Economic integration and the choice of commodity tax base with endogenous market structures

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Abstract

This paper analyzes the choice of commodity tax base when countries set their taxes non-cooperatively in a two-country symmetric reciprocal dumping model of intra-industry trade with free entry and trade costs. We show that the consumption base (destination principle) dominates the production base (origin principle) when trade costs are high or demand is linear. For lower levels of trade costs and nonlinear demand, the welfare ranking of the two tax bases is ambiguous. Hence, there is no clear preference for a tax principle with an ongoing movement towards closer economic integration.
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1 Introduction

This paper uses a model of imperfect competition to investigate the choice between commodity tax principles as integration progresses. The innovation of this paper is that the number of active firms is not fixed but determined endogenously. A fixed market structure may be a reasonable assumption in the short run, but in the long run firms will enter if they see opportunities for positive profits as a result of changes in tax policy. Conversely, incumbent firms will exit if their profits decline and become negative. In this setting, we demonstrate that consumption taxes dominate production taxes if trade costs are high or if demand is linear. The welfare ranking for nonlinear demand is ambiguous. This is in contrast to the existing literature on commodity taxation under imperfect competition which seems to agree by and large that production taxes are favorable for low trade costs. Hence, our paper demonstrates that there is no clear policy recommendation even if trade becomes less and less costlier.

The choice of commodity tax base has become an important policy issue with the ongoing movement towards closer economic integration. Under the destination principle traded commodities are taxed in the country of consumption, while under the origin principle they are taxed in the country of production. The majority of international trade in the past has been taxed under the destination principle, which is largely true of trade today. Implementation of tax policy under the destination regime requires border tax adjustments, making administration more costly and difficult as integration proceeds. This is because as economies become more integrated, it becomes easier to engage in cross-border shopping in neighboring countries. Furthermore, the advent of internet shopping and other forms of mail-order purchase have led to increased opportunities for consumers to purchase goods from abroad. This increased cross-border movement of goods leads to high compliance costs and difficulty in enforcement of border tax adjustments under the destination regime. Taxation under the origin principle has no such problems. Goods are taxed in the country of production and so there is no need for any border tax adjustments. It is therefore clear that, from an administration cost perspective, the origin principle is favorable as barriers to trade are reduced.

Beyond the administration cost perspective, a number of recent papers have looked at the choice of commodity tax base, when countries set their taxes non-cooperatively, under perfect competition and using several different models of imperfect competition.[1] For example, Keen and Lahiri (1998) find in a duopoly model with integrated markets, a homogeneous good and no transport costs that taxation under the origin principle leads to a first-best outcome when taxes are set non-cooperatively and the firms and countries are symmetric. Haufler *et al.* (2005) focus on the role of trade costs in a two-country symmetric reciprocal dumping model of international trade in identical commodities. They find that for high trade costs the destination principle dominates, while for low trade costs the origin principle dominates. Thus they support the use of the origin principle in more integrated economies. Hashimzade *et al.* (2005) use a model of Bertrand competition with product differentiation and find that with nonlinear demand the origin principle dominates the destination principle if integration is sufficient (*i.e.*, for sufficiently low levels of trade costs) and tax revenue is not valued. They also replicate the results of Haufler *et al.* (2005) and find that the results with Cournot competition are robust to some degree of product differentiation.

The results of all these papers depend on the assumption that government policy interventions have no effect on the decisions made by firms on entry and exit. Only Haufler and Pflüger (2004) investigate the welfare implications of the two tax principles in a model with free entry. They employ a model of monopolistic competition with transport costs and international mobility of capital and firms, and they find that in a symmetric two-country model tax competition under the destination principle will lead to a first best outcome. However, tax competition in their model under the origin principle leads to a tax rate that deviates from the Pareto efficient level.

[1] Under perfect competition, the destination principle is favorable because it warrants production efficiency when countries employ different tax rates (see Mintz and Tulkins, 1986, and Kanbur and Keen, 1993) unless terms of trade effects become dominant (Lockwood, 1993). For a detailed survey of cooperative and non-cooperative commodity taxation, see Lockwood (2001).

