



Laffer Curves in Japan*

Kengo Nutahara†
Department of Economics, Senshu University;
and the Canon Institute for Global Studies

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Abstract

This paper investigates the Laffer curves in Japan, based on a neoclassical growth model. It is found that while the labor tax rate is smaller than that at the peak of the Laffer curve, the capital tax rate is either very close to, or larger than, that at the peak of the Laffer curve. This problem is more serious when the consumption tax rate is high. It is also found that to maximize total tax revenue, the government should increase the labor tax rate but decrease the capital tax rate.

Keywords: Laffer curve; fiscal policy; labor tax; capital tax; consumption tax;
Japan

JEL classification: E13; E62; H20; H30; H60

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†Postal address: 2-1-1, Higashimita, Tama-ku, Kawasaki, Kanagawa, 214-8580, Japan. Tel.: +81-411-911-1230. Fax.: +81-411-911-1231. E-mail: nutti@isc.senshu-u.ac.jp

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Phone: +81-3-6213-0550 <http://www.canon-igs.org>

1 Introduction

Arthur B. Laffer stated that “there are always two tax rates that yield the same revenues” during a business dinner in 1974 (Wanniski, 1978). An increase in a tax rate would have two opposing effects. One is to increase tax revenue directly. The other is to reduce tax revenue because a high tax rate decreases the incentive to supply labor and to investment. As a result, tax revenue is possibly a hump-shaped function of tax rate; this is the so called “Laffer curve.”

Tax revenue is a very important issue for the Japanese government. Japan has the highest debt-to-GDP ratio in the world, and the best way to improve Japan’s fiscal health is discussed often. Increasing government expenditure associated with the aging population, and long economic stagnation are often cited as reasons to increase tax rates. However, there is a possibility where an increase in tax rates may reduce tax revenue. In this case, knowledge of the peak levels of the Laffer curves for each tax is important for policy makers.

This paper investigates the Laffer curves for labor, capital and consumption taxes in Japan based on a neoclassical growth model à la Trabandt and Uhlig (2011). The model is calibrated to the Japanese data, and the average marginal taxes estimated by Gunji and Miyazaki (2011) are used for labor and capital taxes. The Laffer curves for labor and capital taxes have single peaks, but that for the consumption tax is monotonically increasing in the tax rate as shown by Trabandt and Uhlig (2011). We find that while the labor tax rate is lower than that of the peak of the Laffer curve, the capital tax rate is very close to that of the peak of the Laffer curve or even larger than it under certain specifications. Trabandt and Uhlig (2011) report that the capital tax rates in Sweden and Denmark are higher than those at the peaks, and this paper finds that Japan is similar to these countries. When the consumption tax rate is high, the tax rate at the peak of the Laffer curves for labor and capital taxes is smaller, and this problem becomes more serious. We also find that to maximize total tax revenue, the government should increase

the labor tax rate but decrease the capital tax rate. Our result implies that the current plan of the Japanese government to decrease the corporate tax rate might have positive effects on tax revenue because capital taxes in our model include corporate taxes.

It is important to note that an increase in tax revenue is a different problem from an increase in welfare. In the model, taxes are distortionary, and if an increase in tax revenue is not used for government expenditure or if government expenditure yields no utility to households, increasing tax revenue would be welfare reducing. Even if government expenditure yields utility to households, the welfare implications are dependent upon the situation. On the other hand, some economists believe that an increase in tax revenue or the tax rate might have beneficial effects in certain situations. Yanagawa and Uhlig (1996) show that an increase in the capital tax rate can increase the rate of economic growth theoretically. Braun and Uhlig (2006) find that an increase in the capital tax rate has positive welfare effects in an economy with incomplete markets. Miyazawa and Nutahara (2013) find that an increase in tax revenue has positive effects on the Japanese economy in the medium term using a structural VAR with sign restrictions. However, welfare analysis is beyond the scope of this paper, and we mainly focus on the effect on tax revenue. Instead of welfare analysis of increasing tax revenue, in Section 3.4, we will consider the optimal taxation problem of the model given the total tax revenue level. It is found that total tax revenue is financed only by consumption tax is optimal in our model.

This paper is closely related to Trabandt and Uhlig (2011, 2013), who investigate the Laffer curves of the US and EU economies using a neoclassical growth model. This paper follows their methodology. The marginal labor and capital tax rates are important in our research, and we use the average marginal labor and capital tax rates estimated by Gunji and Miyazaki (2011), who use the methodology of Joines (1981). This paper is close in nature to the studies on fiscal policy reform in Japan. Hiraga (2011) considers the effects of a corporate tax rate reduction. Braun and Joines (2013) and Hansen

and Imrohorglu (2013) investigate fiscal policy as it relates to the sustainability of the Japanese economy.

The remainder of the paper is organized as follows. Section 2 introduces the model. Section 3 explains the calibration of the model, and presents the main results. Section 4 makes some concluding remarks.

2 The model

The representative households hold capital stock k_{t-1} and debt b_{t-1} as assets at the beginning of the period. They supply labor h_t and capital stock k_{t-1} to firms, and earn wage rate w_t , rental rate of capital d_t , and the interest rate on debt R_t^b . They also receive government transfers s_t and transfers from abroad m_t . The transfers from abroad m_t can be interpreted as net imports as discussed by Trabandt and Uhlig (2011). Let τ_t^C , τ_t^W , and τ_t^K denote the consumption tax, labor tax, and capital tax rates, respectively. The budget constraint of households is

$$(1 + \tau_t^C)c_t + x_t + b_t \leq (1 - \tau_t^W)w_t h_t + (1 - \tau_t^K)(d_t - \delta)k_{t-1} + \delta k_{t-1} + R_t^b b_t + s_t + m_t, \quad (1)$$

where δ denotes the depreciation rate of capital and x_t is investment. The capital stock evolves according to the following equation

$$k_t = (1 - \delta)k_{t-1} + x_t. \quad (2)$$

Finally, the objective function of households is

$$\sum_{t=0}^{\infty} \beta^t [u(c_t, h_t) + v(g_t)]. \quad (3)$$

As a baseline, we employ the Constant Frisch Elasticity (CFE) utility function,

$$u(c_t, h_t) = \begin{cases} \frac{1}{1-\eta} \left\{ (c_t)^{1-\eta} \left[1 - \kappa(1-\eta)h_t^{1+1/\varphi} \right]^\eta - 1 \right\} & \text{if } \eta \neq 1 \\ \log(c_t) - \kappa h_t^{1+1/\varphi} & \text{if } \eta = 1 \end{cases}, \quad (4)$$

where $\eta > 0$ denotes the inverse of the intertemporal elasticity of substitution (IES), κ , weighting of the disutility of labor supply, and φ , Frisch elasticity of labor supply. The standard Cobb–Douglas utility function, that is

$$u(c_t, h_t) = \sigma \log(c_t) + (1 - \sigma) \log(1 - h_t)$$

is also used as a sensitivity check.

