Welfare Effects of Tax Policy in Open Economies: Stabilization and Cooperation*

Jinill Kim, Korea University†

Sunghyun Kim, Sungkyunkwan University and Suffolk University‡

May, 2013

Abstract

This paper studies welfare implications of a simple operational tax policy (under which tax rates respond to changes in productivity) by employing an open-economy dynamic stochastic general-equilibrium model with incomplete asset markets. We investigate the possibility of welfare-improving tax policies on factor incomes and consumption. Simulation results show that countercyclical tax policies are optimal in the closed economy due to stabilization gains. However, in the open economy, optimal tax policies become less countercyclical and under certain cases can even become procyclical, in particular capital income tax. A two-country exercise suggests that tax policy coordination on capital and labor income produces only small welfare gains, while consumption tax policy coordination produces sizeable welfare gains.

- JEL Classification: F4, E6.
- Keywords: tax and welfare, simple tax rule, optimized tax rule, procyclical tax, countercyclical tax, policy coordination.

*We appreciate comments from Margarida Duarte, Jordi Galí, Juergen von Hagen, Robert Kollmann, Roland Straub, and seminar participants at Boston College, Boston Fed, Clark University, FRB, IMF, KDI, Korea University, NBER, Seoul National University, University of Bologna, University of Bonn, University of Montreal, University of Virginia, and the "Quantitative Evaluation of Stabilization Policies" conference at Columbia University.

†Department of Economics, Korea University, Seoul, Korea. E-mail: jinillkim@korea.ac.kr.

‡Corresponding Author. Department of Economics, Sungkyunkwan University, Seoul, Korea and Department of Economics, Suffolk University, Boston MA, USA. E-mail: shenrykim@skku.edu.

1 Introduction

Fiscal policy can be effectively used for stabilization purposes under certain circumstances. For example, in a monetary union such as the European Union, monetary policy cannot be used for stabilization purpose against regional shocks.[1] Another case when monetary policy is ineffective is when nominal interest rates are close to zero such as Japan in the late 1990s and many other developed economies during recent global financial crisis.[2] In order to properly use active fiscal policy rules under such circumstances, it is important to obtain accurate welfare implications of fiscal policies.

This paper studies welfare implications of a simple operational tax policy rule using a dynamic stochastic general equilibrium (DSGE) model. In our model, government levies taxes on capital and labor income as well as on consumption to meet exogenous government purchase requirements. The government uses state-contingent tax policy by setting tax rates as linear functions of productivity.[3] We numerically derive the optimal feedback coefficients of tax rates to productivity and calculate welfare gains from such optimal contingent tax policy against fixed (exogenous) tax policy.[4] Since we focus on simple operational tax policy and set the steady state levels of tax rates from the data instead of from the fully-fledged Ramsey problem, our policy can arguably provide realistic policy implications.

We study both closed- and open-economy models to examine how optimal tax policies change with open capital markets. Our open-economy models feature incomplete financial markets with bonds; two versions we analyze are a small-open-economy model with exogenously given interest rate and a two-country model with endogenously determined interest rate. Using the two-country model, we examine welfare effects of domestic tax policies on both domestic and foreign countries and derive the non-cooperative Nash equilibrium and cooperative equilibrium for optimal tax policies. If non-cooperative and cooperative equilibria are significantly different, then there is room for welfare improvement via tax policy coordination. These results can provide plausible implications on potential welfare gains of international tax policy coordination.

This paper contributes to the literature in the following ways. First, we adopt an open-economy framework. The literature on welfare analysis of tax policy has focused on closed-economy.[5] However, these results can significantly change in an open economy because tax policies can have effects on other countries through various channels such as the world interest rate and capital flows.[6] Second, we analyze tax policies in a stochastic setup, which has been used extensively

[1] See, for example, Gali and Perotti (2003) and Gali (2005).

[2] See Feldstein (2002) for the discussion on the positive role of discretionary fiscal policy in this case.

[3] Some considered active tax policy unrealistic because it takes too much time to change statutory tax rates in response to stochastic shocks. However, in this paper, we rely on the fact that active tax policy can be rather easily implemented through changes in effective tax rates by using tax credits, deductions, and exemptions—without changing statutory tax rates.

[4] Our search for 'optimal' tax policy is by assuming a certain parametric family of tax policy rules and optimizing over the parameters of the rule. Such an optimizing procedure—common in monetary policy analysis as in Bergin et al. (2007)—is different from Ramsey approach which defines optimal tax policy as the best possible tax rate responses to disturbances and all the state variables, as in Chari et al. (1994) and Gali and Monacelli (2008).

[5] Papers with the closed economy setup include Greenwood and Huffman (1991), McGrattan (1994), Chari et al. (1994) and Kletzer (2006). In many cases, tax policies aiming for the stabilization of the economy produce allocation distortions that outweigh the stabilization gains and therefore reduce welfare. Tax policies can be welfare-improving if the economy is already subject to other distortions such as imperfect competition or externalities, e.g. Easley et al. (1993) and Hairault et al. (2001).

[6] For example, Baxter (1997) and Kollmann (1998) examined the effects of taxes as well as government spending

for the analysis of monetary policy (e.g. Obstfeld and Rogoff 2002, and Canzoneri et al. 2005). Most papers in the literature have analyzed tax policies in a deterministic setup and focused on the effects of permanent changes in tax policies or tax policy reform.[7] However, certain economic phenomena should be analyzed under the stochastic framework. For example, recent discussion in the European Union about the role of fiscal policies as absorbers of asymmetric shocks must deal with the stochastic nature of such shocks. Finally, in order to capture the nonlinear dynamics of the model which matters for welfare analysis, we solve the model using a second-order accurate solution method based on Kim et al. (2008).

Our main findings are as follows. In the closed economy, optimal tax policy is countercyclical for all three types of taxes. Countercyclical tax policy produces stabilization gains by reducing volatility of the economy, which improves welfare. In the open economy, optimal tax policies in general become less countercyclical than the closed-economy case. Current account plays a stabilization role, which reduces the role of countercyclical tax policies in stabilizing the economy. More importantly, optimal capital income tax policy becomes procyclical in the open economy under some parameter values, in the sense that increasing capital income tax rate when facing negative productivity shocks increases welfare.

Two-country analysis shows that both optimal capital and labor income tax policies generate negative spillovers to foreign countries. Under the non-cooperative Nash equilibrium, both countries become worse off by adopting active tax policies due to negative spillovers. Even under the cooperative equilibrium when both countries maximize world welfare, active income tax policies generate negligible welfare gains. On the other hand, optimal consumption tax policy generates positive spillovers to foreign countries and both countries gain under the Nash equilibrium. Moreover, cooperative equilibrium produces large welfare gains over the Nash equilibrium.

The remainder of this paper proceeds as follows. Section 2 describes a DSGE model with linear tax policies. Section 3 reports simulation results for welfare implications of optimal tax policy in both closed and open economies. In order to help interpret the welfare results, we examine impulse responses to a positive productivity shock with countercyclical and procyclical tax policies. Section 4 provides the results of tax policy transmission and coordination. We compare the non-cooperative Nash equilibrium and the cooperative equilibrium and calculate potential welfare gains from tax policy coordination. Finally, section 5 concludes.

2 The Model

This section explains the two country open economy model. Two countries are symmetric with identical preference and production technology. There is a single nondurable tradable good serving as the numeraire. Each country consists of a representative household, a representative firm, and a government. Households decide the level of consumption, leisure, investment, and bond holdings subject to budget constraints. Bond holdings and investment are subject to adjustment costs. We assume that the international financial market is incomplete in the sense that agents can trade only non-state-contingent bonds.

The government is described as a sequence of government spending and tax rates on consumption, capital income, and labor income. The entire amount of tax revenue, net of fixed government

to explain the twin deficits and the U.S. trade balance, respectively.

[7] Papers with deterministic open-economy models include Frenkel and Razin (1992), Easterly and Rebelo (1993), Razin and Sadka (1994), Bovenberg (1994), Karayalcin (1995), and Mendoza and Tesar (1998, 2001).

spending, is distributed to households as lump-sum transfers in each period. The transfers can be negative and in this case they operate as lump-sum taxes. The use of lump-sum transfers allows us to avoid potential additional distortions from adjusting other tax rates to balance the budget. The only source of disturbances in the economy is productivity shocks which can be correlated across countries. Foreign variables are denoted by asterisks and their behavior is symmetric to the home country when not specified.

2.1 Households and Firms

Household in each country maximizes the expected lifetime utility given by

$$\mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t U_t, \text{ where } U_t = \frac{\left[C_t^{\theta} (1 - L_t)^{1-\theta}\right]^{1-\sigma}}{1 - \sigma}, \tag{1}$$

where C_t is the level of consumption, and $(1 - L_t)$ is the amount of leisure. Households in both countries have the same discount factor β.

The budget constraint of household is given by:

$$\begin{aligned} & (1 + \tau_{ct})C_t + I_t + B_t + \frac{\zeta}{2} (B_t)^2 \\ = \ & (1 - \tau_{lt})w_t L_t + [(1 - \tau_{kt})r_t + \tau_{kt}\delta] K_t + R_{t-1}B_{t-1} + T_t, \end{aligned} \tag{2}$$

where B_t denotes the quantity of international bonds purchased in period t maturing in $t + 1$, R_t is the gross interest rate on bonds, r_t is the rental rate, w_t is the wage rate, and τ represents tax rates (τ_c = consumption tax rate, τ_k = capital income tax rate, and τ_l = labor income tax rate). Note that there is a depreciation allowance, $\tau_{kt}\delta K_t$, and bond holdings are subject to quadratic holding costs, $\frac{\zeta}{2} (B_t)^2$.[8] T_t is the lump-sum transfer (tax) to the household which amounts to the budget surplus (deficit).

