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

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Abstract

This paper studies optimal tax policy problem by employing an open economy dynamic general equilibrium model with incomplete asset markets. We investigate the possibility of welfare-improving active tax policies (under which tax rates respond to changes in productivity) on factor incomes and consumption. Simulation results show that countercyclical tax policies are optimal in the closed economy. However, in the open economy, optimal tax policies become less countercyclical and under certain cases become procyclical, in particular capital income tax. Procyclical tax policy generates efficiency gains that outweigh stabilization loss. Two country analysis suggests that tax policy coordination on capital and labor income produces only small welfare gains, while consumption tax policy coordination produces sizable welfare gains.

- JEL Classification: F4, E6;
- Key Words: optimal tax, procyclical, countercyclical, stabilization, cooperation.

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1 Introduction

Under certain circumstances, fiscal policy can be effectively used for stabilization purposes. An example is monetary union such as the European Union where stabilizing monetary policy is not available for regional shocks.[1] Another case when monetary policy is ineffective is a deflationary economy with zero or negative real interest rate such as Japan in the late 1990s.[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 investigates an optimal simple tax policy rule in a dynamic stochastic general equilibrium model. In our model, a stabilization problem exists because a fixed amount of government spending should be financed by distortionary taxes (on consumption, and capital and labor income). We analyze tax policies that are active—contingent and fully committed in the sense that governments change tax rates in response to productivity shocks in the economy.[3] We derive the optimal level of tax rate adjustment to productivity shocks and calculate the amount of welfare gains from the optimal contingent tax policy against fixed (exogenous) tax policy.[4] In order to understand the mechanism behind welfare gains, we further decompose welfare gains into efficiency gains (mean effect generated by changes in the mean of the variables) and stabilization gains (variance effect generated by changes in the variance of the variables).

We study both closed and open economy models to examine how optimal tax policies behave under different assumptions for international capital markets. We assume that open economy models have incomplete asset markets with non-contingent bonds only. Two versions of the open economy model are considered: 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

[1] See, for example, Galí and Perotti (2003) and Galí (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 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. This is different from defining optimal tax policy as the best possible tax rate responses to disturbances and all the state variables, as in Chari et al. (1994).

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 different, then there is a room for welfare improvement via tax policy coordination. These results can provide plausible implications on potential welfare effects of international policy coordination.

This paper contributes to the literature in the following three 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 dramatically change under open economy because tax policies can have significant 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 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 is an example due to 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. We adopt the second-order perturbation method following Kim et al. (2004). It is crucial to adopt a second-order method in calculating the level of welfare because the conventional method of linearization, such as the one used in King, Plosser and Rebelo (1988), can produce inaccurate welfare calculation as documented in Kim and Kim (2003).

Our main findings are as follows. In the closed economy, optimal tax policy is countercyclical for all three types of taxes. Countercyclical tax

[5] Papers with the closed economy setup include Greenwood and Huffman (1991), McGrattan (1994), Chari et al. (1994) and Kletzer (2005). 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 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).

policy produces stabilization gains that outweigh efficiency loss. 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. Efficiency gains of procyclical tax policy outweigh stabilization loss, improving the overall 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 factor 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 two-country model of a production economy with capital and labor. We also explain the second-order accurate solution method. Section 3 reports simulation results for welfare implications of optimal tax policy in both the closed and open economies. We analyze two versions of the open economy model: small open economy and two-country models. In order to help interpret the welfare results, we examine impulse responses of main macro variables to a positive productivity shock with countercyclical and procyclical tax policies. Section 4 provides the results of tax policy transmission and coordination. We compare non-cooperative Nash equilibrium and 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 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:

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

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).

[8] Using the 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.

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

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

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.[9]

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. A No-Ponzi-Game condition is imposed on the household's borrowing.

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

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

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.[10] 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

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

[9] See Kim (2003) for comparison of this with other specifications of investment adjustment costs.

[10] 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 size of bond holding costs quite low.

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 deviate from the Ramsey tradition and take the steady state tax rates from the data, not from an optimization problem. Active (contingent) and fully committed tax policy means that governments change tax rates according to the observed current-period productivity.[11] 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).[12] 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.[13]

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

[11] Another possible form of tax policy is to change tax rate in response to the changes in directly observable data such as output. However, both types of policies give similar results.

[12] 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..

[13] 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. (2004) for more on this.

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) for 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).[14] 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. These estimates, however, can be sensitive to cyclical factors and shocks to tax revenues and bases.

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. We also estimate persistence of tax rates assuming an AR(1) structure. 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).

[14] 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.

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.

2.4 Solution Method

We adopt a second-order accurate solution method to correctly calculate the level of welfare. The conventional linearization method, as in King, Plosser and Rebelo (1988), is widely known to be satisfactory in computing second moments such as variances and correlation coefficients. However, the linearization method can generate inaccurate results in terms of welfare calculations, especially in open-economy models.[15] We follow Kim et al. (2004) and adopt the second-order perturbation method to correctly calculate the level of welfare.

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 compared to 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. Next, we 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 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

[15] Kim and Kim (2003) showed that the conventional linearization is so inaccurate as to generate a paradoxical result of spurious welfare reversal: the level of welfare under autarky is higher than that of the complete markets economy using a two-country model.

rates are positive, which introduce distortions in the static and intertemporal optimality conditions. Therefore, contingent tax policies can improve welfare by reducing distortions in those conditions. 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).[16] 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. Fluctuations of tax rates according to these optimal policies are within the range of empirical observations in Table 1.

Welfare gains from 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% of permanent consumption for consumption, capital income and labor income taxes, 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 0.05% of permanent consumption (Lucas, 1987).

In order to understand the mechanism behind these welfare gains, we further decompose welfare gains into efficiency gains (mean effect generated by changes in the conditional mean of the variables) and stabilization gains (variance effect generated by changes in the conditional variance of the variables).[17] Table 2 shows that in every case under autarky, welfare gains of countercyclical tax policy come from the variance effects. Countercyclical tax policy reduces volatility of the variables and stabilizes the economy. These stabilization gains exceed the efficiency loss due to negative mean effects.