The first-order conditions of the households' problem are

$$c_t : (1 + \tau_t^C) \lambda_t = u_1(c_t, h_t), \quad (5)$$

$$h_t : \lambda_t (1 - \tau_t^W) w_t = -u_2(c_t, h_t), \quad (6)$$

$$k_t : \lambda_t = \beta E_t \left\{ \lambda_{t+1} \left[(1 - \delta) + (1 - \tau_{t+1}^K)(d_{t+1} - \delta) + \delta \right] \right\}, \quad (7)$$

$$b_t : \lambda_t = \beta E_t \left[\lambda_{t+1} R_{t+1}^b \right]. \quad (8)$$

The firms are perfectly competitive. Their production function is

$$y_t = \xi^t k_{t-1}^\theta h_t^{1-\theta}, \quad (9)$$

where ξ denotes the technology growth rate, and θ denotes the capital share in production. The profit maximization problem implies

$$w_t = (1 - \theta) \frac{y_t}{h_t}, \quad (10)$$

$$d_t = \theta \frac{y_t}{k_{t-1}}. \quad (11)$$

The government budget constraint is

$$g_t + s_t + R_t^b b_{t-1} \leq b_t + T_t, \quad (12)$$

where total tax revenue T_t is defined by

$$T_t = \tau_t^C c_t + \tau_t^W w_t h_t + \tau_t^K (d_t - \delta) k_{t-1}. \quad (13)$$

The analyses focus on the balanced growth path as in Trabandt and Uhlig (2011). Let the growth rate on the balanced growth path be $\psi = \xi^{1/(1-\theta)}$. It is assumed that government debt b_t and government spending g_t are on the balanced growth path; $b_{t-1} = \psi^t \bar{b}$ and $g_t = \psi^t \bar{g}$, and transfers are determined by

$$s_t = \psi^t \bar{b}(\psi - R_t^b) + T_t - \psi^t \bar{g}. \quad (14)$$

Alternatively, two cases will be considered: one is the case where (b_t, s_t) are on the balanced growth path, $b_{t-1} = \psi^t \bar{b}$, $s_t = \psi^t \bar{s}$, and $g_t = \psi^t \bar{b}(\psi - R_t^b) + T_t - \psi^t \bar{s}$, and the other is where (g_t, s_t) are on the balanced growth path, $g_t = \psi^t \bar{g}$, $s_t = \psi^t \bar{s}$, and $g_t + s_t + R_t^b b_{t-1} \leq b_t + T_t$.

The resource constraint of this economy is

$$y_t = c_t + x_t + g_t - m_t. \quad (15)$$

A competitive equilibrium is defined as the sequence of prices and quantities such that (i) households maximize their utility subject to their budget constraint and evolution of the capital stock, (ii) firms maximize their profits, and (iii) all markets clear, given the fiscal policy. The equilibrium system is described by

$$(1 + \tau_t^C)\lambda_t = u_1(c_t, h_t), \quad (16)$$

$$\lambda_t(1 - \tau_t^W)w_t = -u_2(c_t, h_t), \quad (17)$$

$$\lambda_t = \beta E_t \left\{ \lambda_{t+1} \left[(1 - \delta) + (1 - \tau_{t+1}^K)(d_{t+1} - \delta) + \delta \right] \right\}, \quad (18)$$

$$\lambda_t = \beta E_t \left[\lambda_{t+1} R_{t+1}^b \right], \quad (19)$$

$$k_t = (1 - \delta)k_{t-1} + x_t, \quad (20)$$

$$y_t = \xi^t [k_{t-1}]^\theta h_t^{1-\theta}, \quad (21)$$

$$w_t = (1 - \theta) \frac{y_t}{h_t}, \quad (22)$$

$$d_t = \theta \frac{y_t}{k_{t-1}}. \quad (23)$$

$$y_t = c_t + x_t + g_t - m_t, \quad (24)$$

$$T_t = \tau_t^C c_t + \tau_t^W w_t h_t + \tau_t^K (d_t - \delta) k_{t-1}, \quad (25)$$

where the marginal utilities are defined by

$$u_1(c_t, h_t) \equiv (c_t)^{-\eta} \left[1 - \kappa(1 - \eta) h_t^{1+1/\varphi} \right]^\eta, \quad (26)$$

$$u_2(c_t, h_t) \equiv -\eta \left(1 + \frac{1}{\varphi} \right) \left\{ (c_t)^{1-\eta} \left[1 - \kappa(1 - \eta) h_t^{1+1/\varphi} \right]^{\eta-1} \kappa h_t^{1/\varphi} \right\} \quad (27)$$

in the case of the CFE utility function, and

$$u_1(c_t, h_t) \equiv \sigma \frac{1}{c_t}, \quad (28)$$

$$u_2(c_t, h_t) \equiv -(1 - \sigma) \frac{1}{1 - h_t} \quad (29)$$

in the case of the Cobb–Douglas utility function.¹

3 Results

3.1 Calibrations

The calibrated values are summarized in Table 1. To calibrate the values on the balanced growth path (steady state), we use Japanese annual data during the period 1980–2009. The data of nominal GDP, government consumption, GDP deflator, and net imports are taken from the 1993 SNA (System of National Accounts). GDP, government consumption, and net imports are deflated by the GDP deflator. The real interest rate is calculated as the difference between the call rate from the Bank of Japan, and the inflation rate calculated from the GDP deflator.² The data of general government gross debt for Japan is taken from World Economic Outlook. Labor supply is calculated following Hayashi

¹The details of the calculations of the steady-state values are explained in Appendix A.

²Because call rate data are not available prior to 1985, the real interest rate is calculated during 1985–2007.

and Prescott (2002) and Kobayashi and Inaba (2006). The data of the number of employed persons E is taken from the 93 SNA. The data of total hours worked in a month (establishments with 30 or more employees) H is taken from the Ministry of Welfare and Labor, and the data of working age population N is taken from the Federal Reserve Economic Database (FRED). Labor supply is defined as $E \times H \times 12 / (N \times 5760)$.

The steady-state growth rate (or growth rate on the balanced growth path) $\psi \equiv \xi^{1/(1-\theta)}$ is calculated as the average real GDP growth rate, 1.021. Other steady-state values are also set to the average of the sample period. The steady-state government spending to output ratio is $g/y = 0.154$, the steady-state real interest rate is $R^b = 1.0206$, and the steady-state debt to output ratio is $b/y = 1.107$.³ The steady-state net import to output ratio is $m/y = -0.016$, and the steady-state labor supply is $h = 0.212$. The weighting parameter of preferences, κ for the CFE utility function and σ for the Cobb–Douglas utility function, are calculated so that the steady-state labor supply is $h = 0.212$.

For the labor and capital tax rates, we use the average marginal labor and capital tax rates of Japan estimated by Gunji and Miyazaki (2011) based on the methodology of Joines (1981). As the labor tax rate, the average marginal labor tax rate including the social security premia is employed. The means during 1980–2007 are set equal to the steady state values $\tau^W = 0.308$ and $\tau^K = 0.532$. For the consumption tax rate, the rate for 2013 is set equal to the steady state value, $\tau^C = 0.05$.

The depreciation rate of capital δ and the capital share in production θ are set to 0.06 and 0.37 following Sugo and Ueda (2011) and Fujiwara et al. (2005). The inverse of the IES $\eta = 2$ and Frisch elasticity $\phi = 1$ are used as baseline values following Trabandt and Uhlig (2011); however, we also consider the case of $\eta = 1$ and $\phi = 3$, and the case of the Cobb–Douglas utility function.

³Alternatively, we used $b/y = 2.3$, which was the debt-to-GDP ratio in 2011, and also $b/y = 5$. However, there are no significant differences in the results.

3.2 Laffer curves

The Laffer curve is a graph showing how steady-state total tax revenue T changes in response to changes in one tax rate (with the other tax rates fixed). Trabandt and Uhlig (2011) show that the Laffer curves for labor and capital taxes have single peaks, but the Laffer curve for consumption tax is monotonically increasing under a standard specification. At first, we assume that changing the tax rate does not affect the steady-state debt b , while government spending g is fixed and transfer s is determined endogenously.

