Can Small Economies Act Strategically? The Case of Consumption Pollution and Non-tradable Goods

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1 Motivation

The environmental literature on taxation in deriving the optimal taxation on the polluting goods and on the internationally mobile capital

- has ignore the existence of nontraded goods.

- By large, has ignore the existence of consumption generated pollution.

    1. *According to the US Environmental Protection Agency (EPA 2012), nearly one half of the emissions of smog-forming volatile organic compounds ($VOCs$), more than half of the nitrogen oxides (NOx) emissions, and about half of the toxic air pollutant emissions in US are generated from motor vehicles. . . .*

2. *For OECD countries, up to 90% of the total carbon monoxide (CO_2) is from the source "road" (OECD Statistics 2012)....*

3. *The emissions related to consumption of energy in US are accountable for about 71% of US carbon dioxide emissions...*

- Consumption generated pollution is at least as important as the production generated pollution.

- How the existence on nontraded goods affects the optimal environmental and capital taxes in the presence of consumption generated cross border pollution.

2 Purpose

To build a small open economy model with traded and nontraded goods, consumption generated cross border pollution, international capital nobility and

- derive the Nash equilibrium policies under different scenarios,
- compare them with the ones without nontraded goods and
- examine if these policies are efficient.

3 Literature Review

- Ogawa and Wildasin (2009), show that when pollution is Transboundary and related to the use of capital, the Nash equilibrium policy calls for capital taxes, and these capital taxes are efficient

- In the case where pollution is related to production and capital is internationally mobile, the Nash equilibrium policies have been examined in a variety of models. For example,

  1. Eicher and Pething (2019) show that when the countries are symmetric, the Nash equilibrium policies call for emission tax and a capital subsidy (zero tax) if pollution is transboundary (local).

2. Habla (2018). in a two period model, assuming that fossil energy and capital are complements in production and pollution is transboundary, shows that along with tax on fossil energy capital must be subsidize in the first period and tax in the second.

- Studies which examine the optimal policies under consumption pollution propose that for small open economies, the first-best policy combination requires an emission or a consumption tax and free trade, e.g., Krutilla (1991), Copeland (2011) and Chao *et al*. (2012).

- In the absence of nontraded goods, the International capital mobility does not alter the Nash equilibrium policies when pollution is generated from consumption activities and is local or trasboundary, which is a consumption tax, free trade and a zero capital tax

4 The Model

- Two heterogenous countries, Home and Foreign, with capital mobility and cross-border consumption generated pollution.

- Each country produces three goods; two tradable, good 1 and good 2 and a good 3 which is nontradeable.

- A representative household derives utility from the consumption of the three commodities and clean environment.

- The consumption of good 2 and that of the nontradeble good 3 in both countries may generate transboundary pollution.

- Home and Foreign are assumed small in world goods and capital markets.
- There is a fixed capital endowment in each country. Capital is only mobile between the two countries
- A country's net rate of return to capital is fixed and equal to the rate of return to capital in the *other country.*
- Each country imposes a specific capital tax or subsidy and a specific tax on consumption of the polluting good.
- Capital and consumption tax revenues are lump-sum rebated to the country's representative household.

- Production of all three goods is a clean and untaxed activity.

- Home's GDP function is $R(1,\ p_2,\ p_3,\ K,\ \Omega)$. Ω is the endowments of all other immobile factors. K is the amounts of capital, $R_j\left(=\partial R/\partial p_j\right)$ is the supply function of the j^{th} good, $R_K\left(=\partial R/\partial K\right)$ is the marginal revenue product of capital. $R_{KK}\left(=\partial R_K/\partial K\right) < 0$ and R_{jj} $\left(=\partial R_j/\partial p_j\right) > 0$. Foreign's (GDP) function is $R^*\left(1,\ p_2,\ p_3^*,\ K^*,\ \Omega^*\right)$,

- The *minimum expenditure function* for Home is $E(1,\ \pi_2,\ \pi_3,\ z,\ u)$,

- $\pi_j = p_j + \tau_j$, is the consumer prices of j^{th} good, and τ_j is the tax on the consumption of the j^{th}polluting good. $d\pi_2 = d\tau_2$ and $d\pi_3 = dp_3 + d\tau_3$.

- $E_j \left(= \partial E/\partial \pi_j\right)$ is the demand for j^{th} the good, $E_u \left(= \partial E/\partial u\right)$ is the reciprocal of the marginal utility of income, and E_z $\left(= \partial E/\partial z\right)$ is the *marginal willingness to pay for pollution reduction* or alterernatively is the *marginal damage of pollution*. $E_{jj} \left(= \partial E_j/\partial \pi_j\right) < 0$, and $E_{23} = E_{32}$ is positive (negative) depending on whether goods 2 and 3 are substitutes (complements) in consumption.

- We assume that $E_{2u} = E_{3u} = 0$, and $E_{2z} = E_{3z} = 0$.

- Foreign's minimum expenditure function is $E^* \left(1,\ \pi_2^*,\ \pi_3^*,\ z^*,\ u^*\right)$, and $\pi_j^* = p_j^* + \tau_j^*$, $d\pi_2^* = d\tau_2^*$ and $d\pi_3^* = dp_3^* + d\tau_3^*$.