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

[17] See Kollmann (2002) and Bergin and Tchakarov (2004) for similar decomposition of welfare gains.

3.2 Small Open Economy

In this section, we use the small open economy model with exogenously fixed interest rate and calculate optimal tax policies and welfare gains. The main results are reported in Table 2. First, optimal η_c for consumption tax becomes less countercyclical, decreasing to $0.3 \sim 1.4$ (it was $2.5 \sim 2.7$ 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 there is no labor mobility across countries, while consumption and capital goods can be traded across countries.

In an open economy, the current account works as buffer stock against productivity shocks and plays a role for consumption smoothing (other than investment channel which 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 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 (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. These efficiency gains exceed stabilization loss from procyclical tax policy. When $\rho = 0.9$, efficiency gains (mean effect) are 0.006% of permanent consumption, which outweighs stabilization loss (variance effect) of 0.005%. This channel is not available in the closed-economy model where extra output should be consumed domestically. In the closed economy, 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 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 satisfies 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 open economy.

In order to understand the mechanism behind welfare gains, we compare welfare gains from procyclical and countercyclical tax policy when there are 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 mean effect and variance effect. We further decompose mean effect into consumption mean effect and labor mean effect. The results show that procyclical tax policy generates positive variance effects and negative mean effects in all cases, while countercyclical policy generates opposite results (negative variance effects and positive mean effects) in all cases.

To further understand the mean and variance effects, we draw impulse responses.[18] Figures 2-7 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 effects. 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

[18] These impulse responses are based on the "pruned" solution of the second-order perturbation method, as suggested in Kim et al. (2004).

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 loss 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% than the fixed tax policy 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 loss.

These results are analogous to the implications provided by 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.[19] 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 Two Country Model

In the two country world, 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 in the simple exposition of 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).

[19] See, for example, Ireland (1996), Obstfeld and Rogoff (2002), and Kim and Henderson (2005).

Table 2 shows optimal tax policies derived in the two country model. For all three taxes, optimal η's are similar to those in the small open economy case, in particular labor income tax. Welfare 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 spillovers) = 0, ψ (contemporaneous cross-country correlation of shocks) = 0. We first examine the case when bond holding adjustment costs increase ($\zeta = 0.1$). 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 spillovers of productivity shocks across countries (positive ν). An increase in ν has the same effects as increasing persistence of shocks (ρ). Therefore optimal η's when $\rho = 0.9$ and $\nu = 0.08$ become quite similar to the optimal η's with $\rho = 0.95$ and $\nu = 0$.[20] Finally, we experiment by increasing contemporaneous correlation of shocks ($\psi = 0.5$). An increase in ψ has similar effects as increasing shock persistence. Therefore, optimal η_s' become similar to those with high shock persistence and welfare gains of optimal tax policy also increase.

4 Non-cooperative and Cooperative Equilibrium

In this section, we relax the assumption that tax rates are fixed in foreign countries and analyze optimal tax policy of domestic country when 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 throughout 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 maxi-

[20] See Kim et al. (2003) for detailed explanation of the relationship between shock persistence and spillovers in an incomplete markets model.

mum welfare gains are quite small at 0.0005% of permanent consumption, as shown in Table 5. Countercyclical consumption tax policy generates positive spillovers to foreign country as foreign country's 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 taxes, the best response curves come out as 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 gains under the cooperative equilibrium in the case of labor income tax.

In sum, 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

The conventional idea in the literature is that optimal tax policy is countercyclical rather than procyclical. We have shown that this proposition—though true in a closed economy—may not hold in the open economy where countries can trade international bonds for 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 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 loss, improving overall welfare. We also show that positive welfare gains of active tax policy can 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 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:

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

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
	mean effect	-0.020	-0.04	-0.09
	variance effect	0.028	0.05	0.12
Small Open	optimal η	*0.3*	*0.7*	*1.4*
	welfare gains	0.0002	0.001	0.012
	mean effect	-0.0037	-0.0143	-0.066
	variance effect	0.0039	0.0158	0.078
Two Country	optimal η	*0.1*	*0.4*	*1.0*
	welfare gains	0.00003	0.0005	0.005
	mean effect	-0.00195	-0.0121	-0.062
	variance effect	0.00198	0.0126	0.067

<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
	mean effect	-0.0002	-0.001	-0.007
	variance effect	0.0017	0.004	0.012
Small Open	optimal η	*-1.6*	*-0.5*	*0.3*
	welfare gains	0.006	0.001	0.001
	mean effect	0.013	0.006	-0.009
	variance effect	-0.007	-0.005	0.010
Two Country	optimal η	*-1.2*	*-0.3*	*0.1*
	welfare gains	0.002	0.0004	0.0001
	mean effect	0.006	0.0027	-0.0025
	variance effect	-0.004	-0.0023	0.0026

<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
	mean effect	-0.00161	-0.0057	-0.0197
	variance effect	0.00165	0.0059	0.0211
Small Open	optimal η	*0*	*0.06*	*0.17*
	welfare gains	0	0.0001	0.002
	mean effect	0	-0.0029	-0.020
	variance effect	0	0.0030	0.022
Two Country	optimal η	*0.19*	*0.21*	*0.24*
	welfare gains	0.001	0.002	0.004
	mean effect	-0.005	-0.008	-0.026
	variance effect	0.006	0.010	0.030

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. 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.

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 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.