Models of monopolistic competition ignore any strategic interactions and are thus hard to compare with Cournot models. Since we would like to demonstrate that the extension to endogenous market structures is not innocious, the model we consider is a modification of the one used by Haufler *et al.* (2005) to allow for free entry and exit of firms. It is based on Brander and Krugman's (1983) reciprocal dumping model of intra-industry trade.[2] Our extension introduces a zero profit condition which eliminates any rent shifting motives when setting taxes under either tax regime. There are, however, other distortions as too many firms are active each of which produces too little in equilibrium.

The paper is organized as follows. Section 2 sets out the model and looks at the simple case of a closed economy in order to isolate the motives to use taxes to correct for inefficient entry and suboptimal consumption. Section 3 analyzes the optimal non-cooperative tax rates under the destination principle and origin principle. Section 4 derives the optimal coordinated tax rate in order to provide a benchmark against which to compare the outcomes under the two tax regimes and looks at the role of trade costs in the choice of commodity tax base. Section 5 concludes the paper. Since many mathematical derivations and proofs are tedious, we have relegated most of them to the Appendix.

2 The Model

There are two identical countries labelled by subscripts $i = 1, 2$. Each country has an imperfectly competitive industry producing a tradeable good under increasing returns to scale. A four-stage game is considered. In the first stage, the countries agree on a tax principle, and in the second stage they set their tax rates non-cooperatively. The idea behind this setting is that although countries may be able to reach agreement on the tax *principle* they may find it harder to commit to a tax *rate*. In the third stage, given the tax rates, the

[2] Our model is similar to the model investigated by Venables (1985). However, this model deals with trade policy instruments like tariffs and production subsidies whereas commodity taxation is not allowed to discriminate against foreign firms.

firms decide whether to enter. In the final stage, firms engage in quantity competition in a Cournot fashion. The innovation of this paper is the third – allowing the number of firms to be determined endogenously.

For country i we denote the quantity sold of this good by Q_i. Letting utility in each country i be denoted by $U_i = U(Q_i)$ (which is assumed to be three times differentiable) and denoting the inverse demand function by $p_i = p(Q_i)$, we have $p(Q_i) = U'(Q_i), p'(Q_i) = U''(Q_i) < 0$.

Firms within each country are assumed to be identical. With n_i firms in country i, we denote a single representative firm's sales to the domestic market by y_i and its exports by x_i.[3] (In case of symmetry, we will write $y = y_1 = y_2$ and $x = x_1 = x_2$.) Since the quantity sold must be equal to the quantity produced we have the following market-clearing conditions:

$$Q_1 = n_1 y_1 + n_2 x_2, Q_2 = n_1 x_1 + n_2 y_2.$$

Each firm faces a fixed cost f and a constant marginal cost of c. This assumption means that average cost declines with the number of sales and we have increasing returns to scale. Furthermore, each unit exported carries a trade cost s, which is to encompass all barriers to trade except the production and consumption taxes we are considering.

In order to isolate the effects of inefficient entry and suboptimal consumption we first consider the case of a closed economy. In this case the destination and origin principles are equivalent, and the optimal tax rate is set to correct for the inefficiently high number of firms each with an output that is too low.[4] Dropping the subscripts, profits of a representative firm in autarky are given by $\Pi = (p - c - t)y - f$, leading to the first order condition for profit maximization

$$\Pi_y = (p - c - t) + p'y = 0. \qquad (1)$$

[3]The number of firms must, in reality, be an integer, but we follow the literature on endogenous markets structures and ignore this restriction here. If the number of firms is not too small, the integer constraint is not important (see Mankiw and Whinston, 1986, n 12).

[4]We consider only specific taxes in this paper. Note that specific and ad valorem taxes are not equivalent under imperfect competition (see Delipalla and Keen, 1992).