- Total pollution in Home and Foreign is:

$$\begin{aligned} z &= a_2[E_2(.) + \beta E_2^*(.)] + a_3[E_3(.) + \beta E_3^*(.)] \quad \text{and} \\ z^* &= a_2[E_2^*(.) + \beta^* E_2(.)] + a_3[E_3^*(.) + \beta^* E_3(.)], \end{aligned}$$

where $\alpha_j\,(>0)$ is the emissions per unit of consumption of the j^{th} good, $1 \succeq \beta \succeq 0$ is the rate of cross border pollution from Foreign to Home. When $\beta = 0$, pollution is local and $\beta = 1$, transboundary pollution is perfect or complete. Equivalently, $1 \succeq \beta^* \succeq 0$ is the rate of cross-border pollution from Home to Foreign.

- Equilibrium in capital markets requires

$$R_K(1, p_2,\ p_3,\ K) - \rho = R_K^*(1, p_2,\ p_3^*,\ K^*) - \rho^* = \overline{r}.$$

- Equilibrium in the two countries' non-tradable goods markets requires

$$\begin{aligned} E_3(.) &= R_3(1, p_2,\ p_3,\ K) \quad \text{and} \\ E_3^*(.) &= R_3^*(1, p_2,\ p_3^*,\ K^*)\,. \end{aligned}$$

- Income expenditure identities are

$$E(1, \pi_2,\ \pi_3,\ z,\ u) = R(.) + \tau_2 E_2(.) + \tau_3 E_3(.) - (R_K(.) - \rho)\, k \quad (1)$$

$$E^*(1, \pi_2^*, \pi_3^*, z^*, u^*) = R^*(.) + \tau_2^* E_2^*(.) + \tau_3^* E_3^*(.) + (R_K(.) - \rho)\, k^* \quad (2)$$

4.1 Nash equilibrium capital and consumption tax when $\alpha_2 > 0$ and $\alpha_3 = 0$.

For Home, the effect of an increase in capital and consumption taxes on welfare is

$$\Delta \frac{du}{d\rho} = Z_{33} Z_{33}^{*} \left[-\rho + (\alpha_2 E_z - \tau_2) E_{23} Z_{33}^{-1} R_{3K} - \alpha_2 \beta E_z E_{23}^{*} Z_{33}^{*^{-}} R_{3K}^{*} \right].$$

$$\Delta \frac{du}{d\tau_2} = (\alpha_2 E_z - \tau_2)[-E_{22}\Delta + E_{23}E_{32}(HZ_{33}^{*} + R_{K3}^{*}R_{3K}^{*})] + E_{23}R_{3K}(\rho + \alpha_2 \beta E_z E_{2}^{*}$$

where $H = R_{KK} + R^*_{K^*K^*} (< 0)$, $Z_{33} = E_{33} - R_{33} (< 0)$, and $Z^*_{33} = E^*_{33} - R^*_{33} (< 0)$, $\Delta = Z_{33} Z^*_{33} \left(\widetilde{R}_{KK} + \widetilde{R}^*_{K^*K^*} \right) < 0$, $\widetilde{R}_{KK} = R_{KK} + R_{K3} Z^{-1}_{33} R_{K3} (< 0)$ and $\widetilde{R}^*_{K^*K^*} = R^*_{K^*K^*} + R^*_{K^*3} Z^{*-1}_{33} R^*_{K^*3} (< 0)$.

Setting $\frac{du}{d\rho} = \frac{du^*}{d\rho^*} = 0$ and $\frac{du}{d\tau_2} = \frac{du^*}{d\tau_{2^*}} = 0$, the Nash equilibrium for Home is

$$\rho^N = -\alpha_2 \beta E_z E^*_{23} Z^{*-1}_{33} R^*_{3K},$$

$$\tau^N_2 = \alpha_2 E_z.$$

- When $\beta = \beta^* = 0$, or in the absence of non-tradable goods then $\tau^N_2 = \alpha_2 E_z$. and $\rho^N = 0$. .

4.1.1 The efficiency of the Nash equilibrium

The cooperative equilibrium tax rates are the tax rates chosen by Home to maximize Home's and Foreign's joint welfare, and are derived using the first-order-conditions $\frac{du}{d\rho} + \frac{du^*}{d\rho} = 0$ and $\frac{du}{d\tau} + \frac{du^*}{d\tau} = 0$. In evaluating the efficiency of the Nash equilibrium tax rates, it suffices to evaluate the sign of

$$\frac{du^*}{d\tau_2} \mid_{\rho^N,\tau^N} = -\alpha_2 \beta^* E_z^* \widetilde{E}_{22} > 0 \qquad \text{and} \qquad \frac{du^*}{d\rho} \mid_{\rho^N,\tau^N} = -\frac{du^*}{d\rho^*} \mid_{\rho^{*N},\tau^{*N}} = 0.$$

where $\widetilde{E}_{22} = E_{22} - E_{23} Z_{33}^{-1} E_{32} < 0$.

