Journal of Rural Development 18 (Summer 1995) : 121~141

COOPERATIVE AND NON-COOPERATIVE FISCAL POLICY IN ASYMMETRIC MODEL

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I. Introduction

Strategic fiscal policies are an important issue in a world with high capital mobility. One country's tax policy can be affected significantly by the other countries' policies in a world with highly mobile capital. The amount of one government's expenditures can affect economic activities of other countries.

The subject discussed in this paper is the cooperative and non-cooperative tax rates. If one country's purpose does not coincide with those of other countries, this may induce a strategic reaction in the spirit of the game theory. Previous studies show that there is little difference between cooperative and non-cooperative tax policies in a world economy in which all countries are small and strategic interactions between policymakers are not strong. However, this paper shows that optimal cooperative tax policies can be different from non-cooperative tax policies in an asymmetric model. It is found that the non-cooperative tax rate is smaller than the cooperative tax rate.

Recent theoretical works by Hamada(1986), Kehoe(1987), and Ghosh(1991) demonstrate the optimal level of taxation in integrating the world economy. Hamada(1986) addresses the question of interdependence of national fiscal policies through the channel of equalization of real interest rates among countries. Kehoe(1987) analyzes the difference between coordinated and non-coordinated policies. Unlike Hamada(1986) and Kehoe(1987), Ghosh(1991) assumes the existence of distortionary taxes. He compares the provision of public goods under the cooperative and non-cooperative

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tax policies. He concludes that the non-cooperative regime may result in either and over- or and under-provision of public goods.

The structure of the model follows Ghosh(1991) closely. The main difference between Ghosh(1991) and this paper is that Ghosh(1991) assumes the source principle[1] and this paper assumes the residence principle.

In this paper, a two-country two-period model is adopted in which capital can move freely between the two countries. For the analytical tractability, a log utility function and $f(K) = 40\sqrt{k}$ product function are adopted for analytical purpose. This numerical investigation allows to compare the Nash equilibrium tax rate and cooperative equilibrium tax rate.

The remainder of this paper is organized as follows. Section II provides the characteristics of the model. The Nash and the cooperative equilibriums in asymmetric model are presented in section III. In section IV, the conclusion is provided.

II. Characteristics of The Model

This paper considers a simple-two-country two-period model with free capital mobility. There are two countries, a home country(lender) and a foreign country(borrower), producing the same goods that can be consumed, invested, or spent by the government. Population is the same in each country. The representative individual in each country has the same preference on consumption bundles. The representative consumer plans the consumption path for the two periods. Both countries are assumed to adopt the residence principle for collecting tax. This assumption is based on the fact that most European countries and the *U. S.* adopt residence principle for individual tax and corporation tax.[2]

[1] The residence principle adopts the place of residency of the taxpayer as the basis for assessment of tax liabilities no matter where he lives, whereas the source principle uses the source of income as the basis for assessing tax liabilities regardless of where he is from.

[2] Denmark, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, United Kingdom, United States adopt residence principle as dominant tax principle for individual and corporate tax. Source: Lans Bovenberg and George Kopits, "Harmonization of Taxes on Capital Income and Commodities in the European Community," IMF, October 1989, and Individual Taxes: A Worldwide Summary, Price Waterhouse, 1989.

1. Tax System

Each government is assumed to impose capital income tax for the government expenditure by the residence principle. By the definition, people should pay tax to their home country no matter where they invest their capital, whether it be home or abroad. Accrued income from home and foreign investment is assessing tax liabilities.

It is worth noting that under the assumption of residence principle, the real rate of interest of the home country is always equal to the real rate of interest of the foreign country. (see Frenkel, Razin and Sadka 1991). Hence, the government expenditures for the home and foreign countries are given by

$$g = \theta rk + \theta r^* x = \theta r(k + x) = \theta rs,$$
$$g^* = \theta^* r^* k + \theta^* r x^* = \theta^* r(k + x^*) = \theta^* r s^*$$

where,
g = per capita government expenditures of the home country,
θ = capital income tax rate of the home country,
r = real rate of interest of the home country,
k = per-capita capital,
x = per-capita foreign net asset of the home country,
s = per-capita saving of the home country.

Similarly, g^*, θ^*, r^*, k^*, x^*, and s^* denote that of the foreign country, respectively. Under residence principle, the government expenditures are given by $g^i = \theta^i r k^i$ where i denotes home or foreign country.[3]

In this two-country model, the sum of per-capita foreign net asset of the home and foreign country, $x + x^*$, is equal to zero.