With free entry and exit profits are driven to zero, *i.e.*,

$$\Pi = (p - c - t)y - f = 0. \tag{2}$$

Without exports, $Q = ny$, and the system is completetly determined as we have three equations with three unknowns (Q, y, n). The government will set the tax t so as to maximize social welfare which is the sum of consumer surplus and tax revenue, *i.e.*,

$$W = U(Q) - p(Q)Q + tQ = U(Q) - cQ - nf,$$

where the last transformation follows from the zero profit condition (2). The effect on welfare of a change in the tax rate is then given by

$$\frac{dW}{dt} = \underbrace{(p - c)\frac{dQ}{dt}}_{\text{(I)}} - \underbrace{f\frac{dn}{dt}}_{\text{(II)}}. \tag{3}$$

Term (I) is the consumption wedge effect, and term (II) is the market structure effect, which represents the rise in aggregate fixed costs associated with entry of new firms. Using the first order condition for welfare maximization (see Appendix A.1) we solve for the optimal tax rate:

$$t^* = \frac{1}{dQ/dt}\left[p'Q\frac{dQ}{dt} - Q\right] = -\frac{np''y^2}{2}. \tag{4}$$

The second order condition for profit maximization allows us to sign most of the equilibrium changes in firm output, sales and number of firms which are summarized by Table 1.

Table 1: Tax effects under autarky

	dy/dt	dQ/dt	dn/dt
$p'' < 0$	$+$	$-$	$-$
$p'' = 0$	0	$-$	$-$
$p'' > 0$	$-$	$-$	$+/-$

With concave inverse demand a small rise in the tax leads to a rise in the output per firm, a fall in the number of firms in equilibrium, and a fall in overall sales. The optimal tax rate in this case is positive, since the welfare-improving drop in the number of firms outweighs the negative consumption wedge effect. On the other hand, when inverse demand is convex, there is a fall in the output of each firm as a result of a tax increase while there is an ambiguous effect on the number of firms. Thus a subsidy will be optimal as it induces each of the firms to produce more output in equilibrium, with the corresponding efficiency gains outweighing any negative effects on industry fixed costs and the direct cost in subsidy payments. Finally, in the special case of linear inverse demand, the consumption wedge effect and the market structure effect exactly offset each other and so the optimal tax rate is zero.

From the preceding simplified model it is clear that the signs of the optimal tax rates under the destination and origin principles will depend critically on the curvature of the inverse demand function.

3 Commodity taxation and trade

In this section, we consider the effects of commodity taxation on output levels. Under the destination principle, the country i tax rate applies to all sales in country i. Profits for representative firms in both countries under the destination regime, denoted by the superscript D, are given by

$$\Pi^{1D} = (p_1 - c - t_1)y_1 + (p_2 - c - s - t_2)x_1 - f,$$
$$\Pi^{2D} = (p_2 - c - t_2)y_2 + (p_1 - c - s - t_1)x_2 - f,$$

respectively, where t_i denotes the consumption tax imposed by country i.[5]

Appendix A.2 has the details for firm behavior in this environment. As before, we measure country i's welfare as the sum of consumer surplus and tax revenue which is returned to the consumer as a lump sum:

$$W_i^D = U(Q_i) - p_i(Q_i)Q_i + t_iQ_i.$$

[5] We assume that demand is log-concave: $\forall z \in]0, \bar{Z}] : p_i'(z) + p_i''(z)z < 0$, where $\bar{Z}$ is defined as the aggregate output for which the price equals zero. Since marginal costs are constant, log-concave demand implies $\Pi^i_{y_ix_j} \equiv p_i'(z) + p_i''(z)y_i < 0, \forall y_i \in]0, z]$, and $\Pi_{x_iy_j} \equiv p_j'(z) + p_j''(z)x_i < 0, \forall x_i \in]0, z]$, and thus imposes strategic substitutability in the sense of Bulow, Geanakoplos and Klemperer (1985), so that the reaction functions of firms slope down. Furthermore, it guarantees that the second-order conditions are satisfied and that the equilibrium is stable in the sense of Hahn (1962).