Figure 1 shows the Laffer curve for the labor tax. The horizontal axis is the labor tax rate, and the vertical axis is tax revenue. Three types of preference are considered: the case of CFE utility with $\eta = 2$ and $\varphi = 1$, the case of CFE utility with $\eta = 1$ and $\varphi = 3$, and the case of Cobb–Douglas utility. The shading indicates the bands of the marginal tax rate from Gunji and Miyazaki (2011) during 1980–2007, and the vertical dotted line is the mean τ^W . The total tax revenue when tax rates are at their steady-state values in Table 1 is normalized to one hundred.

[Insert Figure 1]

It is found that the peak labor tax rate is higher than the actual marginal labor tax rate by about 20% and more. This means that there is space for the government to increase the labor tax rate.

Figure 2 shows the Laffer curve for capital tax. The horizontal axis is the capital tax rate, and the vertical axis is tax revenue. Three types of preferences are also considered as in Figure 1. The shading indicates the bands of the marginal tax rate, and the vertical dotted line is the mean τ^K .

[Insert Figure 2]

It is found that the peak capital tax rate of the Laffer curve is in the band of actual marginal tax and is lower than the steady-state tax level (vertical dotted line in the graph).

in the case of the CFE utility function with $\eta = 1$ and $\varphi = 3$ and the case of the Cobb–Douglas utility function. In the case of the CFE utility function with $\eta = 2$ and $\varphi = 1$, the peak tax revenue is larger than the upper bound of the band of actual marginal tax, but the difference is quite small. This implies that the current capital tax rate might be too high from the viewpoint of the Laffer curve. At least it is clear that there is no space to increase it, because an increase in the capital tax rate reduces total tax revenue. Trabandt and Uhlig (2011) find that capital taxes in Sweden and Denmark are higher than at the peaks of their Laffer curves. We find that the capital tax rate in Japan is also too high.

Figure 3 shows the historical movement of the marginal capital tax rates, estimated by Gunji and Miyazaki (2011), and the peak tax rate of the Laffer curve.

[Insert Figure 3]

It is found that the capital tax rate was too high during 1985–1990 and after 1995.

Figure 4 shows the Laffer curve for the consumption tax. The horizontal axis is the consumption tax rate, and the vertical axis is tax revenue. Three types of preferences are used in Figure 1. The vertical dotted line is the mean τ^C . As shown by Trabandt and Uhlig (2011), there is no peak in the Laffer curve, and tax revenue increases monotonically.

[Insert Figure 4]

For Figures 1, 2, and 4, it is assumed that changing the tax rate does not affect the steady-state debt b , while government spending g is fixed and transfer s is determined endogenously. The Laffer curves associated with changes in this fiscal policy assumption are shown in Figure 5. The upper panels are the cases where the steady-state values of b and s are constant (changing the tax rate affects g), and the lower ones are the cases where the steady-state values of g and s are constant (changing the tax rate affects b). The shading indicates the marginal tax rate bands, and the vertical dotted lines are the steady-state tax rate values.

[Insert Figure 5]

The lower panels, the case of fixed g and s , are similar to the baseline result as in Figures 1, 2, and 4. There is space to increase the labor tax, but not the capital tax because actual capital tax rate might be larger than the peak tax rate of the Laffer curve. In the upper panels, the case of fixed b and s , the tax rates at the peaks of the Laffer curves are larger than those under other assumptions. In this case, there is space to increase the capital tax. This would be because changing the steady-state value of government consumption g has a positive effect on total tax revenue T through the effect on output y . Then, if revenue from the increase in the tax rate is used to fund government expenditure, there is space to increase the capital tax rate. However, if the revenue is used for other purposes, such as transfers to households as social security payments or decreases in public debt levels, then there is no space to increase the capital tax rate.

Next, consider the effect of the steady-state consumption tax rate on the Laffer curves for labor and capital taxes. As a baseline, τ^C is set to 5%, the actual rate in 2013. However, it is planned to increase the consumption tax rate to 8% from April 2014, and possibly to 10% in the near future. Recent studies by Braun and Joines (2013) and Hansen and Imrohoroglu (2013) claim that the consumption tax rate should be raised to 30% for Japan's fiscal sustainability. In this case, the Laffer curves for labor and capital taxes under a high consumption tax rate would be interesting. Figure 6 shows the results; the upper panels are for $\tau^C = 0.1$ and the lower panels are for $\tau^C = 0.3$.

[Insert Figure 6]

It is found that the peak tax rates of the Laffer curves for labor and capital taxes are decreasing with respect to the steady-state consumption tax rate. If $\tau^C = 0.3$, even in the case of the CFE utility function with $\eta = 2$ and $\phi = 1$, the peak level is less than τ^K . The Laffer curve for the labor tax implies that there is little space to increase the labor tax rate if $\tau^C = 0.3$. Therefore, the problem of a capital tax rate that is too high becomes more serious when the steady-state consumption tax rate increases.

3.3 Laffer hills

The Laffer curve is obtained by changing only one tax rate. Here, we calculate “the Laffer hill” (or iso-revenue curves) by changing both labor and capital taxes. Because the tax revenue is monotonically increasing with respect to the consumption tax rate, we set the consumption tax rate equal to 5%. For the calculation of the Laffer hills, we use the CFE utility function with $\eta = 2$ and $\varphi = 1$.

Figure 7 shows the Laffer hill in the case where b and g are fixed.

[Insert Figure 7]

The horizontal axis is the labor tax rate, and the vertical axis is the capital tax rate. The vertical dotted lines are baseline tax rates. The tax revenue in the case of the steady-state tax rate in Table 1 is normalized to one hundred. The asterisk indicates the peak of the hill. It is found that at the peak, the capital tax rate is zero and the labor tax rate is over 60%. Then, a decrease in the capital tax rate from the current actual level increases tax revenue. Figure 8 presents the Laffer hills under different fiscal policies; the case where b and s are constant (upper graph), and the case where g and s are constant (lower graph). In the case of fixed b and s , the capital tax rate that maximizes tax revenue is positive, and the qualitative implications are robust; a decrease in the capital tax rate and an increase in the labor tax rate increase total tax revenue. The reason why the capital tax rate that maximizes tax revenue under fixed b and s is larger than those of other cases is that changing g has a positive effect on the peak of the Laffer curve as in Figure 7.

[Insert Figure 8]

3.4 Optimal taxation

So far, we focus on the effect of each tax on total tax revenue. Here, we consider the optimal taxation from the viewpoint of welfare for better understanding of our model.

The optimal taxation problem here is choosing steady-state tax rate (τ^C, τ^W, τ^K) . to maximize the steady-state households utility $u(c, h) + v(g)$, given the level of government spending g , debt b , lump-sum transfer to households s , and total tax revenue T . We set g , b , and s to be the same levels where the baseline case of the CFE utility with $\eta = 2$, $\varphi = 1$. In computations, we try various sets of $\tau^W \in (0, 1)$ and $\tau^K \in (0, 1)$ to compute associated τ^C and the utility levels from the equilibrium system. The details are explained in Appendix B.