It is assumed that the government of each country has a

[3] Under source principle, the government expendityres are given by
$g = \theta rk,$
$g^* = \theta^* r^* s^* + \theta^* r^*(s - k).$
Using the world savings constraint, $s - k = k^* - s^*$ (since $k + k^* = s + s^*$), the above foreign government expenditures can be written as $g^* = \theta^* r^* s^* + \theta^* r^* (k^* - s^*) = \theta^* r^* k^*$. Therefore, we can rewrite the above government expenditures as $g^i = \theta^i r k^i$.

spending project only in the second period.

2. Model

Let $U(c_1, c_2)$ denote the utility of the representative consumer in the home country that is derived from the per capita consumption c_1 in time period 1 and c_2 in time period 2. Similarly, $U^*(c_1^*, c_2^*)$ denotes the utility of the representative individual in the foreign country. Every variable with an asterisk indicates a variable in the foreign country. In the first period, both countries possess the income y and y^* that can be either consumed by consumers or spent by the government, or invested for future consumption in the next period. This utility function is assumed to be homothetic. The production function is denoted by $f(k)$. The function $f(\cdot)$. transforms k into output $f(k)$. The real rate of interest, r, is defined by $f'(k) = 1 + r$. Thus, $r = f'(k) - 1$, which implies that the home capital k is equal to foreign capital k^*, since the home interest rate r is always equal to the foreign interest rate r^* under residence principle. Capital is perfectly internationally mobile and can be provided from the saving of either the home or foreign consumer. Both governments are assumed to run a balanced budget. Individuals receive back savings with interest payment from the disposable incomes in the first period.
Labors in each country are immobile, work with capital stocks, and earn wages in the second period. The real wage rate is assumed to be

$$w = f(k) - (1 + r)k,$$

and it is identical in the two countries. It is assumed that the world capital market is perfect and that capital moves freely across the world.

The maximization problem that the representative individual faces in the home country, given the common rate of interest r, is

maximize $U(c_1, c_2)$
subject to

$$c_1 + \frac{c_2}{1 + (1 - \theta)r} = y + \frac{w}{1 + (1 - \theta)r} \tag{1}$$

The above budget constraint stems from the following conditions.

$$c_1 + s\ (= k + x) = y, \tag{2}$$

$$c_2 = s\ (1 + (1 - \theta)r) + w. \tag{3}$$

Similarly, the budget constraint in the foreign country is given by

$$c_1^* + \frac{c_2^*}{1 + (1 - \theta^*)r} = y^* + \frac{w}{1 + (1 - \theta^*)r}. \tag{4}$$

3. Consumer Solution

To obtain analytic solutions, the following log utility function is considered.

$$u(c_1, c_2) = \ln c_1 + \ln c_2$$

The optimal consumption of the home consumer can be obtained as

$$c_1 = \frac{1}{2}(y + \frac{w}{1 + (1 - \theta)r}), \tag{5}$$

$$c_2 = \frac{1 + (1 - \theta)r}{2}\ (y + \frac{w}{1 + (1 - \theta)r}), \tag{6}$$

which indicate that the first and second period consumption depend on the endowment, wage, the world interest rate, and the capital income tax rate.

Similarly, one can solve the optimal consumption for the foreign consumer as

$$c_1^* = \frac{1}{2}(y^* + \frac{w}{1 + (1 - \theta^*)r}), \tag{7}$$

$$c_2^* = \frac{1 + (1 - \theta^*)r}{2}(y^* + \frac{w}{1 + (1 - \theta^*)r}). \tag{8}$$

Saving in each country is given by

$$s = k + x = (y - c_1) = y - \frac{1}{2}(y + \frac{w}{1 + (1 - \theta)r}), \tag{9}$$

$$s^* = k^* + x^* = (y^* - c_1^*) = y^* - \frac{1}{2}(y^* + \frac{w}{1 + (1 - \theta^*)r}). \tag{10}$$

III. Cooperative and Non-Cooperative Fiscal Policy in Asymmetric Model

This section examines how the cooperative and non-cooperative tax rates differ in asymmetric models. To analyze the exact magnitude of the two different tax rates, a numerical method is adopted. As in the previous section, the log utility function is adopted. For the production function, $f(k) = 40\sqrt{k}$ is used in this section.

The home and foreign governments try to maximize the following objective functions, respectively.

$$V(c_1, c_2, g)$$
$$V^*(c_1^*, c_2^*, g^*)$$

1. Non-Cooperative Equilibrium

1.1. The Home Reaction Function

Suppose the home government tries to maximize $V(c_1, c_2, g)$ with respect to its capital income tax rate θ for a given value of foreign tax rate, θ^*. Given a functional form of an objective function, the home reaction function can be derived as below.

