-\phi_b}$, then the steady-state condition (17) is replaced by

$$\rho = (1-\phi_b)\eta_b(B^*)^{-\phi_b}R,$$

which pins down a unique steady-state level of B_t.[9] In this case, we can numerically show that under plausible parameter values, if the tax schedule is regressive ($-\underline{\phi_b} < \phi_b < 0$), then there may exist a continuum of equilibrium path that converges to the unique steady-state equilibrium.

Alternatively, we may assume that the time discount rate, ρ, is endogenously determined. For example, to avoid the zero-root problem, Huang et al. (2017) assume that the time discount rate depends on the average consumption in the economy at large. Combined this assumption with the Guo-Lansing taxation formula, the dynamic behavior of λ_t is described by

$$\dot{\lambda}_t = \lambda_t\left[\rho(C_t) - (1-\phi_b)\eta_b\left(\frac{B^*}{B_t}\right)^{\phi_b}R\right].$$

[9] This formulation is related to Lubick (2007) who examines the stability of a small open economy in which the world interest rate is debt elastic.

Hence, the steady-state level of consumption is determined by $\rho(C^*) = (1 - \phi_b)\eta_b R$, which gives the steady-state level of C_t and, thus, determines the steady-state level of B_t. However, the analysis of the transition dynamics of this generalized model becomes more complex than our formulation, meaning that the stabilization effect of the taxation rule would be affected by the preference structure as well[10].

The Reality of Regressive Tax on Finacial Assets

Although Proposition 3 states that indeterminacy could arise even if the taxation on the interest income is progressive, our numerical experiment has suggested that given plausible parameter values, indeterminacy tends to hold under a regressive tax schedule on the interest income. In modern economies, income taxation is generally progressive, so that one may argue that regressive taxation on the interest income is only a thought experiment. However, it has been often claimed that compared to the taxation on the factor income, it is more difficult to enforce taxation on wealth perfectly. This is particularly true for internationally traded assets. For example, in their detailed study on the wealth tax, Saez and Zucman, 2019 point out that in many countries the self-reported amount of wealth is sensitive to a change in the marginal tax rate on wealth. This suggests that (wealthy) households tend to have a strong incentive to avoid tax on their wealth.

As an example, following a model in Saez and Zucman, 2019, suppose that the households hide $h \times 100\%$ of their holding of foreign bonds. We also assume that the fiscal authority applies a flat-rate tax to the interest income. Then the effective tax rate on the interest income is $(1 - h)\eta_b$, where $\eta_b \in (0, 1)$ is the rate of tax on the interest income. Moreover, assume that the households' incentive to avoid tax on their wealth becomes stronger as the level of their asset increases. Then the government's total tax revenue from taxation on the interest income is $\eta_b[(1 - h(B_t))]RB_t$, where $h'(B_t) > 0$. In this case, the effective average tax rate is $\eta_b[1 - h(B_t)]R$ and the effective marginal tax rate is $\eta_b[1 - h(B_t) - B_t h'(B_t)]R$, so that the average tax rate exceeds the marginal tax rate. Therefore, despite the linear taxation, the effective tax schedule on the interest income is regressive, which corresponds to the case of $\phi_b < 0$ in the Guo and Lansing (1998) formulation.

4. Conclusion

Using a prototype model of open economy macroeconomics, we have examined the stabilization effect of income taxation rules. We have shown that in the standard one-sector model with free capital mobility, indeterminacy will not arise if the tax schedule on interest income from the foreign bond is linear. However, the economy would be totally unstable, and an appropriate choice of a nonlinear tax schedule on the factor income may recover the saddle stability. We have also shown that given plausible parameter values if the tax schedule on the interest income is regressive, the small open economy may generate sunspot-driven fluctuations, while a progressive tax on the interest income can rule out indeterminacy. Those findings demonstrate that as well as in the closed economies, income taxation rules would play a relevant role in keeping the stability of small open economies.[11]

A limitation of our study is that we have employed the representative agent framework, and thus the effects of taxation rules on the wealth and income distributions cannot be explored. As well as in the other branches of macroeconomics, since the 2007-2008 global financial crises, the researchers in international macroeconomics have paid much attention to the models that involve financial frictions and agent heterogeneity. Examining the stabilization effect of taxation rules in a more general environment would deserve further investigation.

