"INTERNATIONAL TRADE AND ENVIRONMENTAL POLICY: PRODUCTION VS CONSUMPTION TAXES"

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International trade and environmental policy: production vs consumption taxes

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Abstract

The paper considers the choice of production versus consumption taxes as corrective instruments for environmental externalities in a two-country international duopoly context. It is shown that the use of either instrument or of any combination of the two is a Nash equilibrium of a taxation game between the two countries. However the equilibrium where both countries use exclusively a production tax Pareto-dominates all other ones in a symmetric game.

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1 Introduction

With few exceptions, the literature on corrective taxation for environmental externalities in the open economy has up to now focused primarily on the perfectly competitive case [in the closed economy, by contrast, issues relating to imperfect competition have been largely explored; see Cropper and Oates (1992) for a survey]. While some results are now firmly established, there is a gap between this literature and the theory of international trade, which has been mainly concerned in the last decades with imperfect competition. We consider here a problem of choice of taxation instruments (production or consumption tax) aimed at regulating a production externality in an international Cournot duopoly context *à la* Brander and Krugman (1980). The conventional wisdom, dating back to Mirrlees, is that the most direct corrective policy is in general the best, implying that if the externality comes from production, a production tax should dominate a consumption tax. However it has been shown in a recent paper [see Hung (1994)] that in an international Cournot duopoly, the Nash equilibrium of a production-tax game between the two governments is suboptimal, in the sense that the production tax is set too low for the global welfare optimum. The reason is that a production tax raises the marginal cost of the home firm, inducing a deterioration of the country's trade balance. The equilibrium level of the tax trades off the benefit of a reduction in the externality against this adverse trade-balance effect, leading to a level that is too low from the point of view of global welfare. By contrast, a consumption tax *improves* the country's trade balance, so that the trade off disappears, and so should – presumably – the incentive to set the tax too low. Because the strategic interaction between the two governments is different in a production-tax game and in a consumption-tax game, it is thus not clear which instrument dominates in the sense of national and global welfare. This paper sets up a simple Cournot duopoly model with two firms and two governments to answer two distinct questions: first, what is the set of Nash equilibria of a game of instrument choice? Second, and provided that the set is nonempty, can the equilibria be Pareto-ranked?

2 The model

Consider the market for a homogenous good produced in an international Cournot duopoly (one home firm and one foreign firm). Let the home sales of the home (respectively foreign) firm be x (respectively x^*) and let its exports be z (respectively z^*), where we use asterisks to denote foreign variables. Home consumption is $q = x + z^*$, home production is $y = x + z$, and inverse demand on the home market is given by a monotone decreasing function $p(q)$. Production generates a welfare-reducing externality $E(y)$, $E' > 0$, which does not cross national boundaries. Clearly, the presence of such an externality introduces a discrepancy between private production decisions which are based on profit maximization and the social optimum, calling for corrective taxation. In order to keep matters simple, we will assume that, for both firms, the marginal cost of production is zero while the fixed cost is $F > 0$. Thus the only variable cost incurred by firms is a specific tax, denoted by t (t^*) if it is based on production and by τ (τ^*) if it is based on consumption. Under a production tax, the home firm's profits net of fixed costs are given by

$$\pi(x, z, t) = (p - t)x + (p^* - t)z \tag{1}$$

and under a consumption tax,

$$\pi(x, z, \tau, \tau^*) = (p - \tau)x + (p^* - \tau^*)z \tag{2}$$

Suppose now that both governments use independent convex combinations of a production and a consumption tax, in which the weight on the production tax is denoted by $\mu \in [0, 1]$ (μ^* for the foreign country). The home firm's total profits are now

$$\begin{aligned} \pi(x, z, t, \tau, \mu, \tau^*, \mu^*) &= \mu[(p - t)x + [p^* - t - (1 - \mu^*)\tau^*]z] \\ &\quad + (1 - \mu)[(p - \tau)x + [p^* - (1 - \mu^*)\tau^*]z] - F \\ &= px + p^*z - [\mu t + (1 - \mu)\tau]x \\ &\quad - \mu t z - (1 - \mu^*)\tau^* z - F \end{aligned} \tag{3}$$