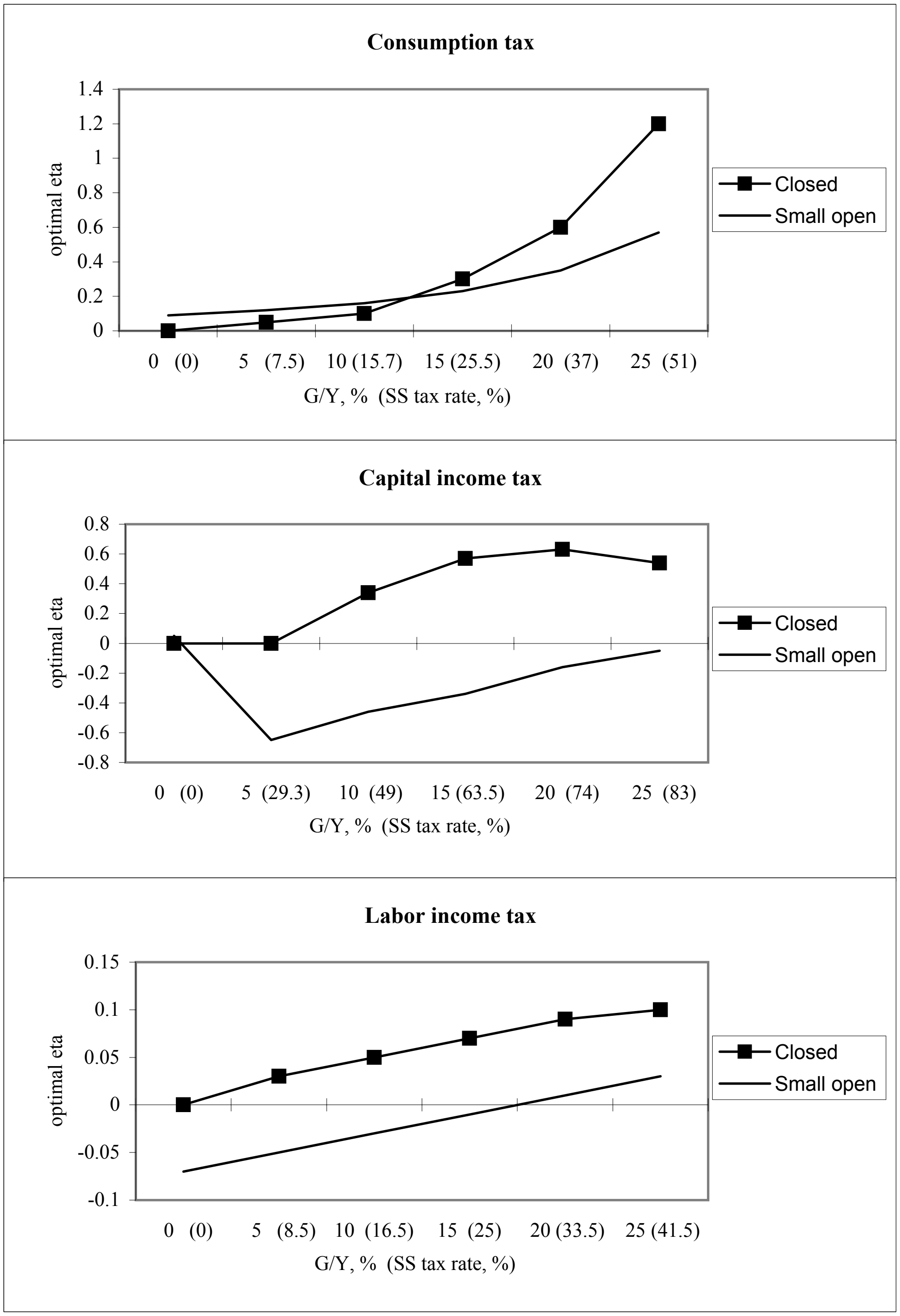
Table 5. Welfare effects of tax policy coordination