The optimal taxation of the current model is $(\tau^C, \tau^W, \tau^K) = (0.497, 0, 0)$, in other words, it is optimal that all tax revenue is financed by consumption tax. Even if we employ the CFE utility with $\eta = 1$ and $\varphi = 3$, or employ the Cobb-Douglas utility, the optimal taxation implication does not change, and then financing all tax revenue by consumption tax is optimal. Because our model is a standard neoclassical growth model, optimal tax rate on capital τ^K is zero as shown by Judd (1985) and Chamley (1986). Consumption and labor taxes show up in the equilibrium condition as the labor wedge $\equiv (1 - \tau^W)/(1 + \tau^C)$ in the intratemporal condition

$$-\frac{u_2(c, h)}{u_1(c, h)} = \frac{1 - \tau^W}{1 - \tau^C} w_t, \quad (30)$$

and the definition total tax revenue $T = \tau^C c + \tau^W w h + \tau^K (d - \delta)k$. Both consumption and labor tax enlarges the labor wedge, and distorts the economy. Then, the optimal choice problem of consumption and labor taxes is reduced to minimize the labor wedge $\equiv (1 - \tau^W)/(1 + \tau^C)$ such that the total tax revenue level is a given constant. Figure 9 shows the Iso-revenue curve of (τ^C, τ^W) with $\tau^K = 0$, computed from the equilibrium system, and the minimized labor wedge curve. It is found that optimal solution is a corner one because the slope of the iso-revenue curve is smaller than that of the labor wedge, approximately one. This would implies that labor income is more elastic than consumption, and financing by consumption tax is better than by labor tax.

[Insert Figure 9]

It should be noted that this normative result might not be applicable to the real world. It is well known that the optimal tax rate on capital can be positive under some conditions. While both labor and capital tax rates are positive in the real world, and much larger than consumption tax rate in many countries, our model cannot explain these facts. However, for the better understanding of our model, the optimal taxation of the current model would be beneficial.

4 Concluding remarks

This paper investigated the Laffer curves for labor, capital and consumption taxes in Japan based on a dynamic general equilibrium model. The model was calibrated to the Japanese data, and marginal tax rates estimated by Gunji and Miyazaki (2011) were used for the labor and capital taxes. The Laffer curves for labor and capital taxes have single peaks; however, consumption tax revenue is increasing monotonically with respect to the tax rate.

We found that while the labor tax rate is smaller than the peak tax rate of the Laffer curve, the capital tax rate is very close to the peak tax rate or might be greater than it for certain specifications. Trabandt and Uhlig (2011) report that capital taxes in Sweden and Denmark are higher than those at the peaks of their Laffer curves. This paper found that Japan is similar to these countries. The labor and capital tax rates at the peaks of their Laffer curves are decreasing with respect to the consumption tax rate, suggesting that the problem of a high capital tax rate is more serious when the consumption tax rate is high. The Laffer hill analysis implies that to maximize total tax revenue, the government should increase the labor tax rate but decrease the capital tax rate from current levels. The optimal taxation analysis, given a level of government spending, debt and lump-sum transfer, implies that financing all tax revenue by consumption tax is optimal in our model.

An increase in the consumption tax rate and a decrease in the corporate tax rate are planned by the Japanese government. According to our result, this policy would have a positive effect on total tax revenue.

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Appendix A: Steady state of the model

Here, we demonstrate how to solve for the steady state in the paper. Detrend the equilibrium system by $\psi = \xi^{1/(1-\theta)}$, and let $a_t/\xi^t \equiv \tilde{a}_t$ (except for $\tilde{k}_{t-1} \equiv k_{t-1}/\xi^t$ and λ):

$$\begin{aligned}
(1 + \tau_t^C)\tilde{\lambda}_t &= u_1(\tilde{c}_t, h_t), \\
\tilde{\lambda}_t(1 - \tau_t^W)\tilde{w}_t &= -u_2(\tilde{c}_t, h_t), \\
\tilde{\lambda}_t &= \beta\psi^{-\eta}E_t\left\{\tilde{\lambda}_{t+1}\left[(1 - \delta) + (1 - \tau_{t+1}^K)(d_{t+1} - \delta) + \delta\right]\right\}, \\
\tilde{\lambda}_t &= \beta\psi^{-\eta}E_t\left[\tilde{\lambda}_{t+1}R_{t+1}^b\right], \\
\psi\tilde{k}_t &= (1 - \delta)\tilde{k}_{t-1} + \tilde{x}_t, \\
\tilde{y}_t &= \left[\tilde{k}_{t-1}\right]^\theta h_t^{1-\theta}, \\
\tilde{w}_t &= (1 - \theta)\frac{\tilde{y}_t}{h_t}, \\
d_t &= \theta\frac{\tilde{y}_t}{\tilde{k}_{t-1}}, \\
\tilde{y}_t &= \tilde{c}_t + \tilde{x}_t + \tilde{g}_t - \tilde{m}_t, \\
\tilde{T}_t &= \tau_t^C\tilde{c}_t + \tau_t^W\tilde{w}_t h_t + \tau_t^K(d_t - \delta)\tilde{k}_{t-1},
\end{aligned}$$

and

$$\begin{aligned}
(i) \quad & \tilde{b}_{t-1} = \bar{b}, \quad \tilde{g}_t = \bar{g}, \quad \tilde{s}_t = \bar{b}(\psi - R_t^b) + \tilde{T}_t - \bar{g}, \\
(ii) \quad & \tilde{b}_{t-1} = \bar{b}, \quad \tilde{s}_t = \bar{s}, \quad \tilde{g}_t = \bar{b}(\psi - R_t^b) + \tilde{T}_t - \bar{s}, \\
(iii) \quad & \tilde{g}_t = \bar{g}, \quad \tilde{s}_t = \bar{s}, \quad \psi\tilde{b}_t = \bar{g} + \bar{s} + R_t^b\bar{b}_{t-1} - \tilde{T}_t.
\end{aligned}$$

On the balanced growth path, the system becomes

$$\begin{aligned}
(1 + \tau^C)\tilde{\lambda} &= u_1(\tilde{c}, h), \\
\tilde{\lambda}(1 - \tau^W)\tilde{w} &= -u_2(\tilde{c}, h), \\
1 &= \beta\psi^{-\eta}\left[(1 - \delta) + (1 - \tau^K)(d - \delta) + \delta\right], \\
1 &= \beta\psi^{-\eta}R^b,
\end{aligned}$$

$$\begin{aligned}
\psi \tilde{k} &= (1 - \delta)\tilde{k} + \tilde{x}, \\
\tilde{y} &= [\tilde{k}]^\theta h^{1-\theta}, \\
\tilde{w} &= (1 - \theta)\frac{\tilde{y}}{h}, \\
d &= \theta\frac{\tilde{y}}{\tilde{k}}, \\
\tilde{y} &= \tilde{c} + \tilde{x} + \tilde{g} - \tilde{m}_t, \\
\tilde{T} &= \tau_t^C \tilde{c} + \tau^W \tilde{w}h + \tau^K(d - \delta)\tilde{k},
\end{aligned}$$

and

$$\begin{aligned}
(i) \quad & \tilde{b} = \bar{b}, \quad \tilde{g} = \bar{g}, \quad \tilde{s} = \bar{b}(\psi - R^b) + \tilde{T} - \bar{g}, \\
(ii) \quad & \tilde{b} = \bar{b}, \quad \tilde{s} = \bar{s}, \quad \tilde{g} = \bar{b}(\psi - R^b) + \tilde{T} - \bar{s}, \\
(iii) \quad & \tilde{g}_t = \bar{g}, \quad \tilde{s}_t = \bar{s}, \quad \tilde{b} = \frac{1}{\psi - R^b} [\bar{g} + \bar{s} - \tilde{T}].
\end{aligned}$$