As in Kim (2003), households accumulate capital according to the following equation:

$$K_{t+1} = \left[\delta (I_t/\delta)^{1-\phi} + (1 - \delta)K_t^{1-\phi}\right]^{\frac{1}{1-\phi}}. \tag{3}$$

A zero ϕ implies no adjustment costs. A positive ϕ implies the presence of adjustment costs and $\phi = 1$ corresponds to a loglinear capital accumulation equation.

For firms, the production function follows a Cobb-Douglas form with labor and capital,

$$Y_t = A_t L_t^{\alpha} K_t^{1-\alpha}. \tag{4}$$

While labor cannot move across countries, investment in the domestic country can be financed by foreign capital.

Productivity variable A_t and A_t^*, representing stochastic components of the production functions of the two countries, follow a symmetric vector Markov process:

$$\begin{bmatrix} \log(A_t) \\ \log(A_t^*) \end{bmatrix} = \begin{bmatrix} \rho & \nu \\ \nu & \rho \end{bmatrix} \begin{bmatrix} \log(A_{t-1}) \\ \log(A_{t-1}^*) \end{bmatrix} + \begin{bmatrix} \varepsilon_t \\ \varepsilon_t^* \end{bmatrix}. \tag{5}$$

[8] Using bond holding adjustment costs allows us to avoid the nonstationarity problem in the small open economy model with incomplete markets. See Kim and Kose (2003) for a detailed discussion on this issue.

where $E(\varepsilon_t) = E(\varepsilon_t^*) = 0$, $E(\varepsilon_t^2) = \sigma_\varepsilon^2$, $E((\varepsilon_t^*)^2) = \sigma_{\varepsilon^*}^2$, and $\rho(\varepsilon_t, \varepsilon_t^*) = \psi$ for all t. ρ is the persistence of productivity shocks and ν represents the spillover effects. A non-zero ψ means that the innovations are contemporaneously correlated across countries.

2.2 Government

Government income includes tax revenues as well as bond holding adjustment costs, and government spending G_t is assumed to be fixed and unproductive.[9] The government does not issue any debt and balances its budget in each period by rebating all the tax revenue. That is, the level of the government transfer satisfies

$$\tau_{ct}C_t + \tau_{lt}w_tL_t + \tau_{kt}(r_t - \delta)K_t + \frac{\zeta}{2}(B_t)^2 = \bar{G} + T_t. \tag{6}$$

In the benchmark case of exogenous tax policy, the tax rates are fixed at the steady state level (denoted with $\bar{\tau}$). Note that we do not solve the "Ramsey" problem in this paper as the steady state tax rates are taken from the data, not from the optimization problem. Active (contingent) and fully committed tax policy means that governments change tax rates according to the observed current-period productivity.[10] That is, tax policies are represented by the parameter η in

$$\tau_t = \bar{\tau} + \eta \log(A_t) \tag{7}$$

where the sign of η indicates whether the tax policies are countercyclical (if positive) or procyclical (if negative).[11] Absolute value of η represents the sensitivity of tax policy (i.e. how much tax rate should be changed to a unit change in productivity).

The country's resource constraint is

$$Y_t + R_{t-1}B_{t-1} = C_t + I_t + \bar{G} + B_t. \tag{8}$$

For the world equilibrium, the model requires bond market-clearing condition that bonds should be in zero net supply:

$$B_t + B_t^* = 0. \tag{9}$$

The equations describing the equilibrium are listed in the Appendix.

We measure welfare gains by calculating the change in welfare when the government implements active tax policies relative to the benchmark economy where both countries face stochastic productivity shocks but tax rates are fixed at the steady state level ($\eta = 0$ for all three taxes). Welfare is measured in terms of consumption units, a common measure in business cycle literature as in Lucas (1987). The certainty equivalent consumption is based on the conditional expectation of lifetime utility.[12]

[9] We assume that bond holding adjustment costs work as domestic taxes on international borrowing and lending. Alternatively, one can assume that bond holding costs are collected by an international authority and disappear from the national income accounting. Effects of bond holding costs on welfare results are negligible becasue we set the bond holding costs quite low.

[10] Another possible form of tax policy is to change tax rate in response to the changes in directly observable data such as output. However, since output is an endogenous variable, it is hard to make interpretation of the simulation results in this case.

[11] This definition of procyclical and countercyclical policy is slightly different from that used in monetary policy literature where cyclicality of policy is determined by the reaction to the output gap or output itself, not productivity as in this paper.

[12] It is important to use conditional mean, instead of unconditional mean, in order to correctly capture the dynamic transitional effects of policy changes. See Kim et al. (2008) for more on this.

2.3 Calibration

As for calibration, we use the conventional parameter values for annual data. We use the annual data because tax rates do not vary much on a quarterly basis. Capital depreciation rate, δ, is 0.1 per year. Labor share, α, is 0.6 and the consumption share parameter, θ, is set to match the steady state share of time devoted to market activities, 0.4. The representative agent's discount factor, β, is 0.95 so that the steady state annual real interest rate is equal to 5%. We set the utility curvature parameter, σ, which determines the household's coefficient of relative risk aversion at 2. The elasticity of bond holding costs, ζ, is set at 10^{-3} to allow only minimal effects from holding costs. Finally, we need to decide the parameter value for ϕ in capital adjustment costs. We set it at 0.2 to match the volatility of investment in the data. Most previous studies reported that productivity measures are highly persistent. For volatility of productivity shocks, we follow Backus et al. (1992) and Baxter and Crucini (1995) and assume that $\sigma_\varepsilon = 0.852\%$. We experiment with different values for other productivity parameters (ρ, ν, Ψ) in simulations.

Measuring aggregate tax rates is a complex and difficult task and there is little consensus on effective tax rate measures. In this paper, we use the aggregate effective tax rates calculated by Mendoza et al. (1994).[13] They calculate effective tax rates for G-7 countries by dividing actual tax payments by corresponding national accounts. These effective tax rates reflect government policies on tax credits, deductions, and exemptions as well as information on statutory tax rates. Moreover, they are consistent with the concept of aggregate tax rates at the national level and with the assumption of representative agents.

Table 1 reports the properties of tax rates of G-7 countries. Average tax rates are 12%, 36% and 31% for consumption, capital and labor income tax, respectively. We use these values as steady state tax rates. Government spending is fixed at the level that allows balanced budget under the steady state tax rates. Table 1 shows that all tax rates are highly persistent. The average persistence for G-7 countries are 0.84, 0.81 and 0.91 for consumption, capital income and labor incomes taxes, respectively. The standard deviation of the tax rates are 1.4%, 5.7% and 4.4% for consumption, capital income and labor income taxes, respectively. Capital income taxes are more volatile than the other two taxes, especially in Japan and UK (9.9% and 9.5%, respectively). Compared to the productivity shocks, tax shocks are as much as or more volatile on average (estimated standard deviation of productivity shocks are around 1% in general for OECD countries). Even though our focus is on the normative side, these numbers indicate that the tax policies that are more than unit elastic to the productivity shocks are within the range of empirical observation.

In order to solve the model, we adopt a second-order accurate solution method to correctly calculate the level of welfare. The conventional linearization method can generate inaccurate results in terms of welfare calculations, especially in open-economy models.[14] We follow Kim et al. (2008) and adopt the second-order perturbation method to correctly calculate the level of welfare.

[13] Their method is in the same line with Lucas (1990) and Razin and Sadka (1994). A number of papers have used this method to construct data on tax rates. See, for example, Mendoza and Tesar (1998). Another widely-used alternative for tax rate data is aggregate marginal tax rates. See Mendoza et al. (1994) for a detailed explanation and comparison of different computation methods.

[14] See Kim and Kim (2003).

3 Welfare Implications of Tax Policy

This section analyzes welfare implications of active (i.e., contingent on the state of the economy) tax policy under both closed and open economies. We derive optimal response of tax rates against productivity shock and measure maximum welfare gains relative to the fixed tax rates. We use two types of open economy models: One model is a small open economy with incomplete markets where the world interest rate is exogenously given; we also analyze the two-country setup where the interest rate is endogenously determined by bond market clearing between the two countries. We use the two-country model to analyze the effects of tax policy transmission and coordination in the next section.

3.1 A Closed Economy

In the closed economy, active tax policy can be welfare improving because governments should finance fiscal spending (which is positive and exogenously given) by collecting distortionary taxes. That is, the steady-state tax rates are positive, which introduce distortions in the static and intertemporal optimality conditions. Therefore, contingent tax policies can improve welfare by reducing such distortions. We first calculate the level of welfare when tax rates are fixed at the steady-state level and then measure potential welfare gains when government adopt active tax policy from the benchmark fixed-tax case.

Table 2 reports optimal η_s for each tax with different values of ρ (persistence of productivity shock).[15] First, optimal tax policy is countercyclical for all three taxes: consumption tax ($2.5 \sim 2.7$), capital income tax ($0.8 \sim 1.6$), and labor income tax ($0.04 \sim 0.15$). We call a tax policy countercyclical when governments lower tax rates when the economy is hit by a negative productivity shock.

Welfare gains from active consumption tax policy is the largest of the three, while labor income tax policy brings almost negligible gains. When productivity shock is very persistent ($\rho = 0.95$), maximum welfare gains from active tax policy are 0.03%, 0.005%, and 0.001% (in terms of permanent consumption) for consumption tax, capital income tax, and labor income tax, respectively. These gains decrease as shocks become less persistent. Even though the absolute magnitude of these welfare gains seems to be small, the size of the welfare gains is comparable to the maximum possible welfare gains from removing business cycles in the economy, which is around 0.01∼0.05% of permanent consumption (Lucas, 1987).