	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

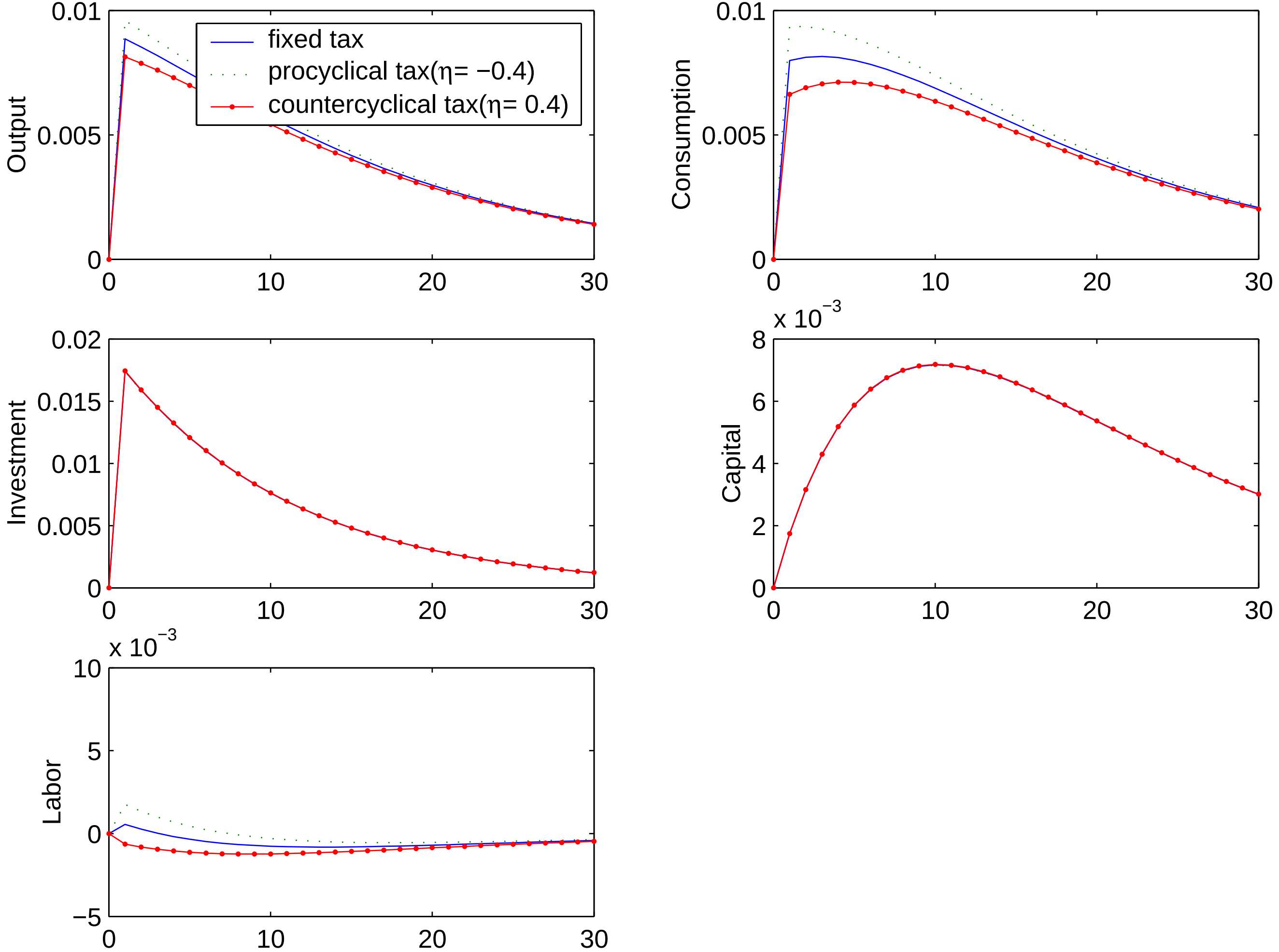


Figure 3. Impulse responses to positive productivity shock (closed economy): K−tax

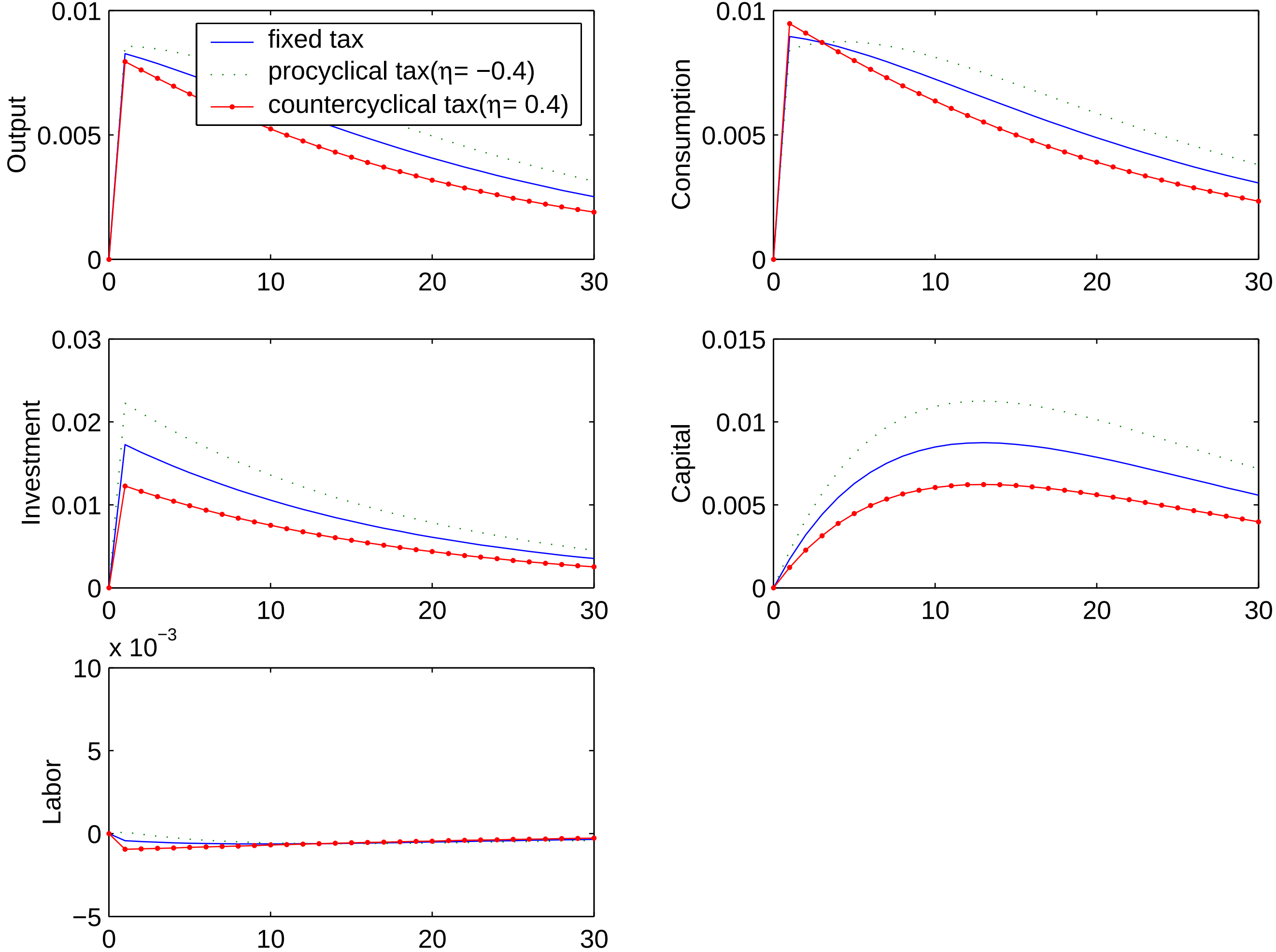


Figure 4. Impulse responses to positive productivity shock (closed economy): L−tax