Country i seeks to maximize is national welfare with respect to its own tax rate. To ensure the second-order conditions for a national welfare maximum hold we assume that W is continuous and quasi-concave in t_i for all tax regimes. In our symmetric setting all the tax rates in country 2 will be identical to those of country 1. So, for brevity, the results will be derived only for country 1.

The nationally optimal destination principle tax rate for country 1 (see Appendix A.2) is given by

$$\begin{aligned} \widehat{t}_1^D &= \frac{1}{\partial Q_1/\partial t_1}\left(p_1'\frac{\partial Q_1}{\partial t_1}Q_1 - Q_1\right) \quad (5) \\ &= \frac{1}{\partial Q_1/\partial t_1}\left[\underbrace{p_1'\left(\frac{\partial n_1}{\partial t_1}y_1 + n_1\frac{\partial y_1}{\partial t_1} + \frac{\partial n_2}{\partial t_1}x_2 + n_2\frac{\partial x_2}{\partial t_1}\right)Q_1}_{\text{(I)},-} - \underbrace{Q_1}_{\text{(II)},+}\right]. \end{aligned}$$

From expression (5), we observe two effects, the *efficiency effect* (I) and the *tax revenue effect* (II). The efficiency effect (I) represents the incentive to subsidize consumption in order to increase the domestic under-consumption of the traded good. This effect is made up of four terms. The signs of these terms determine the absolute size of the efficiency effect. The first two terms reflect, respectively, the incentives to decrease the inefficiently high number of domestic firms each of which incurs a fixed cost of setup, and to increase the production of each of the firms in order to take advantage of economies of scale. The last two terms represent the incentive to decrease imports in order to reduce wasteful transport costs, while recognizing their pro-competitive effects. The tax revenue effect (II) is simply the incentive to use taxation to gather revenue.

The comparative statics results summarized in Table 2 show how a change in the destination regime tax rate in country 1 (with the tax rate in country 2 held constant) affects the firms' production levels, quantities demanded, and the number of firms in equilibrium. For concave inverse demand, a small increase in the tax has the effect in both countries of increasing each firm's production for domestic sale, and decreasing total sales and the number of

Table 2: Consumption tax effects

	$\frac{\partial y_1^D}{dt_1}$	$\frac{\partial x_1^D}{dt_1}$	$\frac{\partial y_2^D}{dt_1}$	$\frac{\partial x_2^D}{dt_1}$	$\frac{\partial Q_1^D}{\partial t_1}$	$\frac{\partial Q_2^D}{\partial t_1}$	$\frac{\partial n_1^D}{\partial t_1}$	$\frac{\partial n_2^D}{\partial t_1}$
$p'' < 0$	$+$	$+$	$+$	$+/-$	$-$	$-$	$-$	$-$
$p'' = 0$	0	0	0	0	$-$	0	0	$+$
$p'' > 0$	$-$	$-$	$-$	$+/-$	$-$	$+$	$+/-$	$+$

firms active in equilibrium. When trade costs are high, each firm in country 2 increases their production for export and their share of the market in country 1 rises. On the other hand, when trade costs are low, the converse takes place.

In the case of convex inverse demand a small rise in the tax rate in country 1 will decrease the total output of each country 1 firm and in particular decrease output for domestic consumption and increase the average cost of domestic production. In general, when inverse demand is convex, a tax rise will have an ambiguous effect on the number of firms in country 1. For sufficiently low or high trade costs the tax will decrease the number of domestic firms in equilibrium and lower total industry fixed costs. Furthermore, the tax will encourage entry in country 2 while having a generally indeterminate effect on each country 2 firm's output for export. When trade costs are high, the tax will increase each of the country 2 firm's output for export and indeed total exports. This is because the tax rise decreases the initially large domestic market share of country 1 firms leading to a large rise in perceived marginal revenue of country 2 firms enabling them to bear the high trade costs and increase export production. When trade costs are low, country 2 firms have a high share of the market in country 1 and so the rise in the tax will have only a small effect on their perceived marginal revenue that will be outweighed by the increased marginal cost of exporting.