First, the steady-state values of R^b and d are obtained by

$$\begin{aligned}
R^b &= \frac{\psi^\eta}{\beta}, \\
d &= \frac{1}{1 - \tau^K} [R^b - 1] + \delta.
\end{aligned}$$

Guess the value of \tilde{k} . Associated other steady-state values are

$$\begin{aligned}
\tilde{x} &= [\psi - (1 - \delta)]\tilde{k}, \\
\tilde{y} &= \frac{d}{\theta}\tilde{k}, \\
h &= \left[\frac{\tilde{y}}{\tilde{k}^\theta} \right]^{1/(1-\theta)}, \\
\tilde{w} &= (1 - \theta)\frac{\tilde{y}}{\tilde{h}}.
\end{aligned}$$

(i) if given \tilde{b} and \tilde{g} ,

$$\begin{aligned}\tilde{c} &= \tilde{y} - \tilde{x} - \tilde{g} + \tilde{m}_t, \\ \tilde{T} &= \tau_t^C \tilde{c} + \tau^W \tilde{w}h + \tau^K(d - \delta)\tilde{k}, \\ \tilde{s} &= \tilde{b}(\psi - R^b) + \tilde{T} - \tilde{g}, \\ \tilde{\lambda} &= \frac{u_1(\tilde{c}, h)}{1 + \tau^C}.\end{aligned}$$

If $\tilde{\lambda}(1 - \tau^W)\tilde{w} = -u_2(\tilde{c}, h)$ holds, thus the initial guess of \tilde{k} is correct. Otherwise, revise the guess of \tilde{k} .

(ii) if given \tilde{b} and \tilde{s} ,

$$\begin{aligned}\tilde{c} &= \frac{1}{1 + \tau^C} [\tilde{y} - \tilde{x} - \tilde{b}(\psi - R^b) - \tau^W \tilde{w}h - \tau^K(d - \delta)\tilde{k} + \tilde{s}], \\ \tilde{g} &= \tilde{y} - \tilde{c} - \tilde{x} + \tilde{m}_t, \\ \tilde{T} &= \tau_t^C \tilde{c} + \tau^W \tilde{w}h + \tau^K(d - \delta)\tilde{k}, \\ \tilde{\lambda} &= \frac{u_1(\tilde{c}, h)}{1 + \tau^C}.\end{aligned}$$

If $\tilde{\lambda}(1 - \tau^W)\tilde{w} = -u_2(\tilde{c}, h)$ holds, thus the initial guess of \tilde{k} is correct. Otherwise, revise the guess of \tilde{k} .

(iii) if given \tilde{s} and \tilde{g} ,

$$\begin{aligned}\tilde{c} &= \tilde{y} - \tilde{x} - \tilde{g} + \tilde{m}_t, \\ \tilde{T} &= \tau_t^C \tilde{c} + \tau^W \tilde{w}h + \tau^K(d - \delta)\tilde{k}, \\ \tilde{\lambda} &= \frac{u_1(\tilde{c}, h)}{1 + \tau^C}, \\ \tilde{b} &= \frac{1}{\psi - R^b} [\tilde{g} + \tilde{s} - \tilde{T}].\end{aligned}$$

If $\tilde{\lambda}(1 - \tau^W)\tilde{w} = -u_2(\tilde{c}, h)$ holds, thus the initial guess of \tilde{k} is correct. Otherwise, revise the guess of \tilde{k} .

Appendix B: Optimal taxation

We solve the optimal taxation problem as follows. First, we calculate the steady state of g , s , b , and T of the baseline case following Appendix A.

Then, we choose a pair of $\tau^W \in (0, 1)$ and $\tau^K \in (0, 1)$. The associated steady-state values of R^b and d are obtained by

$$R^b = \frac{\psi^\eta}{\beta},$$

$$d = \frac{1}{1 - \tau^K} [R^b - 1] + \delta.$$

Guess the value of \tilde{k} . Associated other steady-state values are

$$\begin{aligned}\tilde{x} &= [\psi - (1 - \delta)] \tilde{k}, \\ \tilde{y} &= \frac{d}{\theta} \tilde{k}, \\ h &= \left[\frac{\tilde{y}}{\tilde{k}^\theta} \right]^{1/(1-\theta)}, \\ \tilde{w} &= (1 - \theta) \frac{\tilde{y}}{\tilde{h}}, \\ \tilde{c} &= \tilde{y} - \tilde{x} - \tilde{g} + \tilde{m}_t, \\ \tau_t^C &= \frac{1}{\tilde{c}} \left[\tilde{T} - \tau^W \tilde{w} h - \tau^K (d - \delta) \tilde{k} \right], \\ \tilde{s} &= \bar{b}(\psi - R^b) + \tilde{T} - \bar{g}, \\ \tilde{\lambda} &= \frac{u_1(\tilde{c}, h)}{1 + \tau^C}, \\ U &= u(\tilde{c}, h).\end{aligned}$$

If $\tilde{\lambda}(1 - \tau^W)\tilde{w} = -u_2(\tilde{c}, h)$ holds, thus the initial guess of \tilde{k} is correct. Otherwise, revise the guess of \tilde{k} . The optimal taxation is the pair of τ^W and τ^K and associated τ^C that maximizes U .

parameters	symbols	values	sources
Depreciation rate of capital	δ	0.06	Sugo and Ueda (2011)
Capital share in production	θ	0.37	Sugo and Ueda (2011)
Steady-state growth rate	ψ	1.021	Data
Steady-state real interest rate	R^b	1.0206	Data
Steady-state government spending to output ratio	g/y	0.154	Data
Steady-state debt to output ratio	b/y	1.107	Data
Steady-state net import to output ratio	m/y	-0.016	Data
Steady-state labor supply	h	0.212	Data
Steady-state labor tax rate	τ^W	0.308	Gunji and Miyazaki (2011)
Steady-state capital tax rate	τ^K	0.532	Gunji and Miyazaki (2011)
Steady-state consumption tax rate	τ^C	0.05	Actual rate in 2013