CRediT author statement

Before revising the paper, the corresponding author ((Mino) and the coauthors (Chen and Hu) discussed how to respond to the comments from the referee and the Editor. We collaborated to modify the model and examine some numerical examples. In writing the paper, the corresponding author wrote a fist draft, and the coauthors revised the manuscript. Therefore, each author equaly contibuted to preparing the current version of the paper.

References

Benhabib, J., Farmer, R., 1994. Indeterminacy and increasing returns. Journal of Economic Theory 63, 19–41.
Chen, B.-L., Hsu, M., Hsu, Y.S., 2018. Progressive taxation and macroeconomic stability in two-sector models with social constant returns. Journal of Economics 125, 51–68.
Chen, S.-H., Guo, J.T., 2013. Progressive taxation and macroeconomic (in)stability with productive government spending. Journal of Economic Dynamics and Control 37, 951–963.
Chen, S.-H., Guo, J.T., 2016. Progressive taxation, endogenous growth, and macroeconomic (in)stability. Bulletin of Economic Research 68, 20–27.
Chen, S.-H., Guo, J.T., 2017. Progressive taxation as an automatic destabilizer under endogenous growth. Journal of Public Economic Theory 10, 329–349.
Dromoel, N., Pintus, P., 2007. Linearly progressive income taxes and stabilization. Research in Economics 61, 25–29.
Dromoel, N., Pintus, P., 2008. Are progressive income taxes stabilizing? Journal of Public Economic Theory 10, 329–349.
Gokan, Y., 2013. Indeterminacy, labor and capital income taxes, and nonlinear tax schedules. Journal of Macroeconomics 36, 138–149.
Greenwood, J., Hercowitz, Z., Huffman, G., 1988. Investment, capacity utilization, and the real business cycle. American Economic Review 78, 402–417.
Greiner, A., 2006. Progressive taxation, public capital, and endogenous growth. Finaz Archiv 62, 353–366.

[10] Schmitt-Grohé and Uribe (2003) offer several alternative ways to avoid the zero-root problem.
[11] Chen et al. (2018) examine the stabilization effect of nonlinear income taxation in a wide class of small open economy models.

Guo, J.-T., Harrison, S., 2001. Tax policy and stability in a model with sector-specific externalities. Review of Economic Dynamics 4, 75–89.
Guo, J.-T., Harrison, S., 2015. Indeterminacy with progressive taxation and sector-specific externalities. Pacific Economic Review 20, 268–281.
Guo, J.-T., Lansing, K., 1998. Indeterminacy and stabilization policy. Journal of Economic Theory 84, 481–490.
Hu, Y., Mino, K., 2013. Trade structure and belief-driven fluctuations in a global economy. Journal of International Economics 90, 414–424.
Huang, K., Meng, Q., Xue, J., 2017. Balanced-budget income taxes and aggregate stability in a small open economy. Journal of International Economics 105, 90–101.
Lloyd-Braga, T., Modesto, .L., Seegmuller, T., 2008. Tax rate variability and public spending as sources of indeterminacy. Journal of Public Economic Theory 10, 399–421.
Lubick, T., 2007. Non-stationarity and instability in small open-economy models even when they are "closed". Economic Quarterly 93, 393–412.
Meng, Q., 2003. Multiple transitional paths in endogenously growing open economies. Journal of Economic Theory 108, 365–376.
Meng, Q., Velasco, A., 2004. Market imperfections and the stability of open economies. Journal of International Economics 64, 503–519.
Mino, K., 2017. Growth and Business Cycles with Equilibrium Indeterminacy. Springer.
Saez, E., Zucman, G., 2019. Progressive wealth taxation. forthcoming in Brooking Papers on Economic Activity.
Schmitt-Grohé, S., Uribe, M., 1997. Balanced-budget rules, distortionary taxes, and aggregate instability. Journal of Political Economy 105, 976–1000.
Schmitt-Grohé, S., Uribe, M., 2003. Closing small open economy models. Journal of International Economics 61, 163–185.
Schmitt-Grohé, S., Uribe, M., 2017. Open Economy Macroeconomics. Princeton University Press.
Weder, M., 2001. Indeterminacy in a small open economy ramsey growth model. Journal of Economic Theory 98, 339–356.
Zhang, J., 2000. Public services, increasing returns, and equilibrium dynamics. Journal of Economic Dynamics and Control 24, 227–246.
Zhang, Y., 2015. Fiscal policy and indeterminacy in a small open economy. unpublished manuscript.