Max $V(c_1, c_2, g) = \ln c_1 + \ln c_2 + \ln g$
s.t.

$$c_1 = \frac{1}{2}(y + \frac{w}{1 + (1 - \theta)r}),$$

$$c_2 = \frac{1 + (1 - \theta)r}{2}(y + \frac{w}{1 + (1 - \theta)r}),$$

$$g = \theta rs.$$

Substituting all the equations into a value function yields

$$\begin{aligned}\text{Max } V &= 2 \ln \{y(1 + (1 - \theta)r) + w\} - \ln (1 + (1 - \theta)r) - 2 \ln 2 \\ &+ \ln \theta + \ln r + \ln (k + x).\end{aligned}$$

Taking derivative of the above objective function, w.r.t. θ yields the home reaction function given as

$$\begin{aligned}&\frac{2}{y(1 + (1 - \theta)r) + w}(-ry + y(1 - \theta)\frac{dr}{d\theta} - kf''\frac{dk}{d\theta}) \\ &- \frac{1}{(1 + (1 - \theta)r)}(-r + (1 - \theta)\frac{dr}{d\theta}) + \frac{1}{\theta} + \frac{1}{r}\frac{dr}{d\theta} + \frac{1}{k + x}\frac{d(k + x)}{dq} = 0.\end{aligned}$$

which is equal to

$$\begin{aligned}&\frac{-2ry}{y\Delta + w} + \frac{1 + r}{\theta\Delta} - \frac{rw}{4\Delta^2 H}[\frac{2f''(y(1 - \theta) - k}{y\Delta + w} \\ &+ \frac{f''}{r\Delta} + \frac{2\Delta}{y\Delta - w}(2 - \frac{f''k}{2\Delta^*} - \frac{f''w(1 - \theta^*)}{2\Delta^{*2}})] = 0\end{aligned}$$

where, for the above equations

$$\frac{dk}{d\theta} = - \frac{rw}{4\Delta^2 H},$$

$$\frac{d(k + x)}{d\theta} = - \frac{rw}{4\Delta^2 H}(2 - \frac{f''k}{2\Delta^*} - \frac{f''w(1 - \theta^*)}{2\Delta^{*2}}),$$

$$H = 1 - \frac{f''k}{4}(\frac{1}{\Delta} + \frac{1}{\Delta^*}) - \frac{f''w}{4}(\frac{1 - \theta}{\Delta^2} + \frac{1 - \theta^*}{\Delta^{*2}}),$$

where, $\Delta = 1 + (1 - \theta)r > 0$ and $\Delta^* = 1 + (1 - \theta^*)r > 0$.

The home reaction function can be explicitly obtained in terms of θ and θ^* with $f(k) = 40\sqrt{k}$ production function and the market capital condition. The market capital condition can be derived as follows.

$$k = \frac{1}{4}(y + y^* - \frac{w}{1 + (1 - \theta)r} - \frac{w}{1 + (1 - \theta^*)r}). \tag{11}$$

TABLE 1 The Projection of Home Tax Rate in Home Reaction Curve: Home Reaction Curve ($f(k) = 40\sqrt{k}, y = 1.1, y^* = 0.9$)

$$\frac{-2ry}{y\Delta + w} + \frac{1+r}{\theta\Delta} - \frac{rw}{4\Delta^2 H}\left[\frac{2f''(y(1-\theta)-k)}{y\Delta + w} + \frac{f''}{r\Delta} + \frac{2\Delta}{y\Delta - w}\left(2 - \frac{f''k}{2\Delta^*} - \frac{f''w(1-\theta^*)}{2\Delta^{*2}}\right)\right]$$
$$= 0$$

θ^*	θ
0.1	0.516610
0.2	0.519560
0.3	0.523106
0.4	0.527401
0.5	0.532708
0.6	0.539379
0.7	0.547846
0.8	0.558215
0.9	0.566431

The home tax rate is calculated at $y = 1.1$ and $y^* = 0.9$[4] assuming the foreign tax rates are given. The results are in Table 1. As the foreign tax rate rises, the home tax rate rises in the home reaction function. When the foreign tax rate is 0.1, the home tax rate is 0.516610. It increases to 0.532708 as the foreign tax rate increases to 0.5.