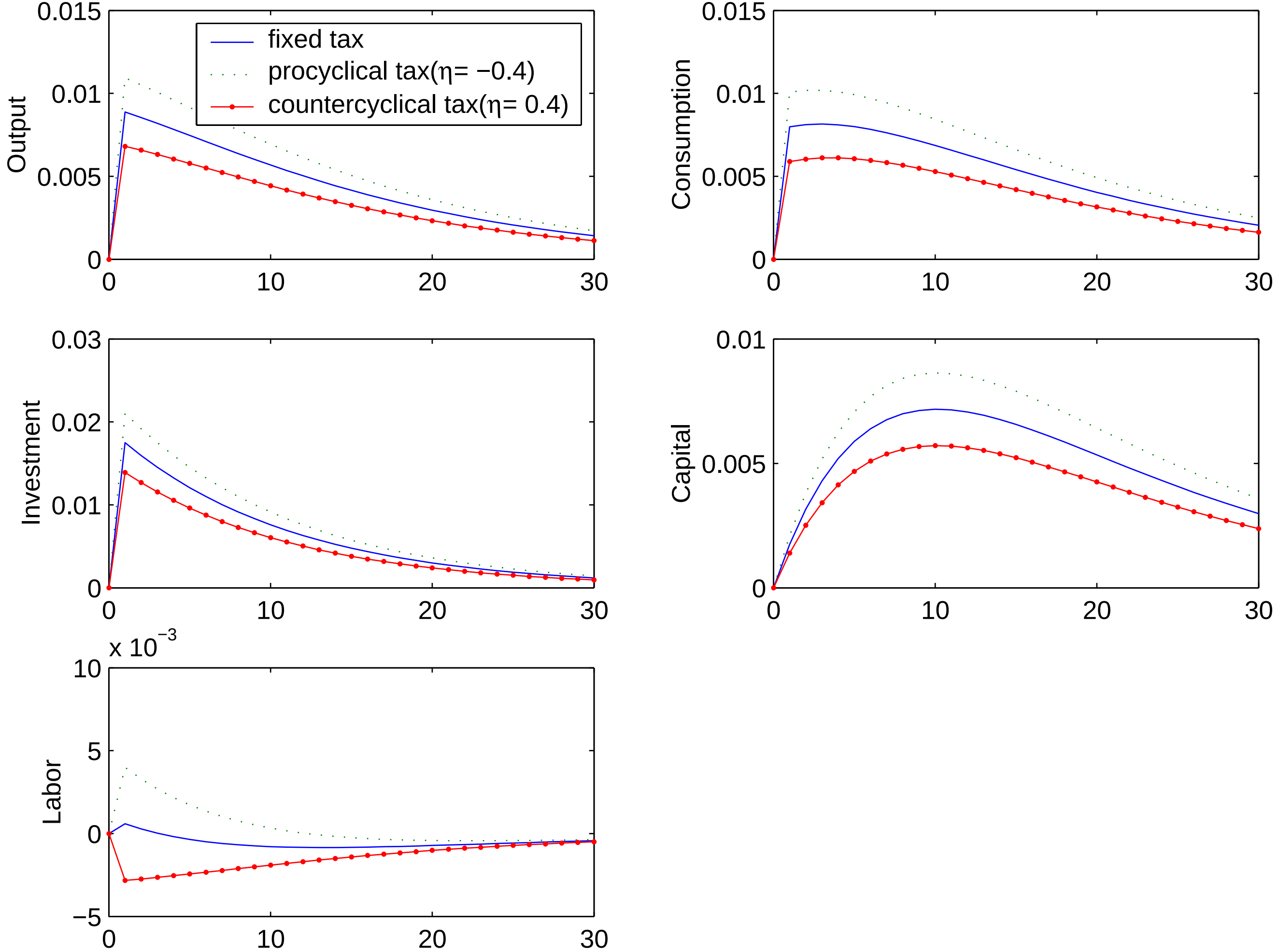


Figure 5. Impulse responses to positive productivity shock (small open economy): C−tax