Ignoring income effects, consumer surplus is given by $S = \int_0^q p(\xi)d\xi - pq$, and tax revenue is given by $\mu t y + (1 - \mu)\tau q$. So welfare in the home country can be written as

$$
\begin{aligned}
W(.) &= \int_0^{x+z^*} p(\xi)d\xi - p(x+z^*) + px + p^*z + (1-\mu)\tau z^* \\
&\quad - (1-\mu^*)\tau^* z - F - E(x+z) \qquad (4)
\end{aligned}
$$

and the home country's welfare maximization problem, given the policy of the foreign country, can be written as

$$
\begin{aligned}
\max_{x,z,t,\tau,\mu} \quad & \int_0^{x+z^*} p(\xi)d\xi - p(x+z^*) + px + p^*z + (1-\mu)\tau z^* \\
& - (1-\mu^*)\tau^* z - F - E(x+z) \qquad (5)
\end{aligned}
$$

s.t.

$$
\begin{aligned}
p + xp' - \mu t - (1-\mu)\tau &= 0 \qquad (6) \\
p^* + zp'^* - \mu t - (1-\mu^*)\tau^* &= 0 \qquad (7) \\
p^* + x^*p'^* - \mu^* t^* - (1-\mu^*)\tau^* &= 0 \qquad (8) \\
p + z^*p' - \mu^* t^* - (1-\mu)\tau &= 0 \qquad (9)
\end{aligned}
$$

3 Results

Consider now a game where governments decide on the mix and levels of a production and a consumption tax, and firms set home and export sales in order to maximize profits given the mix and level of taxes at home and abroad. Setting up the game in this way allows us to enrich the governments' instrument sets compared to recent studies on fiscal competition among jurisdictions [see Mintz and Tulkens (1986) or Wildasin (1988)]. Note that a pair (μ, μ^*) can be viewed equivalently as a combination of instrument mixes or as a combination of mixed strategies in a discrete instrument-choice game. What is important is that the level of each instrument be set optimally in the appropriate subgame. The formula for the optimal production tax in a model identical to this one can be found in Hung (1994). We will refer to this game as the "tax game", and we can now state the paper's first result:

PROPOSITION 1

Any convex combination of optimal production and consumption taxes is a Nash equilibrium of the tax game.

PROOF

Let $\tilde{W}$ denote the social welfare function evaluated at the point where all quantity decisions (x and z) and all taxes (t and τ) have been set optimally. Denote respectively by $\lambda, \theta, \lambda^*$ and θ^* the Lagrange multipliers affected to the constraints (6)-(9) in the welfare-maximization problem. By the envelope theorem,

$$\begin{aligned} \frac{\partial \tilde{W}}{\partial \mu} &= -\tau z^* + \tilde{\lambda}(\tau - t) - \tilde{\theta} t + \tilde{\theta}^* \tau \\ &= (\tilde{\lambda} + \tilde{\theta}^* + z^*)\tau - (\tilde{\lambda} + \tilde{\theta})t \end{aligned} \tag{10}$$

where tildes indicate that the Lagrange multipliers are evaluated at the optimum of W. Now since t and τ are set optimally, applying again the envelope theorem gives

$$\frac{\partial \tilde{W}}{\partial t} = -(\tilde{\lambda} + \tilde{\theta})\mu = 0 \tag{11}$$

and

$$\frac{\partial \tilde{W}}{\partial \tau} = (1 - \mu)(z^* - \tilde{\lambda} - \tilde{\theta}^*) = 0 \tag{12}$$

Substituting (11) and (12) into (10) gives $\partial \tilde{W} / \partial \mu = 0 \; \forall \; (\mu, \mu^*)$. Therefore the home country's best response correspondence is $R(\mu^*) = [0,1] \; \forall \; \mu^*$. By symmetry, $\partial \tilde{W}^* / \partial \mu^* = 0 \; \forall \; (\mu, \mu^*)$. Any point on the unit square is thus a fixed point of the game's best-response correspondence.

□

The next question is whether a Pareto ranking can be established over the unit square or a subset of it. This can be done only for a narrow class of games (symmetric ones) where a pair of production taxes dominates, as we show in the following corollary.