1.2. The Foreign Reaction Function

As for the home reaction function, let us suppose the foreign government tries to maximize $V^*(c_1^*, c_2^*, g^*)$ with respect to its

[4] It is assumed that the home country is a capital exporting country and the foreign country is a capital importing country. There is no doubt that the endowment of capital exporting country is greater than that of a capital importing country.

capital income tax rate θ^* for a given value of home tax rate, θ. Given a functional form of an objective function, the foreign reaction function can be obtained.

Max $V^*(c_1{}^*, c_2{}^*, g^*) = \ln c_1{}^* + \ln c_2{}^* + \ln g^*$
s.t.

$$c_1^* = \frac{1}{2}(y^* + \frac{w}{1 + (1 - \theta^*)r})$$

$$c_2^* = \frac{1 + (1 - \theta^*)r}{2}(y^* + \frac{w}{1 + (1 - \theta^*)r})$$

$$g^* = \theta^* r s^*$$

Substituting all the equations into value function yields,

$$\text{Max } V = 2\ln \{y^*(1 + (1 - \theta^*)r) + w\} - \ln (1 + (1 - \theta^*)r) - 2\ln 2 + \ln \theta^* + \ln \mathrm{r} + \ln (k + x^*).$$

Taking derivative of the above objective function, w.r.t. θ^* yields the foreign reaction function given as

$$\frac{2}{y^*(1 + (1 - \theta^*)r) + w}(-ry^* + y^*(1 - \theta^*)\frac{\mathrm{d}r}{\mathrm{d}\theta^*} - kf''\frac{\mathrm{d}k}{\mathrm{d}\theta^*})$$

$$-\frac{1}{(1 + (1 - \theta^*)r)}(-r + (1 - \theta^*)\frac{\mathrm{d}r}{\mathrm{d}\theta^*}) + \frac{1}{\theta^*} + \frac{1}{\mathrm{r}}\frac{\mathrm{d}r}{\mathrm{d}\theta^*} + \frac{1}{k + x^*}\frac{\mathrm{d}(k + x^*)}{\mathrm{d}\theta^*} = 0,$$

which is equal to

$$\frac{-2ry^*}{y\Delta^* + w} + \frac{1 + r}{\theta^*\Delta^*} - \frac{rw}{4\Delta^{*2}H}[\frac{2f''(y^*(1 - \theta^*) - k}{y^*\Delta^* + w}$$

$$+\frac{f''}{r\Delta^*} + \frac{2\Delta^*}{y^*\Delta^* - w}(2 - \frac{f''k}{2\Delta} - \frac{f''w(1 - \theta)}{2\Delta^2})] = 0,$$

where, for the above equations

$$\frac{dk}{d\theta^*} = -\frac{rw}{4\Delta^{*2}H},$$

$$\frac{d(k+x^*)}{d\theta^*} = -\frac{rw}{4\Delta^{*2}H}\left(2 - \frac{f''k}{2\Delta^*} - \frac{f''w(1-\theta)}{2\Delta^2}\right),$$

$$H = 1 - \frac{f''k}{4}\left(\frac{1}{\Delta} + \frac{1}{\Delta^*}\right) - \frac{f''w}{4}\left(\frac{1-\theta}{\Delta^2} + \frac{1-\theta^*}{\Delta^{*2}}\right),$$

$$\Delta = 1 + (1-\theta)r > 0 \text{ and } \Delta^* = 1 + (1-\theta^*)r > 0.$$

with the market capital condition which is equation (11), the foreign reaction function can be expressed in terms of θ and θ^*. The foreign tax rate is calculated at $y = 1.1$ and $y^* = 0.9$ assuming the home tax rates are given. The results are summarized in Table 2.

As the home tax rate increases, the foreign tax rate increases. When the home tax rate is 0.1, the foreign tax rate is 0.461806. It rises to 0.486341 as the home tax rate increases to 0.5.

TABLE 2 The Projection of Foreign Tax Rate in Foreign Reaction Curve: Foreign Reaction Curve ($f(k) = 40\sqrt{k}$, $y = 1.1$, $y^* = 0.9$)

$$\frac{-2ry^*}{y\Delta^* + w} + \frac{1+r}{\theta^*\Delta^*} - \frac{rw}{4\Delta^{*2}H}\left[\frac{2f''(y^*(1-\theta^*) - k)}{y^*\Delta^* + w}\right.$$

$$\left. + \frac{f''}{r\Delta^*} + \frac{2\Delta^*}{y^*\Delta^* - w}\left(2 - \frac{f''k}{2\Delta} - \frac{f''w(1-\theta)}{2\Delta^2}\right)\right] = 0$$