3.2 A Small Open Economy

The second rows in Table 2 report the results of a small open economy model with exogenously fixed interest rate. First, optimal η_c for consumption tax becomes less countercyclical, decreasing to $0.3 \sim 1.4$ (relative to $2.5 \sim 2.7$ in the closed economy) and welfare gains dramatically decrease compared to the closed economy model. Optimal tax response η for capital income tax becomes procyclical when shocks are not very persistent. Optimal η_k decreases to -1.6 when $\rho = 0.85$, and to -0.5 when $\rho = 0.9$. Welfare gains from optimal capital income tax policy is around $0.001 \sim 0.006$, similar to the closed economy case. Optimal η_l for labor income tax and the amount of welfare gains are similar in both closed- and open-economy cases. This similarity is due to the fact that

[15] Other parameters than ρ also affect optimal η_s but the effects are not significant in most cases.

there is no labor mobility across countries, while consumption and capital goods are traded across countries.

In an open economy, the current account works as a buffer against productivity shocks and plays a role for consumption smoothing (other than investment channel that also exists in the closed economy as well). The level of consumption smoothing achieved in the open economy is larger than that in the closed economy and therefore the role of business cycle stabilizing tax policies is reduced. In the case of consumption tax where the optimal tax policy is countercyclical in the closed economy, governments—when facing positive shocks—do not have to increase tax rates as much as in the closed economy case to stabilize business cycles. With positive shocks, agents can smooth consumption by accumulating international bonds (i.e. lending to other countries). Therefore, optimal consumption tax policy becomes less countercyclical and the amount of welfare gains significantly decrease in the open economy because of a decrease in stabilization gains.

Another channel of welfare gains is through improving efficiency. This channel becomes most evident in the case of capital income tax policy. The results in Table 2 show that optimal tax policy for capital income tax becomes procyclical in the open economy when shocks are not very persistent. Lowering tax rates with positive productivity shocks generates efficiency gains by stimulating agents to produce more in a more productive state and lend additional output to foreign countries. This channel is not available in the closed-economy model where extra output should be consumed domestically. In the closed-economy model, efficiency gains from procyclical policy are always outweighed by stabilization loss, resulting in welfare loss.

3.2.1 Sensitivity Analysis

So far, we have assumed that distortions are generated by all three types of taxes. In order to analyze each tax policy individually, we now assume that only one tax is used to finance government spending. Figure 1 plots how the optimal tax policy η changes with the amount of distortions, in both closed and small open economies. Government spending (as a ratio of output) and the corresponding steady-state tax rates (that satisfy balanced budget at the steady state) are on the X-axis, while Y-axis represents optimal η. The figure shows that the results in Table 2 hold in most cases. For all three taxes, optimal tax policy is countercyclical in the closed economy (positive η) and the absolute value of η increases with the amount of distortions (steady state $\bar{\tau}$). Optimal tax policy in the open economy becomes less countercyclical than that in the closed economy in all cases except for consumption tax when distortions are low (G/Y is less than 15%). For capital income tax and labor income tax with low distortions (G/Y is less than 15%), optimal policy is procyclical in an open economy.

In order to understand the mechanism behind welfare gains, we compare welfare gains from procyclical and countercyclical tax policies when there are significant distortions ($G/Y = 20\%$) in Table 3. For each tax, we set η at 0.4 (countercyclical) and -0.4 (procyclical) and calculate welfare gains, which are decomposed into the mean effect (generated by changes in the conditional mean of the variables) and the variance effect (generated by changes in the conditional variance of the variables). We further decompose the mean effects into consumption mean effect and labor mean effect. The results show that countercyclical tax policy generates positive variance effects and negative mean effects in all cases, while procyclical policy generates opposite results (negative variance effects and positive mean effects) in all cases. Kollmann (2002) and Bergin et al. (2007) used the terms "efficiency gains" for mean effect and "stabilization gains" for variance effect in analyzing welfare gains of monetary policy.[16] Countercyclical tax policy reduces volatility of the variables and stabilizes the economy. These stabilization gains exceed the size of negative mean effects.

To further understand the mean and variance effects, we draw impulse responses.[17] Figures 2 $\sim$ 7 present impulse responses to a positive productivity shock of the economy with procyclical ($\eta = -0.4$) and countercyclical ($\eta = 0.4$) tax policy. All countercyclical tax policies lower the magnitude of responses of consumption and labor to the shock, which lowers volatility of consumption and labor. This generates positive variance effect. On the other hand, procyclical tax policy generates more volatility of consumption and labor, resulting in negative variance effects. Figures 3 and 6 also show how procyclical capital income tax policy can improve welfare. In the open economy with positive productivity shock, procyclical capital income tax policy increases investment by almost 50% more than the case with fixed tax policy. Consumption also rises more than in the fixed tax policy case. With procyclical tax policy, agents can take advantage of positive productivity in a more aggressive manner without sacrificing consumption because of the possibility of international borrowing and lending. These efficiency gains exceed stabilization losses from procyclical tax policy under certain parameter values. On the other hand, in the closed economy, procyclical capital income tax policy increases investment by only 20% relative to the fixed-tax case. Increases in investment are constrained by domestic resource constraints and should be financed by sacrificing consumption. The amount of efficiency gains of procyclical capital income tax policy is less than the amount of stabilization losses.

These results are analogous to the implications provided by the optimal monetary policy literature. A number of studies have shown that optimal monetary policy is procyclical with supply shocks (productivity shocks), while the optimal policy is countercyclical with demand shocks.[18] Procyclical interest rate policy improves welfare by reducing distortions from rigidities in the economy, when hit by supply shocks. In this paper, the sources of distortions are different as our model has no nominal rigidities and the only distortions are from distortionary taxes. Even with different sources of distortions, this model produces the same implication as the monetary policy literature that optimal capital income tax policy is procyclical with supply shocks.

3.3 A Two-Country Model

In the two-country world, the interest rate is endogenously determined by the bond market clearing condition. It is well known that interest rate is a negative function of current world output: When world output increases temporarily, interest rate decreases as illustrated in Kim et al. (2003). With positive shocks, agents would accumulate bonds for consumption smoothing purpose. However, increasing demand for bonds increases bond price (lowers interest rate), which lowers the amount of bond trading. Under the benchmark parameter values, endogenous interest rate (in the two-country model) reduces the amount of bond trading to the one-third of the level achieved in the case of fixed interest rate (in the small open economy model).

Last rows in Table 2 show optimal tax policies derived in the two-country model. For all three types of taxes, optimal η's are similar to those in the small open economy case. Welfare

[16] Our decompoisition follows their convention of defining the gains in term of the original variables, rather than a transformation such as a logarithmic one.

[17] These impulse responses are based on the "pruned" solution of the second-order perturbation method, as suggested in Kim et al. (2008).

[18] See, for example, Ireland (1996) and Obstfeld and Rogoff (2002).

gains significantly decrease in the case of consumption and capital income tax. Table 4 shows how optimal η's and maximum welfare gains change when parameter values for capital mobility and shock correlation change. The following parameter values are used for the benchmark two-country model: ρ (shock persistence) = 0.9, ζ (bond holding adjustment cost parameter) = 0.001, ν (shock spillover) = 0, and ψ (contemporaneous cross-country correlation of shocks) = 0. We first examine the case when bond holding adjustment cost parameter increases to ($\zeta = 0.1$). With higher adjustment costs, agents do not trade bonds as much as in the benchmark case and the behavior of the economy approaches that of the closed economy. Therefore, optimal η increases (become more countercyclical or less procyclical) towards the value of the closed-economy model. Next, we experiment by increasing spillover of productivity shocks across countries (positive ν) and contemporaneous correlation of shocks ($\psi = 0.5$). Both changes imply that home and foreign countries now face similar productivity shocks than before. Therefore, less amount of bond trading is required for consumption smoothing compared to the benchmark case when shocks are neither correlated nor transferred. As a result, optimal tax policies move closer to the closed-economy case (more countercyclical), while optimal labor income tax does not change by much.

4 Non-cooperative and Cooperative Equilibria

In this section, we relax the assumption that tax rates are fixed in the foreign country and instead analyze optimal tax policy of the domestic country when the foreign country also adopts an active tax policy. Two types of exercises are implemented. First, we vary the reaction of the foreign country's tax policy and find the non-cooperative Nash equilibrium using the best response curves of the two countries. Next, we calculate the cooperative equilibrium and analyze welfare gains from tax policy coordination. We set the shock persistence parameter ρ at 0.9 in this section.

Figure 8 shows the welfare gains (of home and foreign countries) of active consumption tax policy when foreign tax rate is fixed ($\eta_c^* = 0$). In this case, domestic welfare is maximized when $\eta_c = 0.4$, an increase in consumption tax rate by 0.4% in response to a 1% increase in productivity. The maximum welfare gains are quite small at 0.0005% of permanent consumption, as shown in Table 5. Countercyclical consumption tax policy generates positive spillovers to the foreign country as its welfare increases by 0.002%. Positive welfare gains are due to positive mean effects that exceed negative variance effects. We can derive the non-cooperative Nash equilibrium by drawing best response curves of the two countries. For all three types of taxes, the best response curves turn out to be vertical or horizontal, which implies that optimal η does not depend on foreign tax policy. Therefore, the Nash equilibrium is achieved when $\eta_c = \eta_c^* = 0.4$ and the welfare gains are 0.003% which is higher than the domestic welfare gains when foreign country does not implement any tax policy. This is due to positive spillover effects.

This non-cooperative Nash equilibrium, however, does not maximize the world welfare. We define the cooperative equilibrium as the outcome when both countries use their tax policy to maximize the sum of domestic and foreign welfare. For consumption tax, the cooperative equilibrium is achieved when $\eta_c = \eta_c^* = 1.5$, suggesting that the consumption tax policy should be more countercyclical than the Nash equilibrium for the maximization of world welfare. The welfare gains at the cooperative equilibrium are 0.006%. We measure the welfare gains from cooperation by taking the difference of welfare level between the Nash solution and the cooperative solution. In the case of consumption tax, the gains from cooperation is 0.003% of permanent consumption.