Table 1: Parameter values

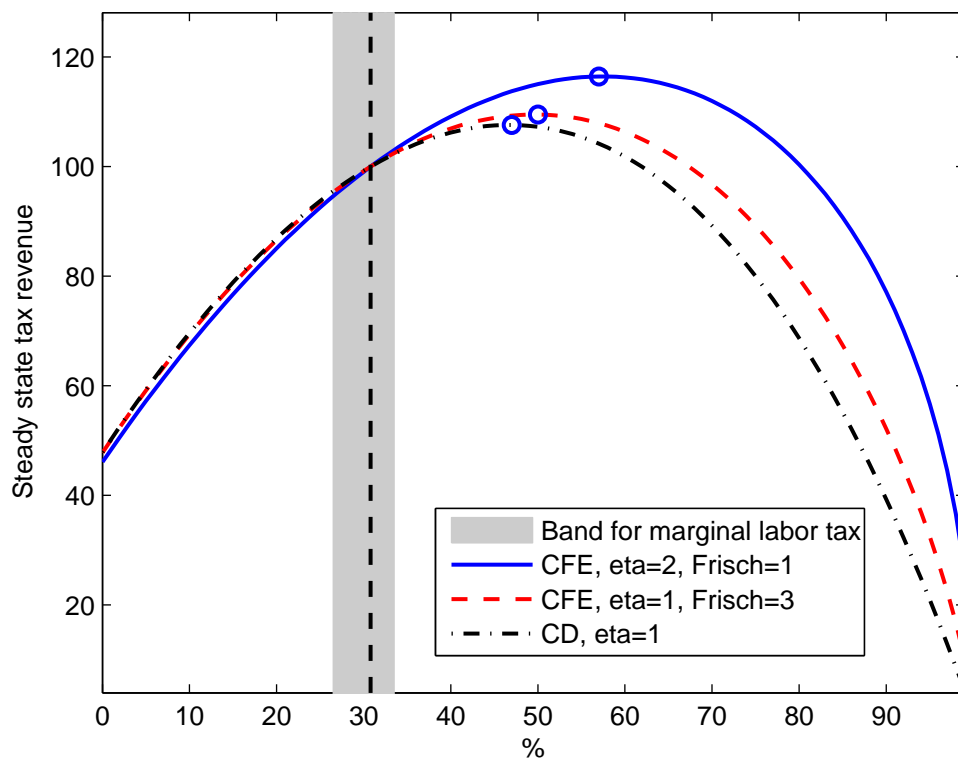


Figure 1: Laffer Curve for Labor Tax

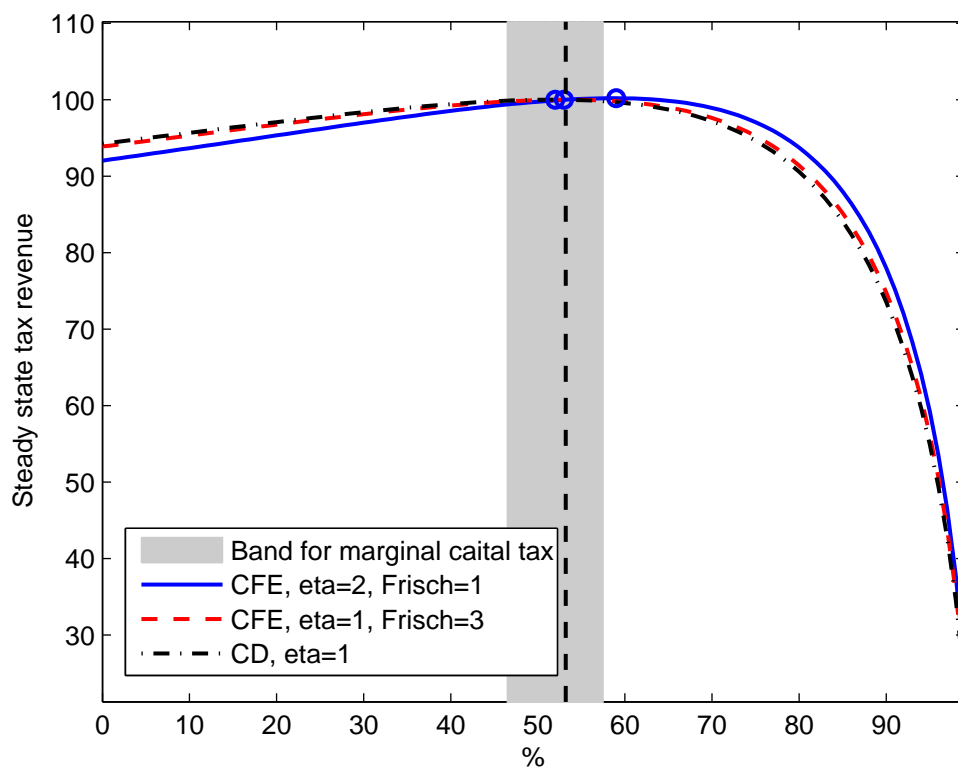


Figure 2: Laffer Curve for Capital Tax

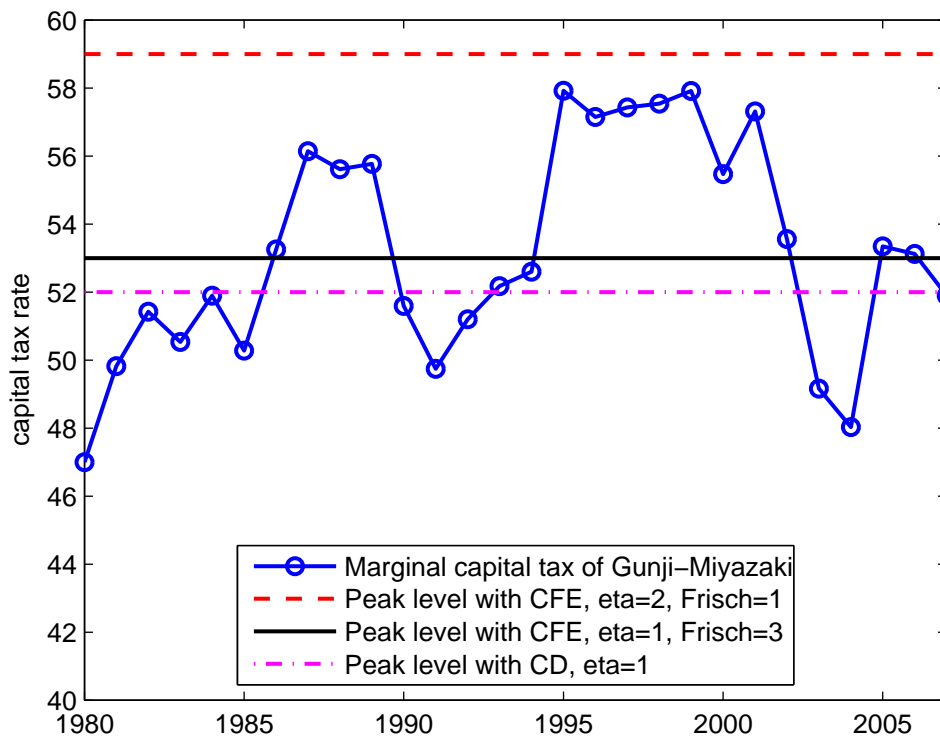


Figure 3: Historical Movement of Capital Tax Rate and Peak Tax Rate Levels of Laffer Curves