COROLLARY

In a symmetric game, the equilibrium combination $(\mu, \mu^*) = (1, 1)$ *dominates all others in the sense of Pareto.*

PROOF

Applying again the envelope theorem,

$$\frac{\partial \tilde{W}}{\partial \mu^*} = -(z + \tilde{\lambda}^* + \tilde{\theta})\tau^* - (\tilde{\lambda}^* + \tilde{\theta}^*)t^* \tag{13}$$

Let $\hat{\lambda}$, $\hat{\theta}$, $\hat{\lambda}^*$, $\hat{\theta}^*$ be the values taken by the Lagrange multipliers affected to constraints (6)-(9) in the foreign welfare maximization problem at the optimum of W^*. Consider a symmetric tax game in which the two functions $W(.)$ and $W^*(.)$ are identical. Then by symmetry

$$\mu^*(\hat{\lambda}^* + \hat{\theta}^*) = 0 \tag{14}$$

$$(1 - \mu^*)(z - \hat{\lambda}^* - \hat{\theta}) = 0 \tag{15}$$

Consider now a symmetric *solution* to this game, in which $t = t^*$, $\tau = \tau^*$ and $\mu = \mu^*$. Then $\tilde{\lambda} = \hat{\lambda}$, $\tilde{\theta} = \hat{\theta}$, $\tilde{\lambda}^* = \hat{\lambda}^*$ and $\tilde{\theta}^* = \hat{\theta}^*$. Then

$$\mu^* > 0 \;\Leftrightarrow\; \tilde{\lambda}^* + \tilde{\theta}^* = 0 \tag{16}$$

$$\mu^* < 1 \;\Leftrightarrow\; \tilde{\lambda}^* + \tilde{\theta} = z \tag{17}$$

Now, note that when $\mu^* = 0$, t^* is indeterminate and when $\mu^* = 1$, τ^* is indeterminate; so we adopt the convention that $t^* = 0$ when $\mu^* = 0$ and

$\tau^* = 0$ when $\mu^* = 1$. Using this convention and substituting (16) and (17) into (13) gives

$$\left.\frac{\partial \tilde{W}}{\partial \mu^*}\right|_{\mu=\mu^*} = \begin{cases} 2z\tau^* & \text{for } \mu^* < 1 \\ 0 & \text{for } \mu^* = 1 \end{cases} \tag{18}$$

Now, note that by proposition 1 $\partial \tilde{W}/\partial \mu = 0 \ \forall \ \mu^*$, so that at any point (μ, μ^*) on $[0,1]^2$ the function $\tilde{W}(\mu, \mu^*)$, being constant in μ, can be written as $\tilde{W}(\mu^*)$.

Furthermore, $\tilde{W}(\mu^*)$ is a monotone increasing function at any point (μ, μ^*) such that $\mu = \mu^*$ except at $(1,1)$. Together these facts imply that $\tilde{W}$ is maximized at $(1,1)$. By the symmetry of the game, the same applies to W^*. Therefore $W + W^*$ is maximized at $(1,1)$.

□

It should be remembered however that while the equilibrium $(1,1)$ is Pareto-optimal on the unit square, it is not the first best [see Hung (1994)].

4 Concluding remarks

Strategic interaction in a production-tax game is markedly different than in a consumption-tax game; for instance, tax levels are strategic substitutes in a consumption-tax game while they are strategic complements in a production-tax game. Furthermore, production and consumption taxes have opposite effects on the trade balance. But we find here that the choice among these two instruments or any combination of them turns out to be irrelevant for national welfare when the taxation choice of the other country (level of each tax and mixture of the two) is given. As a result, any combination of tax mixes is a Nash equilibrium of the taxation game. In a *symmetric* taxation game, equilibria can be completely ranked by the Pareto criterion; then we find that a combination of production taxes dominates all other equilibria.

References

[1] Brander, James and Paul Krugman, 1980, A 'Reciprocal Dumping' Model of International Trade, *Journal of International Economics* 15, 313-321.

[2] Cropper, Maureen L., and Wallace E. Oates, 1992, Environmental Economics: A Survey, *Journal of Economic Literature* 30, 675-740.

[3] Hung, Nguyen M., 1994, Environmental Taxation In An International Duopoly Game; *Economics Letters* 44, 339-343.

[4] Mintz, Jack and Henry Tulkens, 1986, Commodity Tax Competition Between Member States of a Federation: Equilibrium and Efficiency, *Journal of Public Economics* 29, 133-172.

[5] Wildasin, David E., 1988, Nash Equilibria in Models of Fiscal Competition, *Journal of Public Economics* 35, 229- 240.