Figure 9 plots the welfare gains of the two countries when the domestic government changes η_k

holding η_k^* constant at zero. The maximum welfare gains are quite small at 0.0004% of permanent consumption, and it is achieved when $\eta_k = -0.3$, interpreted as a decrease in capital income tax rate by 0.3% with a 1% positive productivity shock. In this case, the procyclical capital income tax policy (negative η_k) decreases the level of foreign welfare, mostly due to negative mean effects. The Nash equilibrium is achieved when $\eta_k = \eta_k^* = -0.3$. Because of the large size of negative spillovers, welfare of each country actually decreases at the Nash equilibrium. The cooperative equilibrium is achieved when the two countries implement slightly countercyclical tax policy at $\eta_k = \eta_k^* = 0.1$, but the size of welfare gain is negligible. Figure 10 shows the welfare gains of labor income tax policy. With no foreign tax policy ($\eta_l^* = 0$), optimal η_l is at 0.2 with welfare gains of 0.0016%. The Nash equilibrium is at $\eta_l = \eta_l^* = 0.2$ with welfare loss of 0.001% due to negative spillovers. There is no welfare gain under the cooperative equilibrium in the case of labor income tax.

Summarizing, when foreign countries also implement an active tax policy, optimal tax policies on capital and labor income lower welfare of both countries at the non-cooperative Nash equilibrium. Tax policy coordination produces a higher level of welfare compared to the Nash equilibrium, but the actual welfare gains are minimal relative to the fixed tax policy case. In the case of consumption tax, active consumption tax policy generates positive spillovers and therefore, both countries gain at the Nash equilibrium. Furthermore, the cooperative equilibrium produces quite large welfare gains compared to the Nash equilibrium.

5 Conclusion

A conventional wisdom is that optimal tax policy is probably countercyclical rather than procyclical. We have shown that this proposition—though true in a closed economy—may not hold in an open economy where countries can trade international bonds for the consumption smoothing purpose. Optimal tax polices in the open economy become less countercyclical compared to the closed economy due to the consumption smoothing role of the current account. More importantly, in the case of capital income tax, optimal tax policy can even be procyclical. Procyclical tax policy stimulates agents to produce more in a more productive state and agents can take advantage of this extra output through international lending and borrowing. For capital income tax, the efficiency gains from procyclical tax policy outweigh stabilization losses, improving overall welfare. We also show that positive welfare gains of active tax policy may disappear when foreign countries use active policy, in particular for the capital and labor income taxes. International tax policy coordination does not generate significant welfare gains, except for the consumption tax.

In general, welfare gains from active tax policies are quite small compared to welfare gains of tax policy reform that changes tax rates permanently, as considered in Mendoza and Tesar (1998, 2001). This is because the tax policies considered in this paper are designed to be fine-tuning in the sense that tax rates can only respond to business cycles (changes in productivity) in the economy. However, it is less difficult to implement such policies compared to the permanent changes in tax rates. Moreover, active tax policies can play an important role in stabilizing an economy where monetary policy cannot be used for the stabilization purpose, such as in the member countries of the European Union.

A Appendix

A.1 The first-order conditions

The domestic economy is described by the following 12 equations together with equations for productivity shocks and tax processes:

$$
\begin{aligned}
0 &= (1-\sigma)U_t - \left[C_t^{\theta}(1-L_t)^{1-\theta}\right]^{1-\sigma}, \\
0 &= Y_t - A_t L_t^{\alpha} K_t^{1-\alpha}, \\
0 &= \lambda_t C_t (1+\tau_{ct}) - \theta(1-\sigma)U_t, \\
0 &= (1-\tau_{lt})\lambda_t w_t (1-L_t) - (1-\theta)(1-\sigma)U_t, \\
0 &= K_{t+1} - \left[\delta\left(I_t/\delta\right)^{1-\phi} + (1-\delta)K_t^{1-\phi}\right]^{\frac{1}{1-\phi}}, \\
0 &= \beta R_t \mathrm{E_t}\left(\lambda_{t+1}\right) - \lambda_t(1+\zeta B_t), \\
0 &= G_t + T_t - \tau_{ct}C_t - \tau_{lt}w_t L_t - \tau_{kt}(r_t-\delta)K_t - \frac{\zeta}{2}\left(B_t\right)^2, \\
0 &= Y_t + R_{t-1}B_{t-1} - C_t - I_t - G_t - B_t, \\
0 &= w_t L_t - \alpha Y_t, \\
0 &= r_t K_t - (1-\alpha)Y_t, \\
0 &= \lambda_t - \mu_t\left[\delta\left(I_t/\delta\right)^{1-\phi} + (1-\delta)K_t^{1-\phi}\right]^{\frac{\phi}{1-\phi}}\left(\frac{I_t}{\delta}\right)^{-\phi}, \\
0 &= \mu_t - \beta \mathrm{E_t}\left[\begin{array}{c} (1-\delta)\lambda_{t+1}\left(I_{t+1}/\delta\right)^{\phi}\left(K_{t+1}\right)^{-\phi} \\ +\lambda_{t+1}\left(r_{t+1}(1-\tau_{k,t+1}) + \delta\tau_{k,t+1}\right) \end{array}\right],
\end{aligned}
$$

where λ_t and μ_t are Lagrangian multipliers for the budget constraint and capital accumulation equation, respectively. There are foreign country analogues to the above equations. The world equilibrium is achieved by imposing the world resource constraint.

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Table 1. Properties of estimated tax rates

<Average tax rates>

	C-tax	K- tax	L-tax
Canada	0.12	0.43	0.25
France	0.20	0.24	0.42
Germany	0.16	0.27	0.38
Italy	0.13	0.29	0.41
Japan	0.05	0.35	0.22
UK	0.15	0.55	0.25
US	0.06	0.42	0.26
average	0.12	0.36	0.31

<Persistence>

	C-tax	K-tax	L-tax
Canada	0.76	0.87	0.92
France	0.96	0.86	0.98
Germany	0.62	0.85	0.89
Italy	0.90	0.79	0.95
Japan	0.92	0.94	0.97
UK	0.88	0.73	0.77
US	0.81	0.63	0.89
average	0.84	0.81	0.91

<Standard deviation>

	C-tax	K-tax	L-tax
Canada	0.012	0.050	0.052
France	0.026	0.038	0.062
Germany	0.011	0.037	0.045
Italy	0.017	0.050	0.046
Japan	0.006	0.099	0.047
UK	0.021	0.095	0.020
US	0.004	0.033	0.034
average	0.014	0.057	0.044

Note: C-tax: consumption tax rate, K-tax: capital income tax rate, and L-tax: labor income tax rate. Persistence is calculated from AR(1) coefficient.

Table 2. Optimal tax policies in closed and open economies

<Consumption tax>

		$\rho = 0.85$	$\rho = 0.9$	$\rho = 0.95$
Autarky	optimal η	*2.5*	*2.7*	*2.5*
	welfare gains	0.008	0.01	0.03
Small Open	optimal η	*0.3*	*0.7*	*1.4*
	welfare gains	0.0002	0.001	0.012
Two Country	optimal η	*0.1*	*0.4*	*1.0*
	welfare gains	0.00003	0.0005	0.005

<Capital income tax>

		$\rho = 0.85$	$\rho = 0.9$	$\rho = 0.95$
Autarky	optimal η	*1.6*	*1.2*	*0.8*
	welfare gains	0.0015	0.003	0.005
Small Open	optimal η	*-1.6*	*-0.5*	*0.3*
	welfare gains	0.006	0.001	0.001
Two Country	optimal η	*-1.2*	*-0.3*	*0.1*
	welfare gains	0.002	0.0004	0.0001

<Labor income tax>

		$\rho = 0.85$	$\rho = 0.9$	$\rho = 0.95$
Autarky	optimal η	*0.04*	*0.09*	*0.15*
	welfare gains	0.00004	0.0002	0.0014
Small Open	optimal η	*0*	*0.06*	*0.17*
	welfare gains	0	0.0001	0.002
Two Country	optimal η	*0.19*	*0.21*	*0.24*
	welfare gains	0.001	0.002	0.004

Note: Small open: Small open economy model with fixed world interest rate.

Two-country: Two country model with endogenously determined world interest rate.

Italic numbers in this table are optimal η_s. Welfare gains are measured as percentage changes in certainty equivalent consumption over the benchmark case with fixed tax policy, while the certainty equivalent consumption is calculated based on conditional welfare changes with labor fixed at the steady state.

Table 3. Decomposition of welfare gains (G/Y = 20%)

<Closed economy>

	η	Welfare gains	Mean effect (Cons, Labor)	Variance effect
C-tax	-0.4	-0.002	0.009 (0.009, -0.0004)	-0.011
$\bar{\tau} = 37\%$	0.4	0.001	-0.008 (-0.006, -0.002)	0.009
K-tax	-0.4	-0.011	0 (0.002, -0.002)	-0.011
$\bar{\tau} = 74\%$	0.4	0.006	-0.003 (-0.004, 0.001)	0.009
L-tax	-0.4	-0.008	0.018 (0.019, -0.001)	-0.026
$\bar{\tau} = 33.5\%$	0.4	-0.003	-0.022 (-0.026, 0.004)	0.019

<Small open economy>

	η	Welfare gains	Mean effect (Cons, Labor)	Variance effect
C-tax	-0.4	-0.002	0.007 (0.010, -0.002)	-0.009
$\bar{\tau} = 37\%$	0.4	-0.001	-0.007 (-0.007, 0.0001)	0.008
K-tax	-0.4	-0.001	0.014 (0.015, -0.001)	-0.015
$\bar{\tau} = 74\%$	0.4	-0.011	-0.024 (-0.026, 0.002)	0.012
L-tax	-0.4	-0.006	0.017 (0.011, 0.006)	-0.023
$\bar{\tau} = 33.5\%$	0.4	-0.005	-0.022 (-0.020, -0.002)	0.016

Note: This table corresponds to Figure 1, where government spending is financed by only one tax at a time. Mean effect is defined as welfare changes due to changes in the mean (first order terms) of utility, while variance effect is welfare changes in the variance (second order terms) of utility. Mean effect is decomposed into the mean effect due to changes in the conditional mean of consumption and labor. Since utility is a negative function of labor, positive mean effect from labor implies that the conditional mean of labor (leisure) decreases (increases).