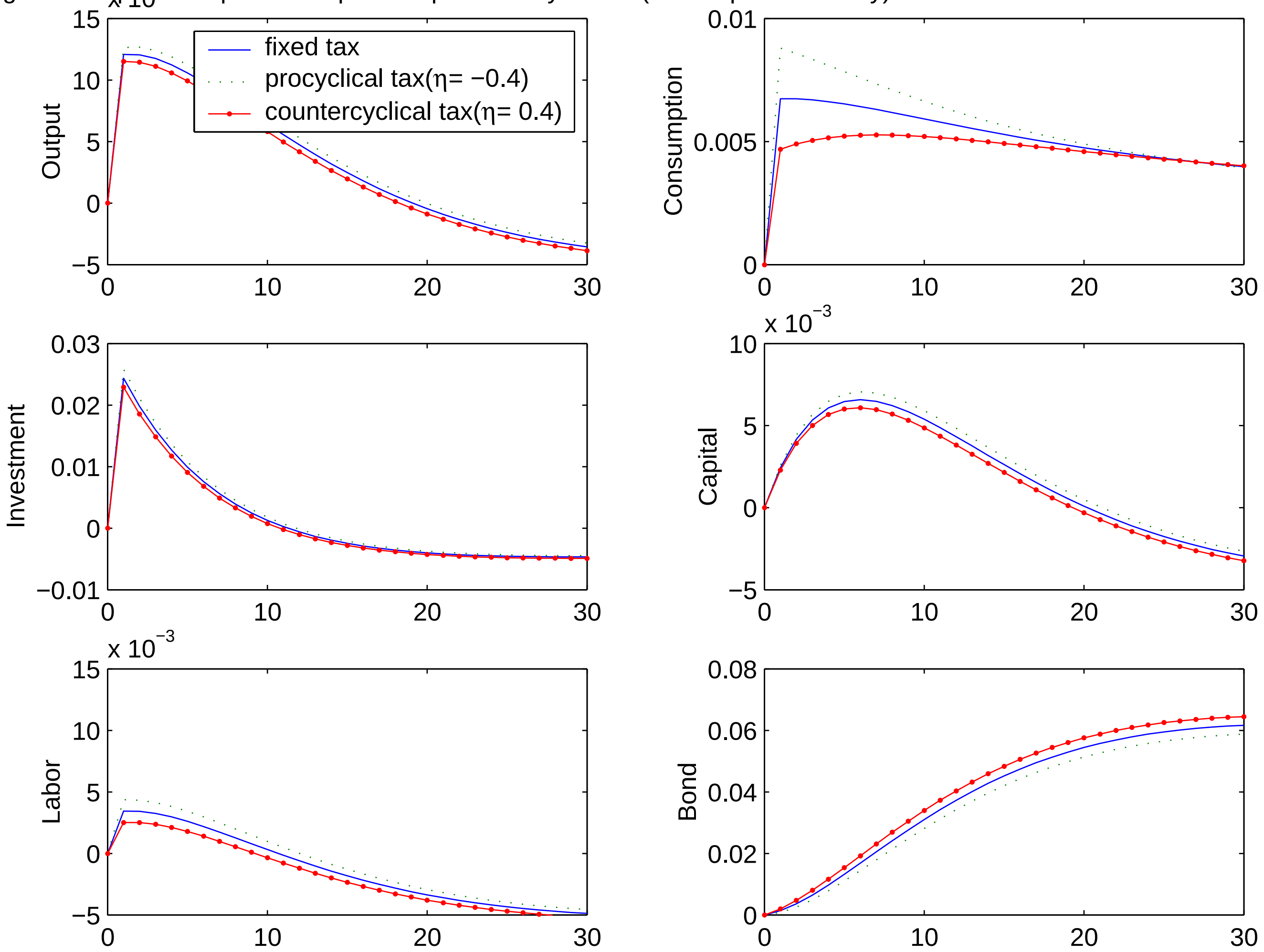


Figure 6. Impulse responses to positive productivity shock (small open economy): K−tax

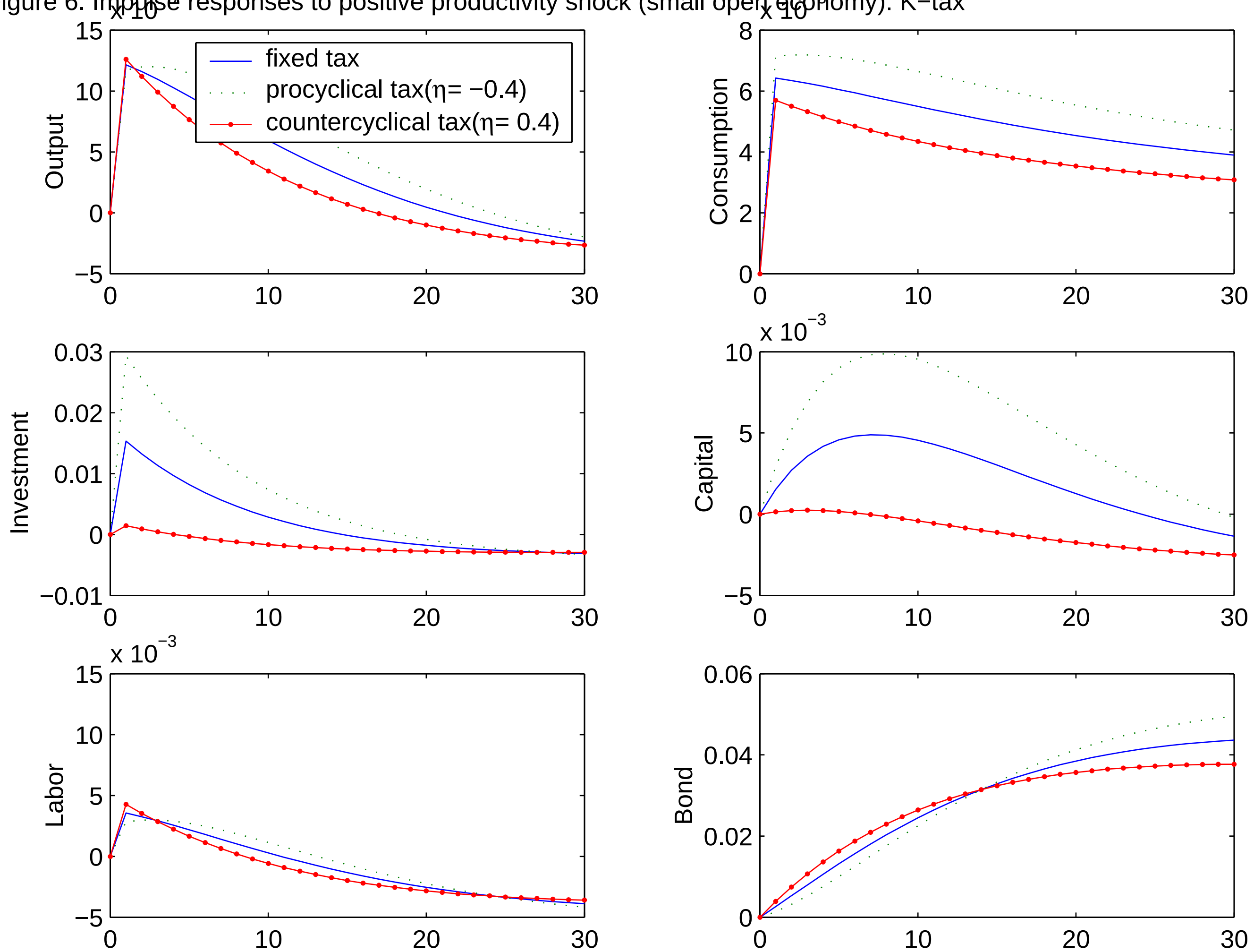


Figure 7. Impulse responses to positive productivity shock (small open economy): L−tax