θ	θ^*
0.1	0.461806
0.2	0.466235
0.3	0.471571
0.4	0.478121
0.5	0.486341
0.6	0.496933
0.7	0.510981
0.8	0.529990
0.9	0.553171

1.3. Nash Equilibrium

The Cournot-Nash equilibrium is given at the intersection of the home and foreign reaction curves. The home reaction curve is given by

$$\frac{-2ry}{y(1+(1-\theta)r)+w}+\frac{1+r}{\theta(1+(1-\theta)r)}$$
$$-\frac{rw}{4(1+(1-\theta)r)^2H}\left[\frac{2f''(y(1-\theta)-k}{y(1+(1-\theta)r)+w}+\frac{f''}{r(1+(1-\theta)r)}\right.$$
$$\left.+\frac{2(1+(1-\theta)r}{y(1+(1-\theta)r)-w}\left(2-\frac{f'k}{2(1+(1-\theta^*)r)}-\frac{f'w(1-\theta^*)}{2(1+(1-\theta^*)r^2}\right)\right]$$
$$=0.$$

The foreign reaction curve is given by

$$\frac{-2ry^*}{y^*(1+(1-\theta^*)r)+w}+\frac{1+r}{\theta^*(1+(1-\theta^*)r)}$$
$$-\frac{rw}{4(1+(1-\theta^*)r)^2H}\left[\frac{2f''(y^*(1-\theta^*)-k}{y^*(1+(1-\theta^*)r)+w}+\frac{f''}{r(1+(1-\theta^*)r)}\right.$$
$$\left.+\frac{2(1+(1-\theta^*)r}{y^*(1+(1-\theta^*)r)-w}\left(2-\frac{f'k}{2(1+(1-\theta)r)}-\frac{f'w(1-\theta)}{2(1+(1-\theta)r^2}\right)\right]$$
$$=0.$$

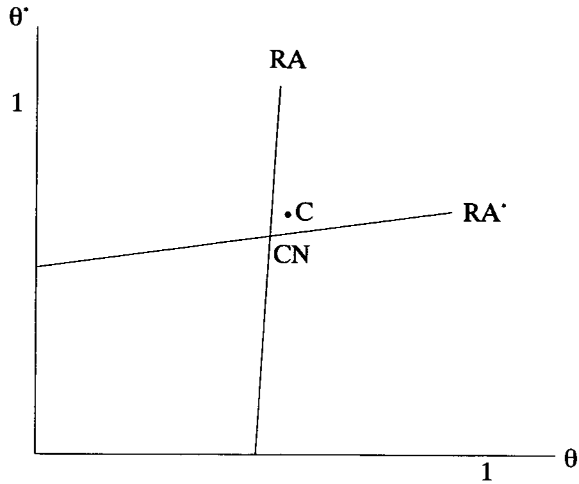
with the market capital condition which is equation (11), the Nash equilibrium can be solved. By the virtue of numerically tractable production function, the Nash equilibrium can be solved numerically.[5]

The home and foreign endowments are assumed at 1.1 and 0.9 respectively. The home and foreign reaction curves are drawn in Figure 1. It is found that the exact Cournot-Nash equilibrium is at θ = 0.532093 and θ^* = 0.489432. The home Nash equilibrium tax rate is greater than the foreign Nash equilibrium tax rate.

The level of objective function is compared. For the home country, the calculated value of objective function is 4.32953. It is a sum of the level of private goods (2.53557) and the level of public goods (1.79396). For the foreign country, the calculated value of

[5] IMSL package is used to find the equilibrium point numerically. The program is attached in the appendix.

FIGURE 1 Cournot-Nash vs. Cooperative Eqilibrium



Note: RA: Reaction curve of the home country
RA*: Reaction curve of the foreign country
CN: The Cournot-Nash Equilibrium
C: The Cooperative Equilibrium

objective function is 3.686635. It is a sum of the level of private goods(2.295812) and the level of public goods(1.390824). Naturally, the level of an objective function of the home country is higher than that of the foreign country. Since the home country is a capital exporting country and the foreign country is a capital importing country. It is found that the level of government spending of the home country is higher than that of the foreign country, which implies that more public goods are provided in the home country than in the foreign country.