Table 4. Sensitivity analysis in a two country case

	Parameters	Optimal η_c	Optimal η_k	Optimal η_l
Two-country (benchmark)		0.4 (0.0005)	-0.3 (0.0004)	0.2 (0.002)
Low capital mobility	$\zeta = 0.1$	2.3 (0.01)	0.8 (0.002)	0.1 (0.0003)
Positive spillovers	$\nu = 0.08$	1.3 (0.01)	0.4 (0.003)	0.2 (0.005)
Correlated shocks	$\Psi = 0.5$	1.0 (0.003)	0.2 (0.0001)	0.2 (0.001)

Note: Benchmark economy is the two-country model with ρ=0.9, taken from table 2. Numbers in the parentheses are welfare gains.

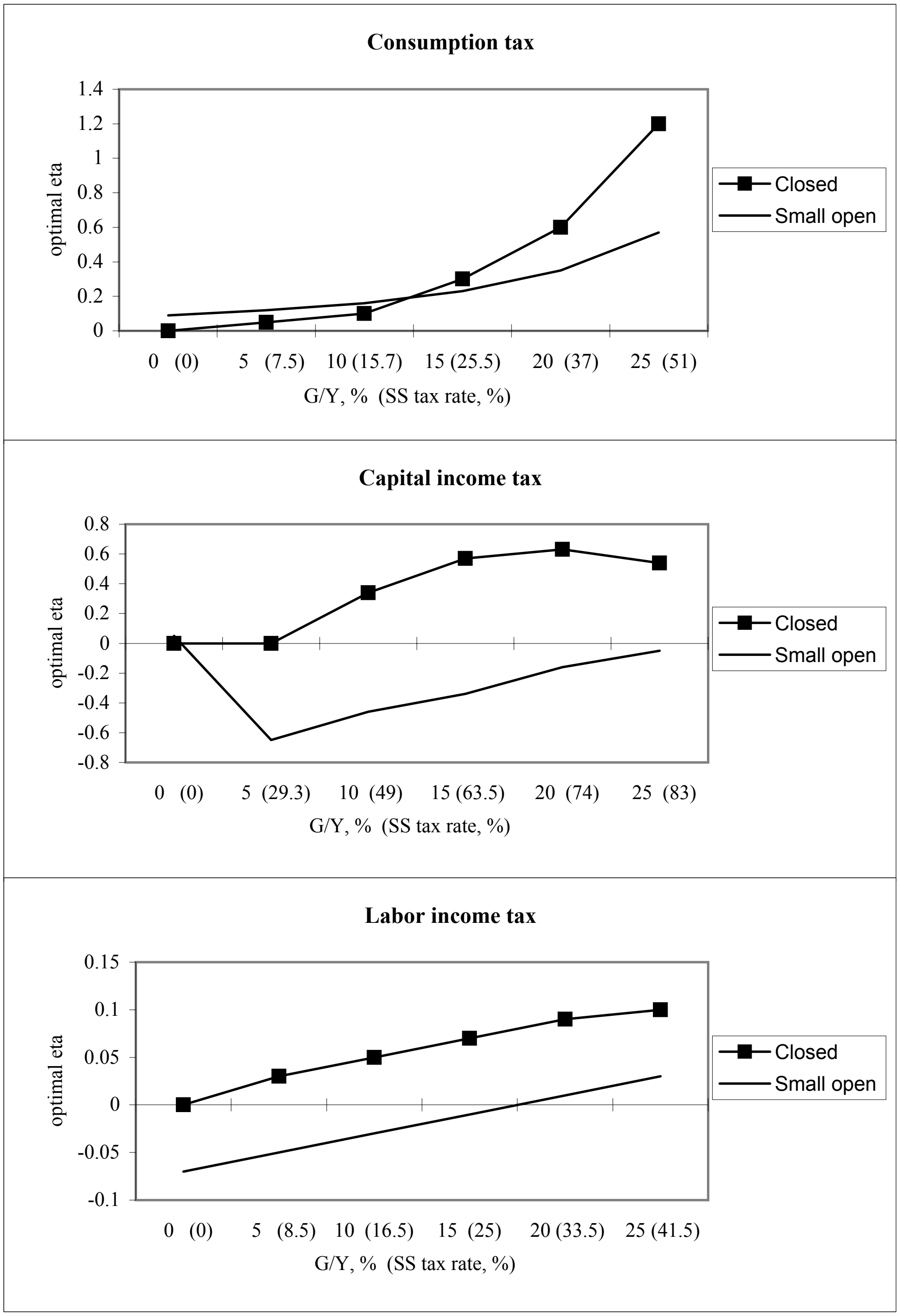
Table 5. Welfare effects of tax policy coordination

	Optimal (η, η^*)	Country	Welfare gains (mean effect, variance effect)
	$(0.4, 0)^1$	Home	0.0005 (-0.0121, 0.0126)
		Foreign	0.0023 (0.003, -0.0007)
C-tax		World	0.0014 (-0.0045, 0.0059)
	$(0.4, 0.4)^2$	H,F,W	0.003 (-0.009, 0.012)
	$(1.5, 1.5)^3$	H,F,W	0.006 (-0.025, 0.031)
	$(-0.3, 0)^1$	Home	0.0004 (0.0027, -0.0023)
		Foreign	-0.0009 (-0.0011, 0.0002)
K-tax		World	-0.0002 (0.0008, -0.0011)
	$(-0.3, -0.3)^2$	H,F,W	-0.0005 (0.0016, -0.0021)
	$(0.1, 0.1)^3$	H,F,W	0.00003 (-0.00065, 0.00068)
	$(0.2, 0)^1$	Home	0.0016 (-0.0086, 0.0103)
		Foreign	-0.0027 (-0.0035, 0.0008)
L-tax		World	-0.0005 (-0.0061, 0.0056)
	$(0.2, 0.2)^2$	H,F,W	-0.001 (-0.012, 0.011)
	$(0, 0)^3$	H,F,W	0 (0, 0)

1. Domestic tax policy only
2. Non-cooperative Nash equilibrium
3. Cooperative equilibrium

For 2 and 3, home, foreign and world welfare gains are identical due to the symmetry of countries.

Figure 1. Optimal tax policy (Sensitivity analysis)



Note: Government spending is financed by only one tax in each graph.
Numbers in the parenthesis in the X-axis is the steady state tax rates that satisfies the balanced government budget.

Figure 2. Impulse responses to positive productivity shock (closed economy): C−tax

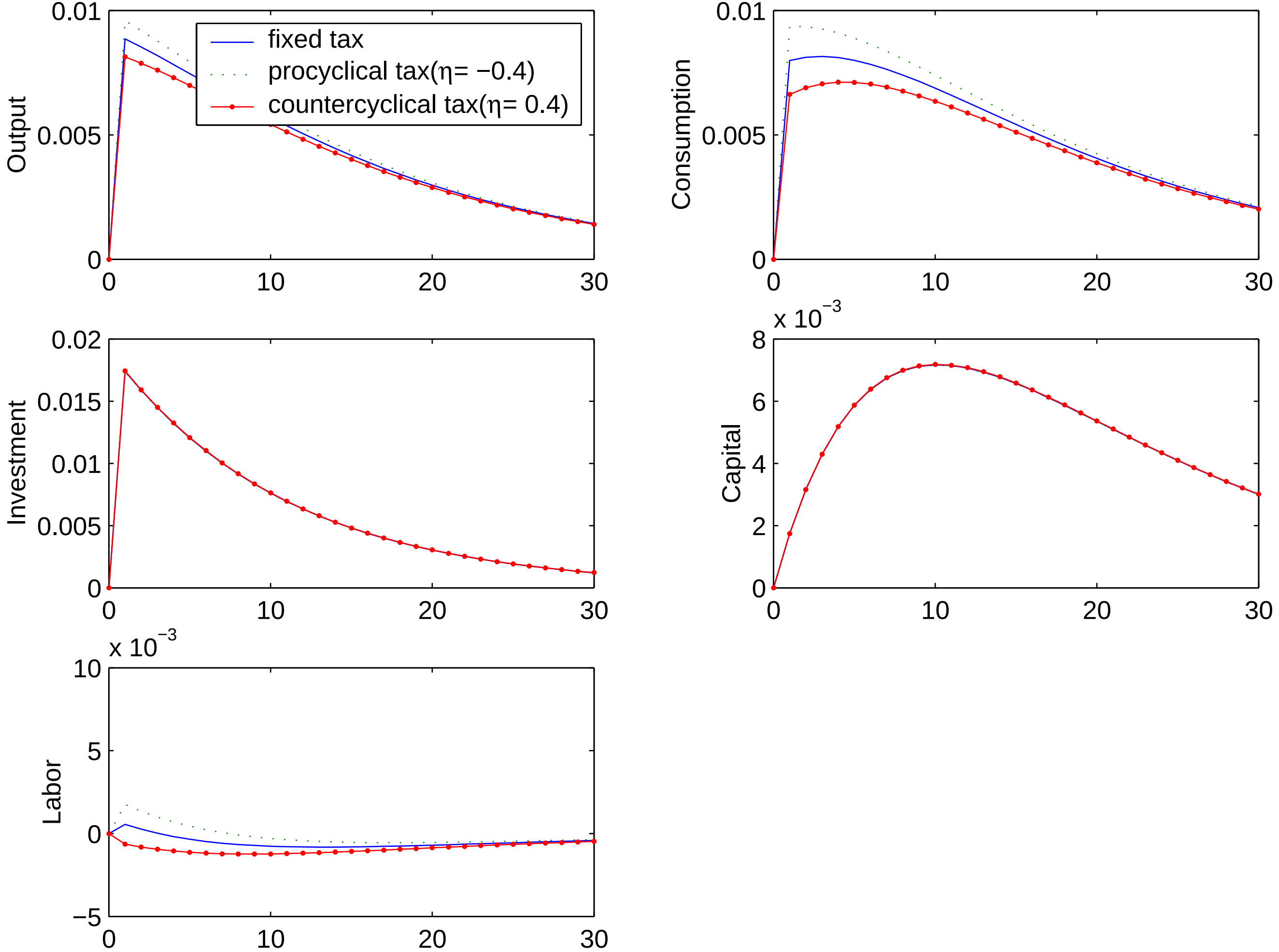


Figure 3. Impulse responses to positive productivity shock (closed economy): K−tax