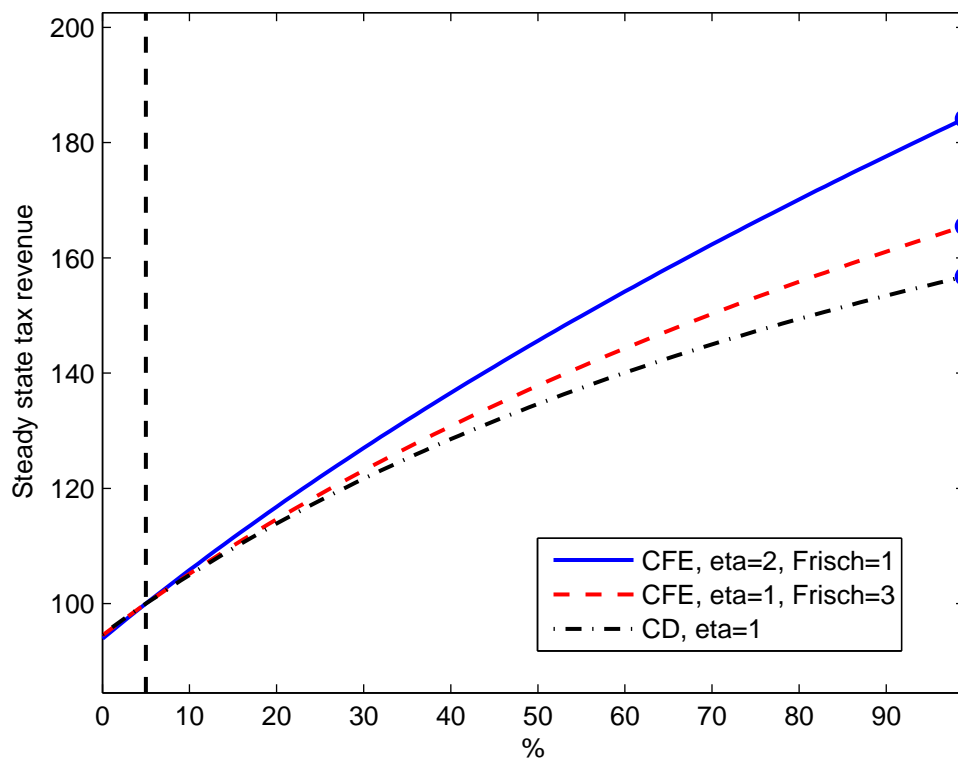


Figure 4: Laffer Curve for Consumption Tax

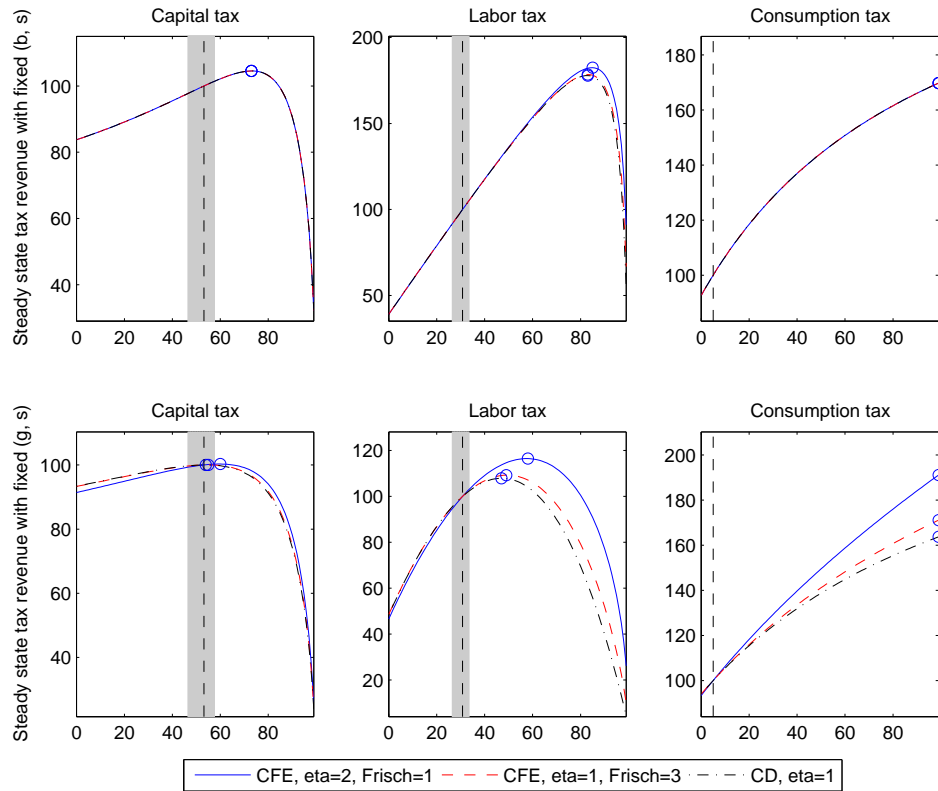


Figure 5: Laffer Curves under Different Fiscal Policies: The upper panels are the cases where the steady-state values of b and s are constant, and the lower ones are the cases where the steady-state values of g and s are constant. The shading indicates the bands for the marginal tax rates, and the vertical dotted lines are the steady-state values of the tax rates.

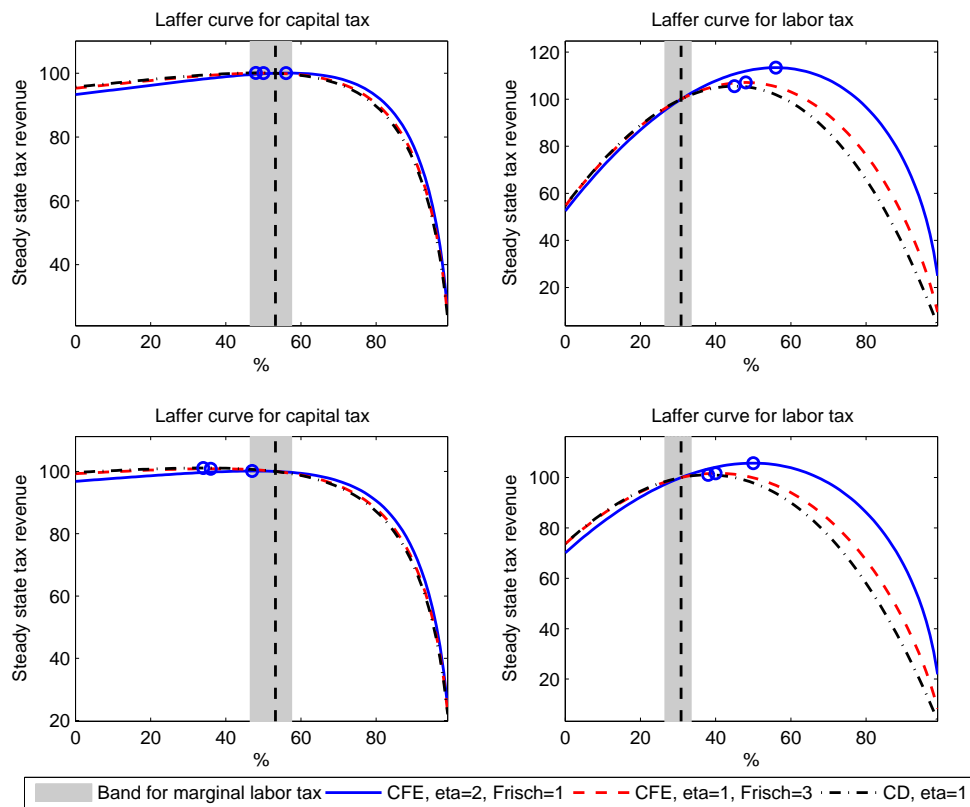


Figure 6: Laffer Curves under Different τ^C : The upper panels are the cases where $\tau^C = 0.1$, and the lower ones are the cases where $\tau^C = 0.3$.