2. Cooperative Equilibrium

If the two governments coordinate to maximize the joint welfare, then the result will be same as that of a single global social planner 's maximization solution.

$$W = \rho V + (1 - \rho)V$$

Since the country size can be determined by the initial endowments, $\rho = y / (y + y^*)$ is chosen. The joint welfare function can be written as,

$$W = \frac{y}{y/(y+y^*)}(\ln c_1 + \ln c_2 + \ln g) +$$

$$\frac{y^*}{(y+y^*)}(\ln c_1^* + \ln c_2^* + \ln g^*)$$

s.t.

$$c_1 = \frac{1}{2}(y + \frac{w}{1 + (1 - \theta)r})$$

$$c_2 = \frac{1 + (1 - \theta)r}{2}(y + \frac{w}{1 + (1 - \theta)r})$$

$$g = \theta rs$$

$$c_1^* = \frac{1}{2}(y^* + \frac{w}{1 + (1 - \theta^*)r}), \tag{7}$$

$$c_2^* = \frac{1 + (1 - \theta^*)r}{2}(y^* + \frac{w}{1 + (1 - \theta^*)r}), \tag{8}$$

$$g^* = \theta^* rs^*$$

The weighted objective function is

$$\begin{aligned}\text{Max } W = {} & y/(y + y^*)\,[2 \ln \{y(1 + (1 - \theta)r) + w\} \\ & - \ln (1 + (1 - \theta)r - 2 \ln 2 + \ln \theta + \ln r + \ln (k + x)] \\ & + y^* / (y^2 + y^*)\,[2 \ln \{y^*(1 + (1 - \theta^*)r) + w\} \\ & - \ln (1 + 1 - \theta^*)r) - 2 \ln 2 + \ln \theta^* + \ln r + \ln (k + x^*)].\end{aligned}$$

The first order optimum conditions with respect to θ is given by

$$= \frac{dW}{d\theta} = \frac{dV}{d\theta} + \frac{y^*}{y}\frac{dV^*}{d\theta}$$

$$= \frac{-2ry}{y(1+(1-\theta)r)+w} + \frac{1+r}{\theta(1+(1-\theta)r)}$$

$$- \frac{rw}{4(1+(1-\theta)r)^2H}\Big[\frac{2f''(y(1-\theta)-k)}{y(1+(1-\theta)r)+w} + \frac{f''}{r(1+(1-\theta)r)}$$

$$+ \frac{2(1+(1-\theta)r}{y(1+(1-\theta)r)-w}\Big(2 - \frac{f''k}{2(1+(1-\theta^*)r)} - \frac{f''w(1-\theta^*)}{2(1+(1-\theta^*)r)^2}\Big)\Big]$$

$$- \frac{y^*rw}{y4(1+(1-\theta)r)^2H}\Big[\frac{2f''(y^*(1-\theta^*)-k)}{y^*(1+(1-\theta^*)r+w} + \frac{f''}{r(1+(1-\theta^*)r)}$$

$$+ \frac{2(1+(1-\theta^*)r}{y^*(1+(1-\theta^*)r)-w}\Big(\frac{f''k}{2(1+(1-\theta^*)} + \frac{f''w(1-\theta^*)}{2(1+(1-\theta^*)r)^2}\Big)\Big],$$

which is equal to

$$= \frac{-2ry}{y\Delta+w} + \frac{1+r}{\theta\Delta} - \frac{rw}{4\Delta^2H}\Big[\frac{2f''(y(1-\theta)-k)}{y\Delta+w} + \frac{f''}{r\Delta}$$

$$+ \frac{2\Delta}{y\Delta-w}\Big(2 - \frac{f''k}{2\Delta^*} - \frac{f''w(1-\theta^*)}{2\Delta^{*2}}\Big)\Big]$$

$$- \frac{y^*rw}{y4\Delta^2H}\Big[\frac{2f''(y^*(1-\theta^*)-k)}{y^*\Delta^*+w} + \frac{f''}{r\Delta^*}$$

$$+ \frac{2\Delta^*}{y^*\Delta^*-w}\Big(\frac{f''k}{2\Delta^*} + \frac{f''w(1-\theta^*)}{2\Delta^{*2}}\Big)\Big].$$

The first order condition with respect to θ^* is given by

$$\frac{dW}{d\theta^*}$$

$$= \frac{y}{y^*} = \frac{dV}{d\theta^*} + \frac{dV}{d\theta^*}$$

$$= \frac{-2ry^*}{y^*(1+(1-\theta^*)r)+w} + \frac{1+r}{\theta^*(1+(1-\theta^*)r)}$$

$$- \frac{rw}{4(1+(1-\theta^*)r)^2H}\left[\frac{2f''(y(1-\theta^*)-k)}{y^*(1+(1-\theta^*)r)+w} + \frac{f''}{r(1+(1-\theta^*)r)}\right.$$