4.2 The Nash equilibrium capital taxes when consumption taxes are zero

- The Nash equilibrium capital taxes for Home is

$$\rho^N = \alpha_2 E_z[E_{23} Z_{33}^{-1} R_{3K} - \beta E_{23}^* Z_{33}^{*-1} R_{3K}^*].$$

- When countries are symmetric, i.e., $E_{23} = E_{23}^*$, $R_{3K}^* = R_{3K}$, and $Z_{33} = Z_{33}^*$.

  Then the Nash equilibrium capital tax is $\rho^N = \alpha_2 E_z[(1-\beta) E_{23} Z_{33}^{-1} R_{3K}]$.

- Efficiency of the Nash equilibrium

$$\Delta \frac{du^*}{d\rho} \mid_{\rho^N, \tau=0} = -\Delta \frac{du^*}{d\rho^*} \mid_{\rho^N, \tau=0} = 0.$$

- Thus, the result of Ogawa and Wildasin (2009), who show that when pollution is related to capital, the Nash equilibrium capital taxes are efficient, hold also in our model where nontraded goods exists and pollution is generated from consumption.

4.3 Nash equilibrium Consumption Tax when the Capital Tax is zero

The effect of changes in consumption taxes on welfare is

$$\Delta \frac{du}{d\tau_2} = [\tau_2 - \alpha_2 E_z] A_2 + B_2,$$

where $A_2 > 0$ and $B_2 > 0$.

- Setting $\frac{du}{d\tau_2} = \frac{du^*}{d\tau_2^*} = 0$, The Nash equilibrium consumption tax is:

$$\tau_2^N = \alpha_2 E_z - (B_2/A_2)$$

- Efficiency of the Nash equilibrium

$$\Delta\frac{du^*}{d\tau_2} = -E^*_{23}[\tau^*_2 - \alpha_2 E^*_z][E_{32}R_{3K}R^*_{3K}] - \alpha_2\beta^* E^*_z A_2.$$

which evaluated at Nash equilibrium becomes

$$\Delta\frac{du^*}{d\tau_2} = [B^*_2/A^*_2][E^*_{23}E_{32}R_{3K}R^*_{3K}] - \alpha\beta^* E^*_z A_2 \leqslant 0.$$

5 Nash equilibrium consumption and capital taxes when $\alpha_2 = 0$ and $\alpha_3 > 0$.

- The Nash equilibrium consumption and capital taxes are

$$\rho^N = -\alpha_3 \beta E_z E^*_{33} Z^{*-1}_{33} R^*_{3K},$$

$$\tau^N_3 = \alpha_3 E_z.$$

- Efficiency of the Nash equilibrium

$$\frac{du^*}{d\tau_3} |_{\rho^N, \tau^N} = -\alpha_3 \beta^* E^*_z E_{33} R_{33} Z^{-1}_{33} > 0 \text{ and } \frac{du^*}{d\rho} |_{\rho^N, \tau^N} = -\frac{du^*}{d\rho^*} |_{\rho^{*N}, \tau^{*N}} = 0$$

5.1 Nash equilibrium capital taxes when consumption taxes are zero.

- The Nash equilibrium policy on capital is

$$\rho^N = \alpha_3 E_z[E_{33} Z_{33}^{-1} R_{3K} - \beta E_{33}^* Z_{33}^{*-1} R_{3K}^*],$$

- When countries are symmetric, i.e., $E_{33} = E_{33}^*$, $R_{3K}^* = R_{3K}$, and $Z_{33} = Z_{33}^*$.

- $\rho^N = \alpha_3 E_z[(1-\beta) E_{33} Z_{33}^{-1} R_{3K}]$.

5.2 Nash equilibrium consumption taxes when capital taxes are zero.

The Nash equilibrium consumption tax is

$$\tau_3^N = \alpha_3 E_z - (B_3/A_3)$$

where $B_3 = \alpha_3 \beta E_z E_{33}^* R_{3K}^* R_{K3} < 0$ and $A_3 = \Delta - E_{33} Z_{33}(R_{KK} + \widetilde{R}_{K^*K^*}^*) < 0$.

6 Concluding Remarks

- In this framework, the imposition of consumption taxes by Home to control the locally generated consumption pollution, causes pollution leakage effects from Foreign and vice versa due to the existence of nontraded goods and international capital mobility. To deal with these pollution leakage effects (spill backs), the governments must use capital taxes or subsidies.

- The Nash equilibrium calls for i) a consumption tax on the polluting goods and ii) a capital tax or subsidy.

  1. When only the consumption of the traded good generates pollution, then the Nash equilibrium calls for a capital tax if the polluting good and the nontraded good are substitutes in consumption.

2. When the consumption of the nontraded good generates pollution, then the Nash equilibrium policy calls for a capital subsidy.

- Irrespectically of which good its consumption is polluting, the Nash equilibrium policy on capital is efficient while the consumption tax is inefficiently low.

- If for some reasons, the governments cannot use simultaneously both policy instruments, but only one, then the Nash equilibrium level of each instrument is chosen in such a way in order to deal with both, the locally generated consumption pollution and the pollution leakage effect from the other country.