The nationally optimal destination principle tax rate is

$$\widehat{t}^D = -\frac{np''(y+x)(y^2\Pi_{yy} + yx(\Pi_{yx} + \Pi_{xy}) + x^2\Pi_{xx})}{2(y\Pi_{yy} + x(\Pi_{yx} + \Pi_{xy}))}, \tag{6}$$

where we have dropped the superscripts (since the equilibrium is symmetric).

The subscripts denote the second derivatives.[6] We see from (6) that the curvature of the inverse demand function determines the balance between the efficiency effect and the tax revenue effect. The following proposition signs the nationally optimal tax rate under the destination principle.

Proposition 1 *(a) Under the destination principle, the nationally optimal tax rate is negative for all levels of trade costs if the inverse demand function is convex ($p'' > 0$). (b) If inverse demand is concave ($p'' < 0$), the optimal tax rate is positive.*

Proof: See equation (6).

The optimal non-cooperative consumption tax has, in general, an ambiguous sign. This is because of the opposing motives for taxation. The efficiency effect encompasses several incentives: to (i) increase domestic consumption through a subsidy, (ii) decrease the inefficiently high number of firms active in both countries and (iii) increase the output of each firm in order to decrease the total fixed costs and to (iv) decrease the wasteful (in the presence of trade costs) cross-shipping of goods keeping in mind that trade is beneficial insofar as it increases competition.

When inverse demand is convex, a negative tax increases the size of domestic firms while the overall effect on the amount produced by home firms for domestic sale and on the amount produced by foreign firms for export is indeterminate. However, the overall effect is to increase the amount sold on the home market. A positive tax would result in prices rising by more than the tax ($p_1'(\partial Q_1^D/\partial t_1) > 1$) and so the optimal tax is negative as this reduces the price in country 1 by more than amount of the subsidy and results in a large increase in consumption.

In the case of concave inverse demand, a positive tax will increase the size of domestic firms and, whatever the level of barriers to trade, have a beneficial effect on the level of imports. A positive tax, when trade costs are high, leads to a decrease in total imports from the foreign country and reduces the wasteful trade costs. On the other hand, when trade barriers are low, the

[6]Note that $\Pi_{yx} = \Pi_{y_1x_2} = \Pi_{y_2x_1}$ and $\Pi_{xy} = \Pi_{x_1y_2} = \Pi_{x_2y_1}$ in the symmetric equilibrium but $\Pi_{yx} \neq \Pi_{xy}$ unless $x = y$. See previous footnote.

motive to increase competition predominates and a positive tax will increase imports. Another effect of a positive tax is to decrease the numbers of firms at home and abroad leading to lower average costs and lower prices net of the tax ($p_1'(\partial Q_1^D/\partial t_1) < 1$). Thus a positive tax has the desired effect on the size of domestic firms, imports and the inefficiently high number of firms. Furthermore, positive tax causes only a small drop in domestic consumption and this effect is overridden by the incentive to gather revenue. In the special case of linear demand, the efficiency effect and the tax revenue effect exactly offset each other ($p_1'(\partial Q_1^D/\partial t_1) = 1$) and so the optimal tax is zero.

Next we turn to the origin principle. In this case taxes are levied in the country of production, *i.e.*, the country i tax rate applies to all the country i firms' sales. So the tax is levied on each country i firm's output for sale in country i and on its exports to country j. Profits for a representative firm in country 1 and country 2 under the origin principle, denoted by the superscript O, are given by

$$\Pi^{1O} = (p_1 - c - t_1)y_1 + (p_2 - c - s - t_1)x_1 - f,$$
$$\Pi^{2O} = (p_2 - c - t_2)y_2 + (p_1 - c - s - t_2)x_2 - f,$$