$$\left.+ \frac{2(1+(1-\theta^*)r}{y^*(1+(1-\theta^*)r)-w}\left(2 - \frac{f''k}{2(1+(1-\theta^*)r)} - \frac{f''w(1-\theta)}{2(1+(1-\theta)r)^2}\right)\right]$$

$$- \frac{rwy}{4y^*(1+(1-\theta^*)r)^2H}\left[\frac{2f''(y(1-\theta)-k)}{y(1+(1-\theta)r+w} + \frac{f''}{r(1+(1-\theta)r)}\right.$$

$$\left.+ \frac{2(1+(1-\theta)r}{y(1+(1-\theta)r)-w}\left(\frac{f''k}{2(1+(1-\theta)r)} + \frac{f''w(1-\theta)}{2(1+(1-\theta)r)^2}\right)\right],$$

which is equal to

$$= \frac{-2ry^*}{y^*\Delta^*+w} + \frac{1+r}{\theta^*\Delta^*} - \frac{rw}{4\Delta^{*2}H}\left[\frac{2f''(y^*(1-\theta^*)-k)}{y^*\Delta^*+w} + \frac{f''}{r\Delta^*}\right.$$

$$\left.+ \frac{2\Delta^*}{y^*\Delta^*-w}\left(2 - \frac{f''k}{2\Delta} \quad \frac{f''w(1-\theta)}{2\Delta^2}\right)\right]$$

$$- \frac{yrw}{y^*4\Delta^*\mathrm{H}}\left[\frac{2f''(y\,(1-\theta)-k)}{y\Delta+w} + \frac{f''}{r\Delta}\right.$$

$$\left.+ \frac{2\Delta}{y\Delta-w}\left(\frac{f''k}{2\Delta} + \frac{f''w(1-\theta)}{2\Delta^2}\right)\right].$$

For the $f(k) = 40\sqrt{k}$ production function, the following condition is derived.

$$f' = 20K^{-0.5}$$
$$f'' = -10K^{-1.5}$$

The firm's optimum condition is given by

$$f' = 1 + r$$
$$w = f(k) - (1 + r)k.$$

Solving the two first order conditions and the market capital condition simultaneously yield the equilibrium cooperative tax rate. When the home and foreign endowments are given at 1.1 and 0.9, the equilibrium home cooperative tax rate is 0.631075 and the equilibrium foreign cooperative tax rate is 0.583165. The cooperative equilibrium is drawn as in Figure 1. Compared to the Nash equilibrium, the equilibrium cooperative tax rate is greater for the both country. The cooperative equilibrium is located on the North-East side of the Cournot Nash equilibrium. When the home and foreign endowments are given at 1.1 and 0.9, the home non-cooperative tax rate is 0.513047 and the foreign non-cooperative tax rate is 0.489432.

Under cooperative regime, the level of objective function is calculated as 4.348102 for the home country and 3.734606 for the foreign country. For the home country, the level of private goods is 2.442688 and the level of public goods is 1.905414. For the foreign country, the level of private goods is 2.216735 and the level of public goods is 1.517871.

Under non-cooperative regime, the objective function value for the home and foreign country is 4.32953 and 3.686635. For the home country, it comes from a sum of the level of private goods(2.53557) and the level of public goods(1.79396). For the foreign country, the objective value is the level of private goods(2.295812) plus the level of public goods(1.390824), which implies that people have more satisfaction under cooperative regime. The value of objective function is higher under the cooperative regime(4.348102) than under non-cooperative regime(4.32953) for the home country. Also, the level of public goods is higher under the cooperative regime (1.905414) than under the non-cooperative regime(1.79396).

If each government acts on the belief that the other government's tax rate is given, the tax rates of both country are smaller than the cooperative tax rate.

IV. Conclusions

This paper shows that the optimal cooperative tax policies can be different from the non-cooperative tax policies. In an asymmetric model, the equilibrium non-cooperative tax rate for both countries turns out to be smaller than the equilibrium cooperative tax rate. This implies that the equilibrium cooperative tax rate is located on the North-East side of the Cournot-Nash equilibrium. It is found that the level of government spending of the home country is higher than that of the foreign country under non-cooperative regime, which implies that more public goods are provided in the home country than in the foreign country.

It is argued that people have more satisfaction under a cooperative regime. Since for the home country, the value of an objective function is higher under a cooperative regime than under a non-cooperative regime. And the level of public goods is higher under the cooperative regime than under the non-cooperative regime.

In comparison with Ghosh(1991), this paper is limited to the Cournot-Nash equilibrium. However, to analyze the Stackelberg equilibrium would be an interesting extension. Future study would include how the Cournot-Nash equilibrium can be different from the Stackelberg equilibrium.