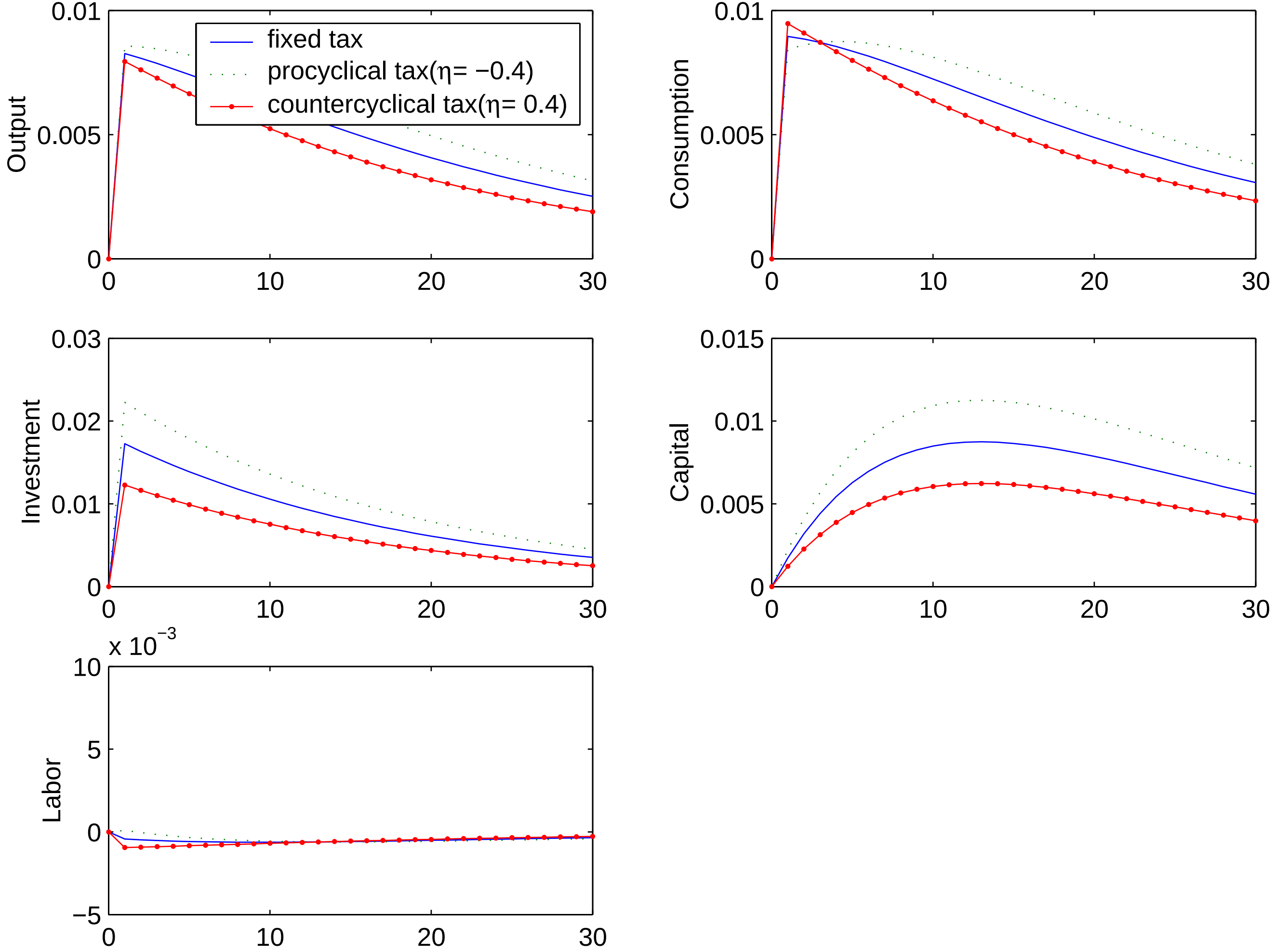


Figure 4. Impulse responses to positive productivity shock (closed economy): L−tax

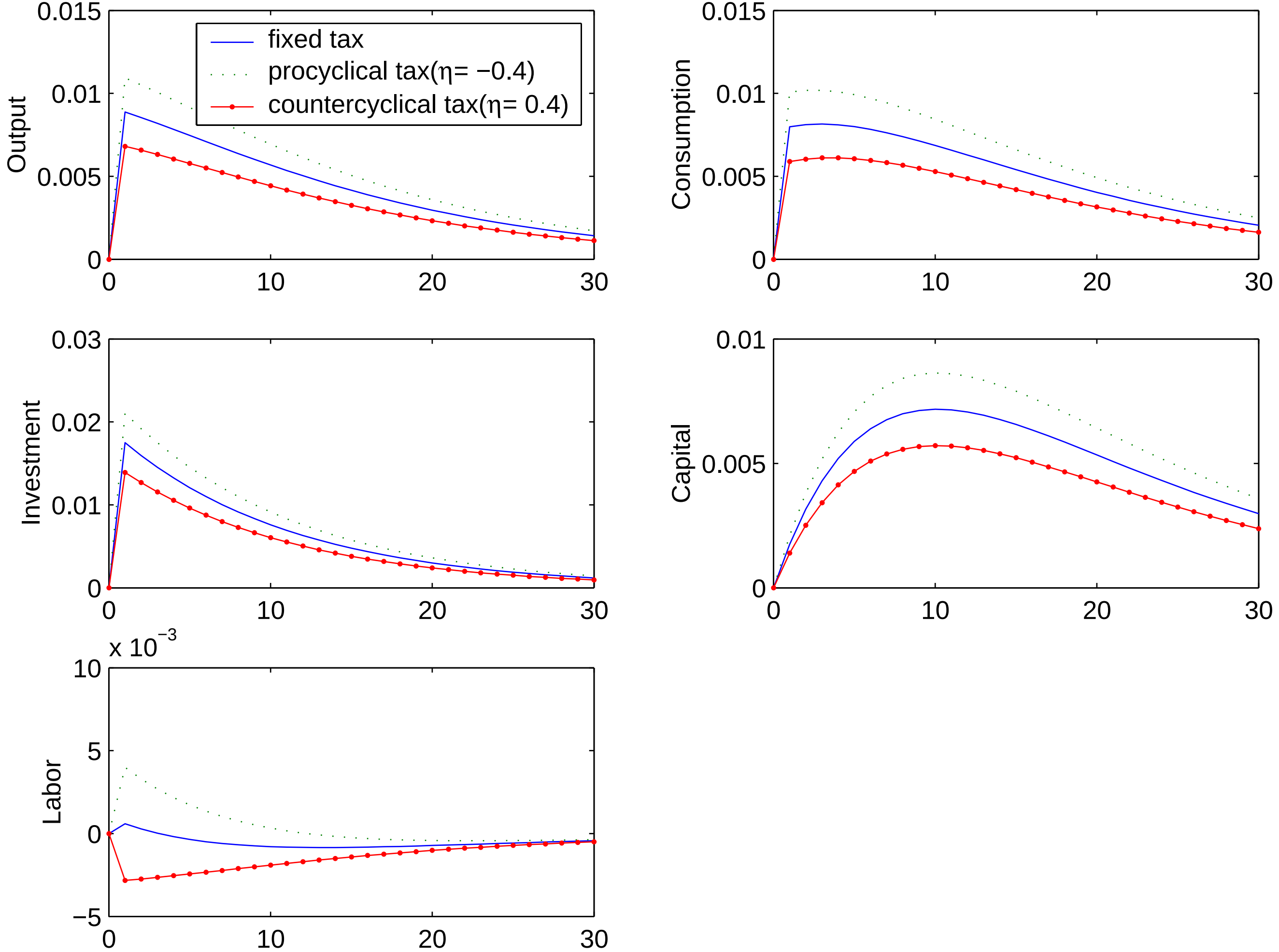


Figure 5. Impulse responses to positive productivity shock (small open economy): C−tax