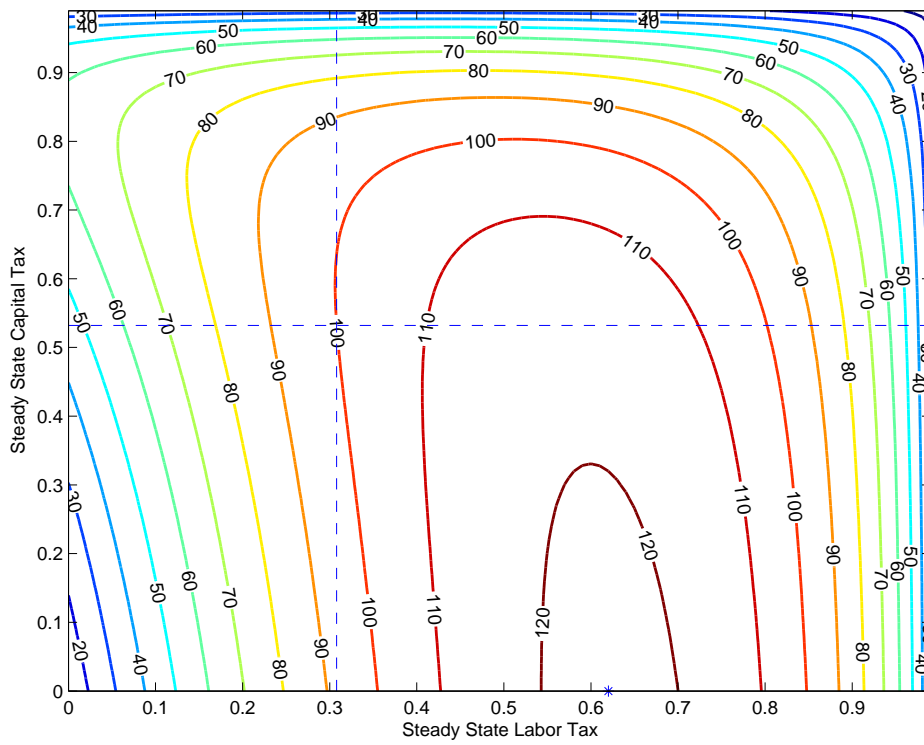


Figure 7: Laffer Hill: The dotted lines are baseline tax values. The asterisk indicates the peak of the hill.

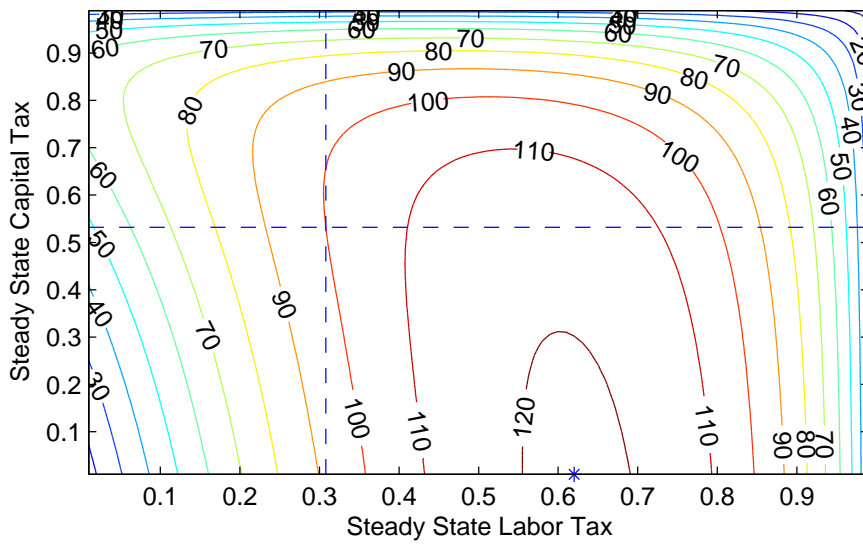
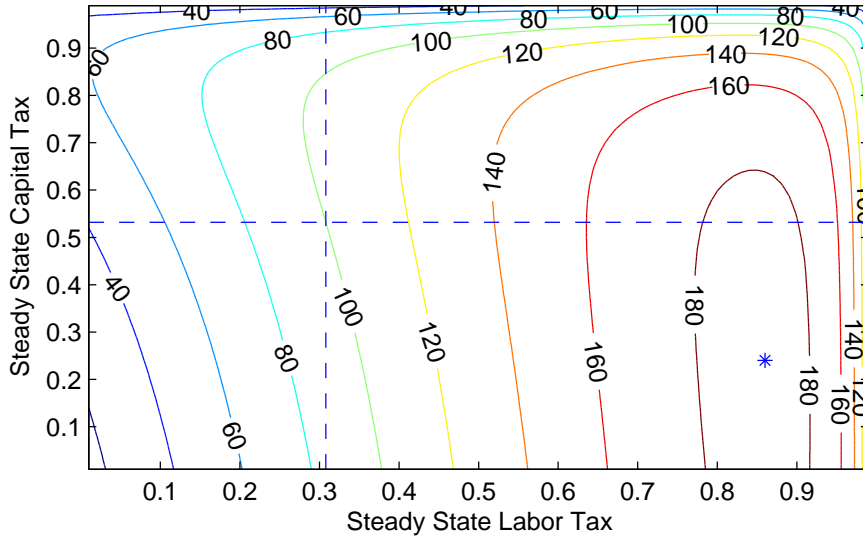


Figure 8: Laffer Hills under Different Fiscal Policies: The upper panels are the cases where the steady-state values of b and s are constant, and the lower ones are the cases where the steady-state values of g and s are constant. The dotted lines are baseline tax values. The asterisks indicate the peaks of the hills.

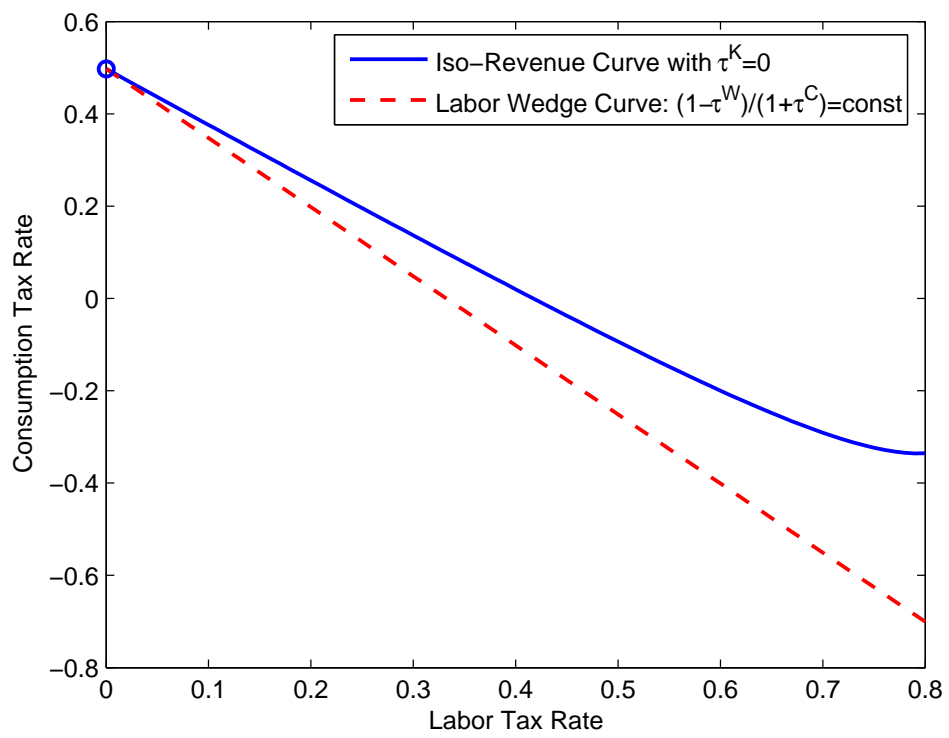


Figure 9: Optimal Taxation: Iso-Revenue Curve of (τ^C, τ^W) with $\tau^K = 0$ and Minimized Labor Wedge $(1 - \tau^W)/(1 + \tau^C)$