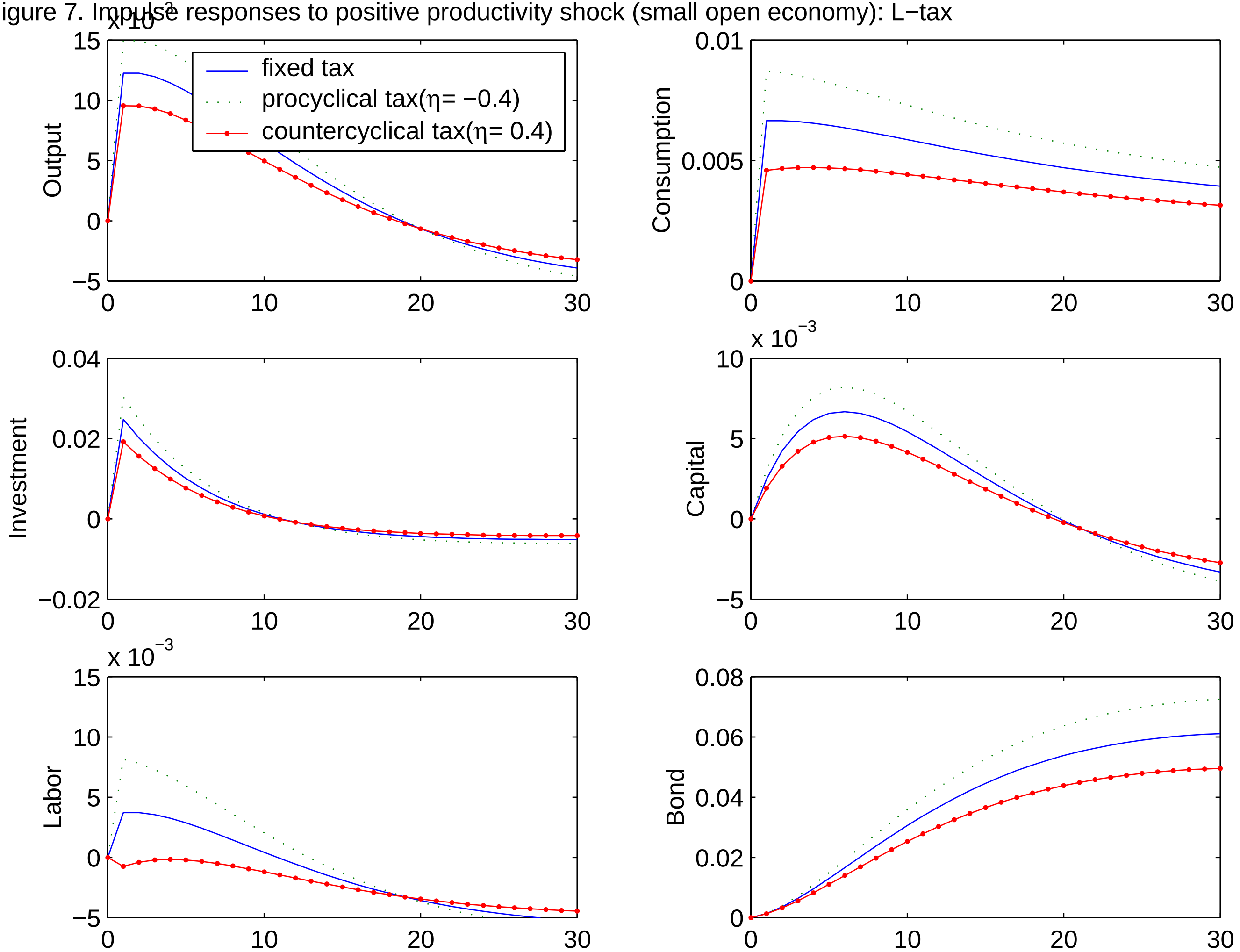
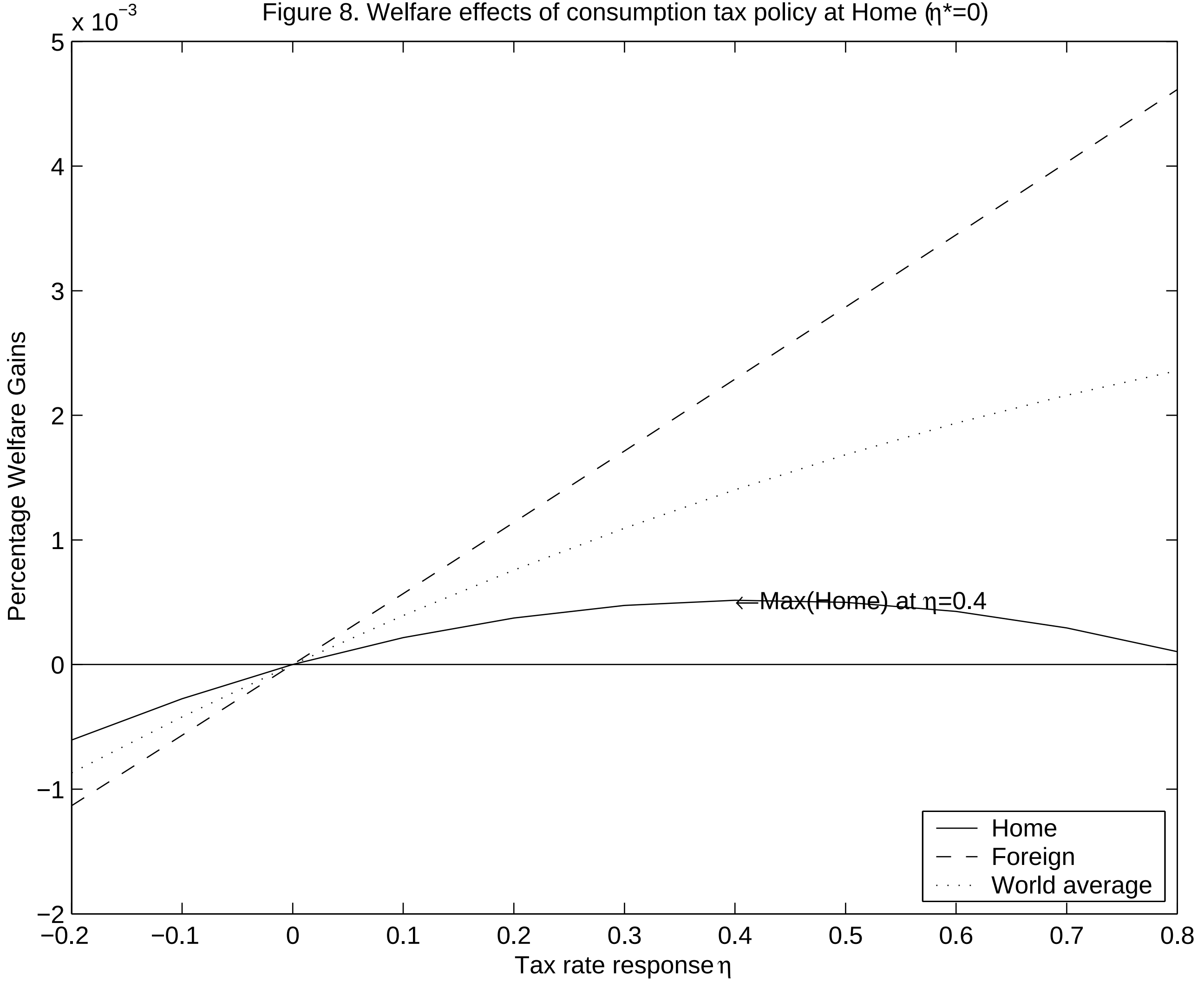