APPENDIX

IMSL program for the cooperative tax rate in an asymmetric model

```
      IMPLICIT DOUBLE PRECISION(A-H, O-Z)
                    DECLARE VARIABLES
      INTEGER     ITMAX, N
      DOUBLE PRECISION   ERRREL
      PARAMETER   (N=3)
C
      INTEGER       K, NOUT
      DOUBLE PRECISION        FCN, FNORM, X(N), XGUESS(N)
      EXTERNAL  FCN, NEQNF, UMACH
C                   SET VALUES OF INITIAL GUESS
C                   XGUESS = (0.2 0.7 0.8)
C     DATA XGUESS/0.2, 0.5, 0.5/
C
      ERREL = 0.001
      ITMAX = 200
C
      CALL UMACH (2, NOUT)
C                   FIND THE SOLUTION
C     CALL DNEQNF (FCN, ERRREL, N, ITMAX, XGUESS, X, FNORM)
      OUTPUT
     WRITE (NOUT, 99999) (X(K), K=1, N), FNORM
99999 FORMAT (' THE SOLUTION TO THE SYSTEM IS' ,/,' X=(',
    &      3F10.6, ')',/,' WITH FNORM =', F5.4, //
C
      END
C                   USER-DEFINED SUBROUTINE
      SUBROUTINE FCN (X, F, N)
      IMPLICIT DOUBLE PRECISION(A-H, O-Z)
      INTEGER       N
      DOUBLE  PRECISION          X(N), F(N)
      DOUBLE  PRECISION          H, SQRT
C
      Z = 40.0 * SQRT(X(1))
      F1 = 20.0 / SQRT(X(1))
```

```
      F2 = -10.0 / (X(1)**1.5)
      R = F1 - 1.0
      W = Z - (F1* X(1))
      E1 = 1.0 + (1.0 - X(2))*R
      E2 = 1.0 + (1.0 - X(3))*R
      H = 1.0 - (F2* X(1)) / 4.0* (1/E1 + 1/E2) -
   &     (F2*W) / 4.0*
   &     (1.0 - X(2))/E1**2 + (1.0 - X(3))/E2**2)
      G1 = 2.0 - (F2 * X(1)) / (2.0 * E2) - (F2 * W * (1.0
   &       - x(3))) / (2.0 * E2**2)
      G2 = 2.0 - (F2 * X(1)) / (2.0 * E1) - (F2 * W* (1.0
   &       - x(2))) / (2.0 * E1**2)
      G3 = (F2 * X(1)) / (2.0 * E2) + (F2 * W* (1.0 -
   &       X(3))) / (2.0 * E2**2)
      G4 = (F2 * X(1)) / (2.0 * E1) + (F2 * W * (1.0 -
   &       X(2))) / (2.0 * E1**2)
       Y1 = 1.0
       Y2 = 1.0
C
      F(1) = 4.0*X(1) - Y1 - Y2 + (W / E1) + (W / E2)
C
      F(2) = (-2.0 * R 8 Y1) / (Y1 * E1 + W) +
   &          (1.0 + R) / (X(2) * E1) + ((2.0 * F2 *
   &          (Y1 * (1.0 - X(2)) - X(1)) / (Y1 * E1 + W) +
   &          F2 / (R * E1) + (2.0 * E1 * G1) / (Y1 * E1 -
   &          w)) * ((- R * W) / (4.0 * E1**2*H)) +
   &          (Y2 / Y1) * ((2.0 * F2 *
   &          (Y2 * (1.0 - X(3)) - X(1))) / (Y2 * E2 + W) +
   &          F2 / (R * E2) + (2.0 * E2 * G3) / (Y2 * E2 -
   &          W)) * (- (R * W) / (4.0 * E1**2 * H))
C
      F(3) = (-2.0 * R * Y2) / (Y2 * E2 + W) +
   &          (1.0 + R) / (X(3) * E2) + ((2.0 * F2 *
   &          (Y2 * (1.0 - X(3)) - X(1))) / (Y2 * E2 + W) +
   &          F2 / (R * E2) + (2.0 * E2 * G2) / (Y2 * E2 -
   &          W)) * ((- R * W) / (4.0 * E2**2 * H)) +
   &          (Y1 * (1.0 - X(2)) - X(1))) / (Y1 * E1 + W) +
   &          F2 / (R * E1) + (2.0 * E1 * G4) / (Y1 * E1 -
   &          W)) * ((-R * W) / (4.0 * E2**2 * H))
  RETURN
  END
```

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