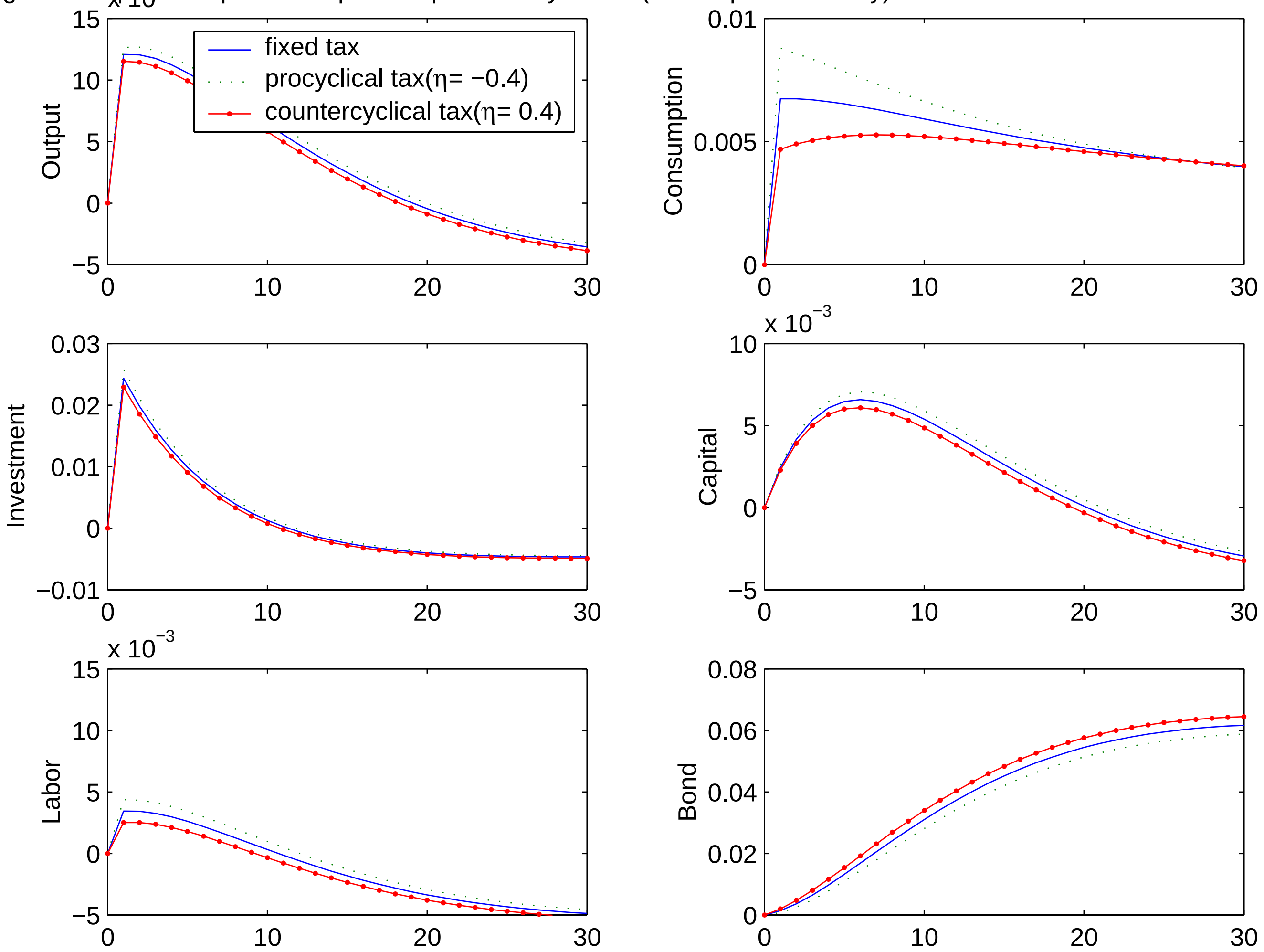


Figure 6. Impulse responses to positive productivity shock (small open economy): K−tax

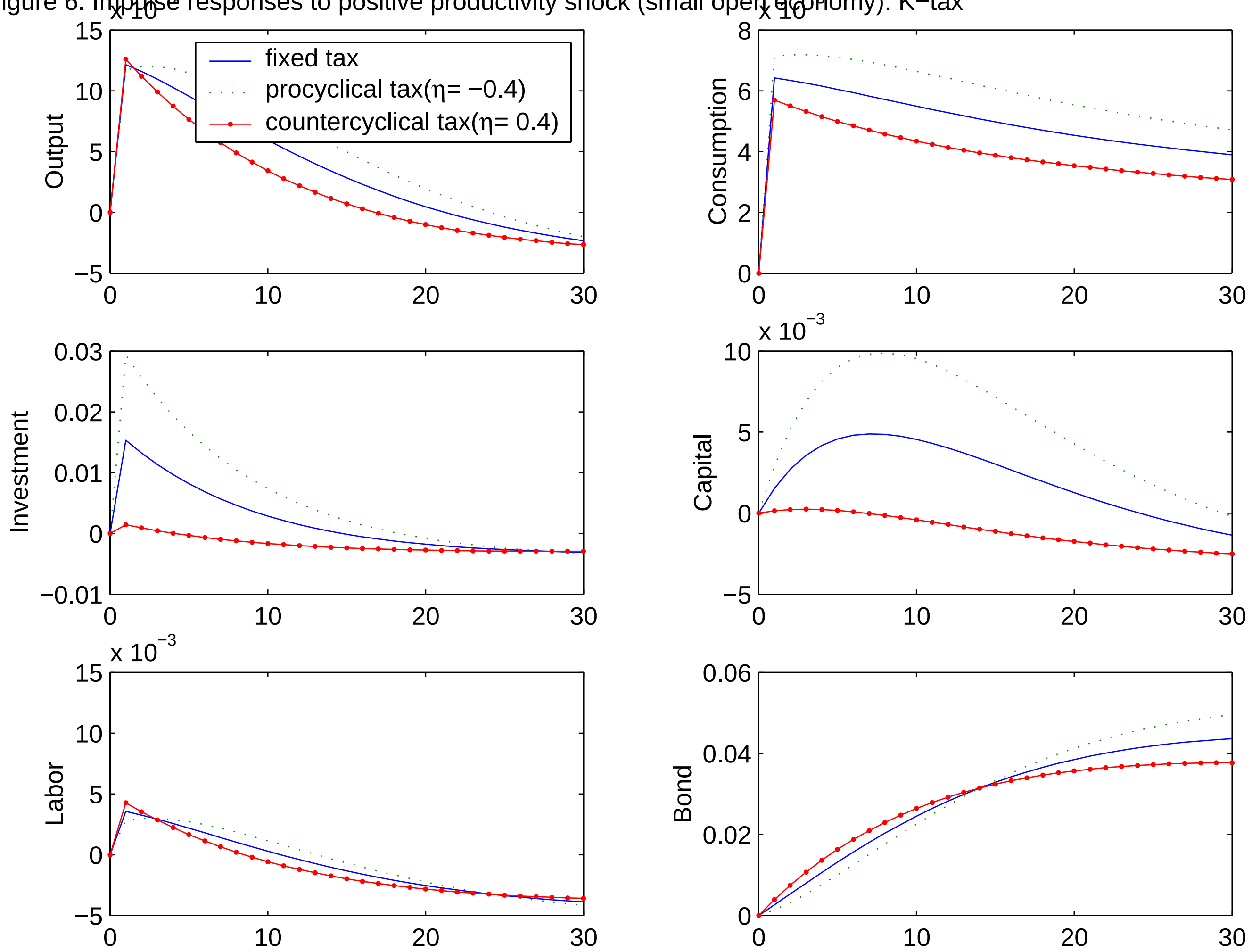


Figure 7. Impulse responses to positive productivity shock (small open economy): L−tax