Figure 8. Welfare effects of consumption tax policy at Home (η*=0)



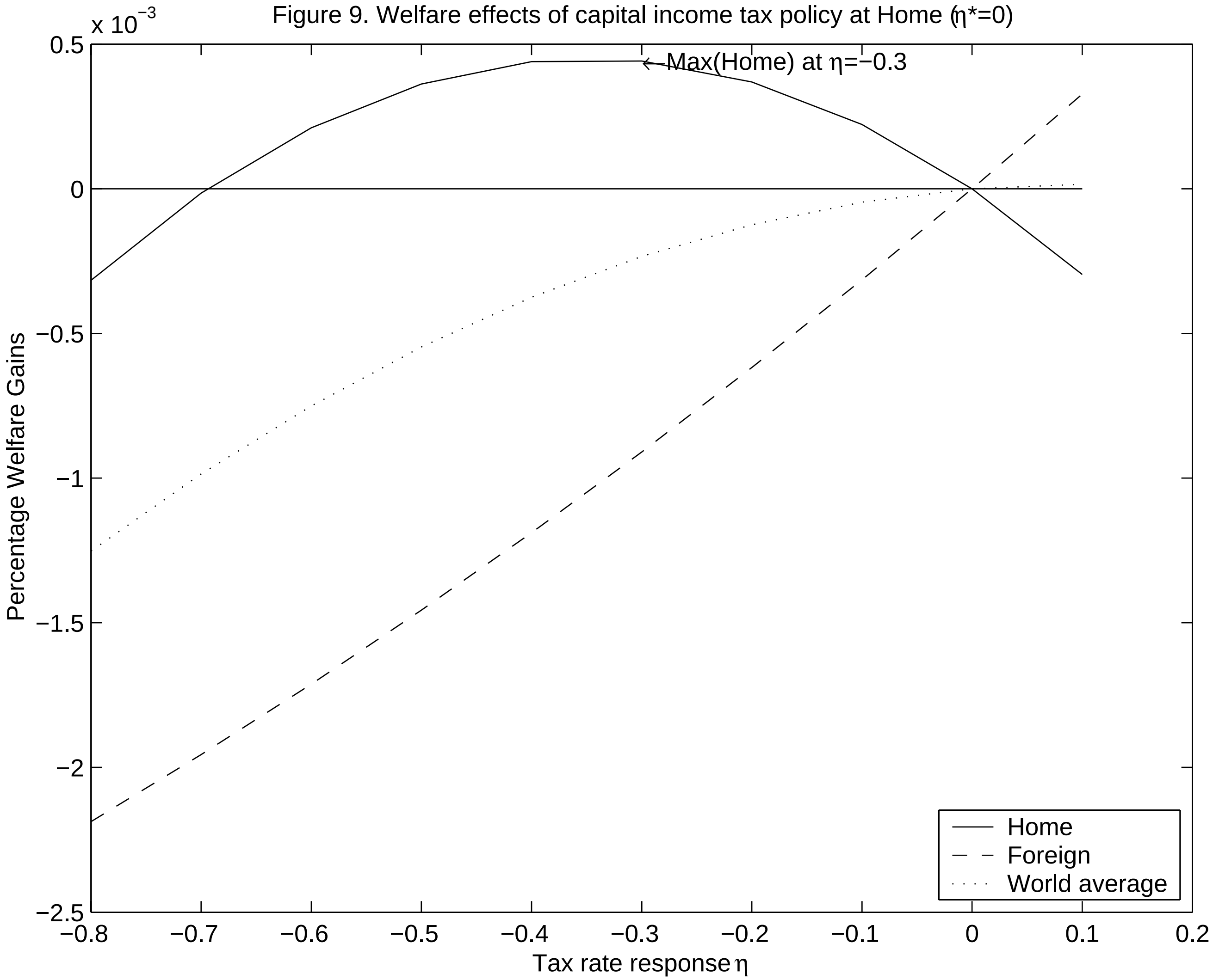


Figure 9. Welfare effects of capital income tax policy at Home (η*=0)
x 10^−3
0.5
0
−0.5
−1
−1.5
−2
−2.5
Percentage Welfare Gains
Max(Home) at η=−0.3
Home
Foreign
World average
−0.8
−0.7
−0.6
−0.5
−0.4
−0.3
−0.2
−0.1
0
0.1
0.2
Tax rate response η

Figure 10. Welfare effects of labor income tax policy at Home ($\eta^*=0$)