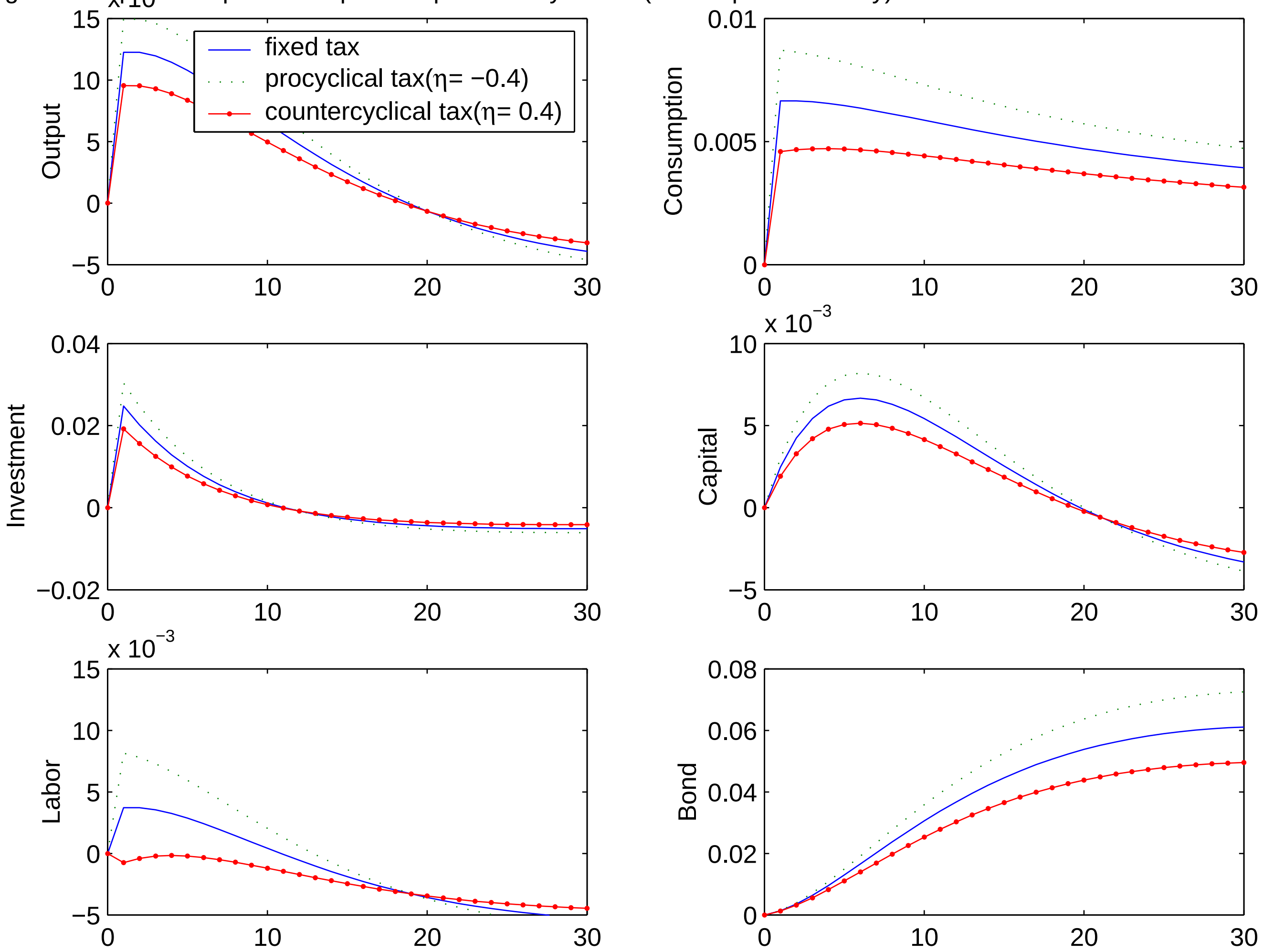
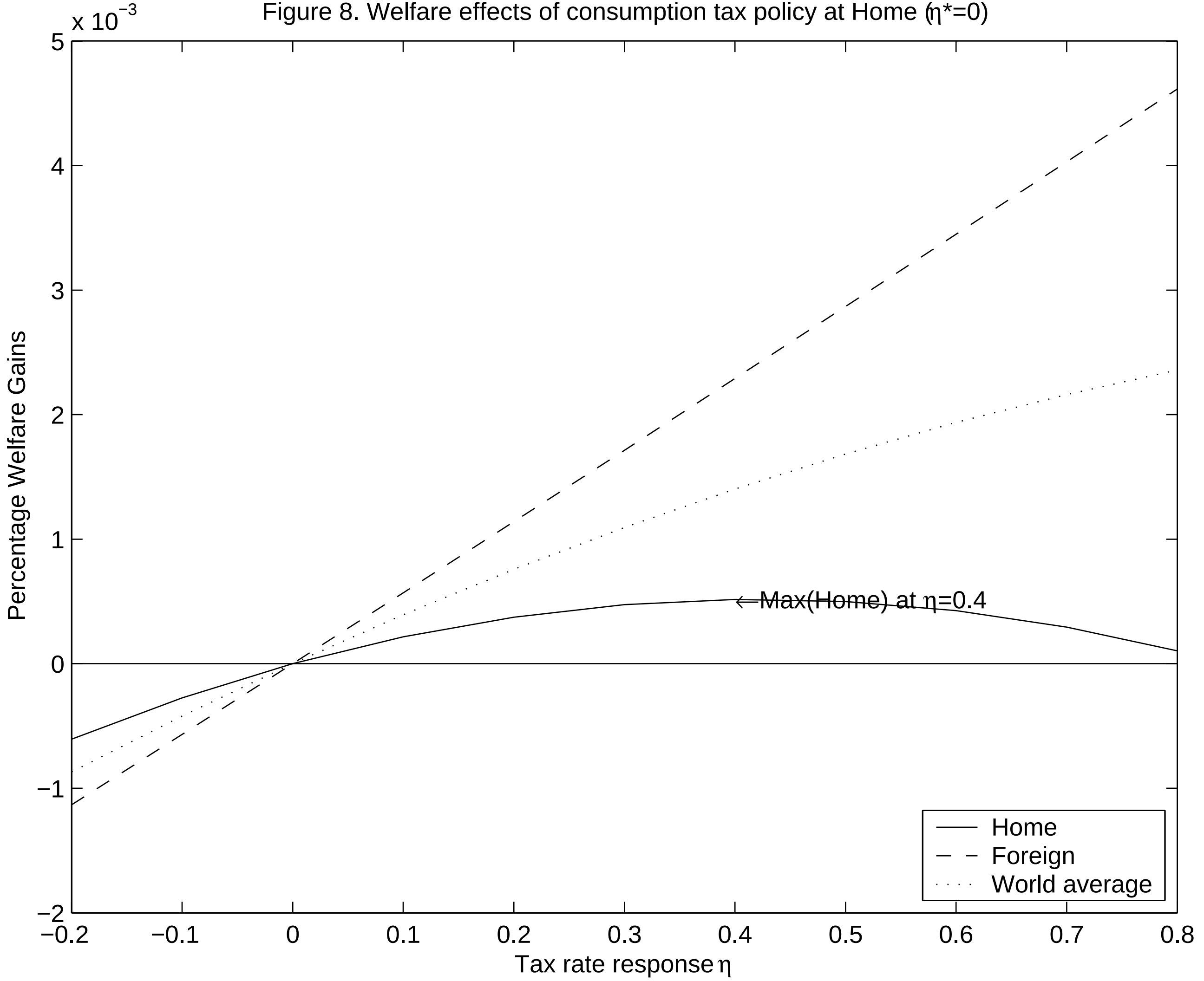


Figure 8. Welfare effects of consumption tax policy at Home (η*=0)



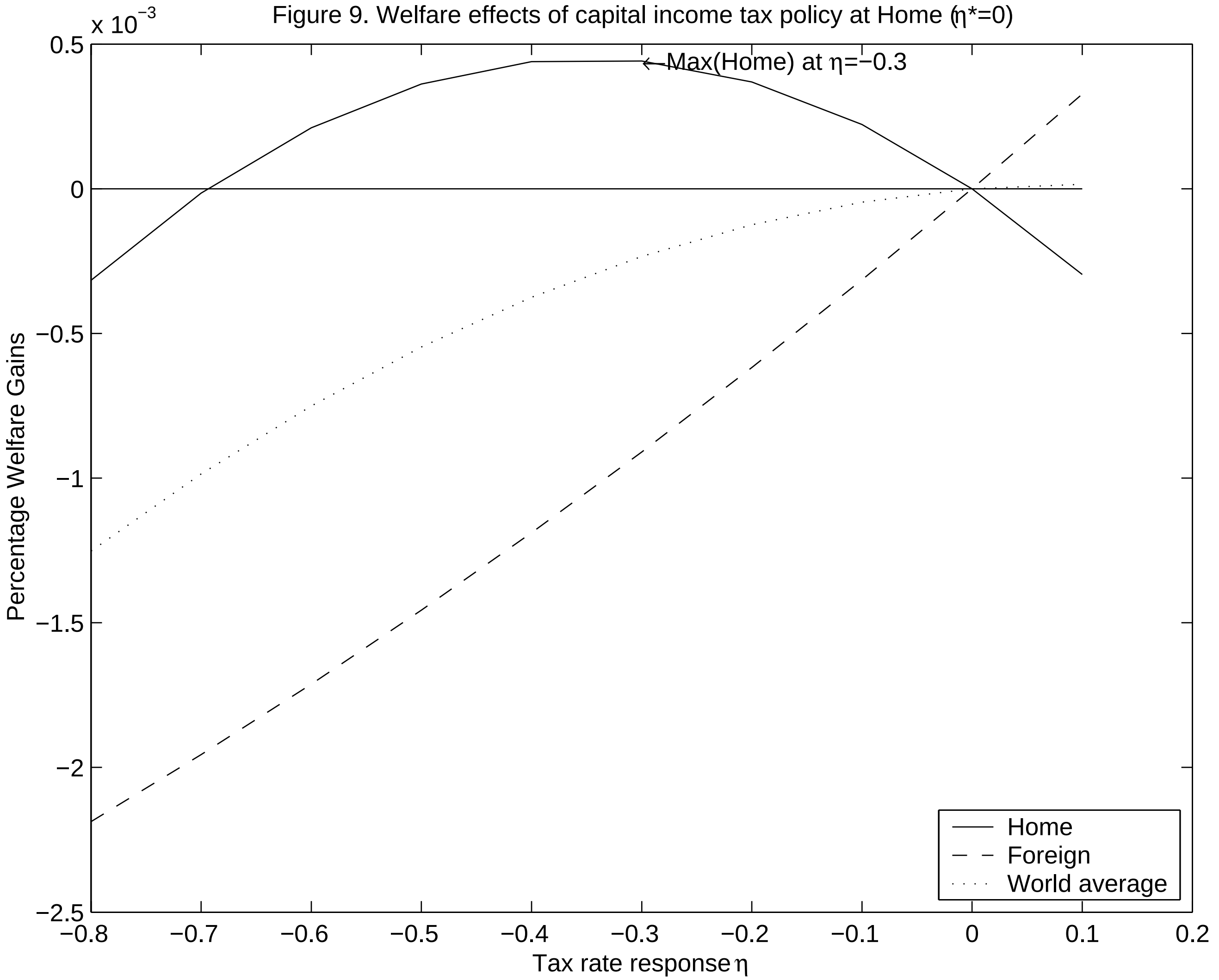


Figure 9. Welfare effects of capital income tax policy at Home (η*=0)
x 10^−3
0.5
0
−0.5
−1
−1.5
−2
−2.5
Percentage Welfare Gains
Max(Home) at η=−0.3
−0.8
−0.7
−0.6
−0.5
−0.4
−0.3
−0.2
−0.1
0
0.1
0.2
Tax rate response η
Home
Foreign
World average

Figure 10. Welfare effects of labor income tax policy at Home (η*=0)