respectively, where t_i denotes the production tax imposed by country i. Appendix A.3 has the details of firm behavior. Welfare is now different as taxes affect production so that

$$W_i^O = U(Q_i) - p_i(Q_i)Q_i + t_i n_i(y_i + x_i).$$

Maximizing welfare yields the nationally optimal origin principle tax rate of country 1 (see Appendix A.3) which is given by

$$\widehat{t}_1^O = \frac{1}{\dfrac{\partial n_1^O}{\partial t_1}(y_1 + x_1) + n_1\left(\dfrac{\partial x_1^O}{\partial t_1} + \dfrac{\partial y_1^O}{\partial t_1}\right)} \left(\underbrace{p_1'\frac{\partial Q_1^O}{\partial t_1 Q_1}}_{\text{(I)}, -} \underbrace{-Q_1}_{\text{(II)},+}\right). \tag{7}$$

As with the destination principle, there are two effects, the *efficiency effect* (I) and the *tax revenue effect* (II). Again, the efficiency effect is negative and captures the incentive to correct for the inefficiency of domestic consumption through the use of a subsidy. The main difference here is the effect of the tax rate on the equilibrium outputs and the number of firms in each country as can be seen from Table 3.

Table 3: Production tax effects

	$\frac{\partial y_1^O}{dt_1}$	$\frac{\partial x_1^O}{dt_1}$	$\frac{\partial y_2^O}{dt_1}$	$\frac{\partial x_2^O}{dt_1}$	$\frac{\partial Q_1^O}{\partial t_1}$	$\frac{\partial Q_2^O}{\partial t_1}$	$\frac{\partial n_1^O}{\partial t_1}$	$\frac{\partial n_2^O}{\partial t_1}$
$p'' < 0$	$+$	$-$	$-$	$+$	$-$	$+$	$-$	$+$
$p'' = 0$	$+$	$-$	$-$	$+$	$-$	$+$	$-$	$+$
$p'' > 0$	$+/-$	$-$	$-$	$+$	$-$	$+$	$-$	$+$

Table 3 shows that the effects of a marginal tax change are qualitatively similar for both concave and convex inverse demand: a marginal tax increase in country 1 decreases profits in country 1 and leads to exit of firms in that country. Firms in country 1 incur a tax on every unit they produce, become less competitive with the firms in country 2 and so produce less for export. On the other hand, each firm in country 2 now produces more for export to take advantage of their lower total marginal costs per unit in comparison to country 1 firms. With the rise in production for export there is a corresponding reduction in production for domestic consumption. The only difference between the comparative statics effects for the two types of inverse demand is the ambiguity of the effect on the output of a representative firm for domestic sale when inverse demand is convex.

The optimal non-cooperative tax under the origin principle (see Appendix A.3) is

$$\widehat{t}^O = -\frac{np'(y-x)(y+x)}{\Omega}[y(p''y^2 - 2p'x)\Pi_{yy} - x^2\Pi_{xx}^2] \quad (8)$$

with

$$\begin{aligned}\Omega \;=\; & np''[y^2\Pi_{yy}(y^2+4x^2) + x^2\Pi_{xx}(x^2+4y^2) + \\ & 3yx(y^2\Pi_{yx} + x^2\Pi_{xy}) + p'yx[(y+x)^2 + 2yx]] \\ & +2p'(2n+1)(y+x)(y^2\Pi_{yy} + x^2\Pi_{xx}),\end{aligned}$$

where, again, we have dropped the superscripts, and all variables are evaluated at the symmetric equilibrium.

As with the optimal tax under the destination principle the balance between the competing incentives under the origin principle depends on the curvature of inverse demand. The next proposition summarizes the results for the nationally optimal origin principle tax rate.

Proposition 2 *(a) Under the origin principle, the nationally optimal tax rate is negative for all levels of trade costs if inverse demand is convex ($p'' > 0$) (b) If inverse demand is concave ($p'' < 0$), the optimal tax rate is positive if s is sufficiently high and negative for sufficiently low (but nonzero) trade costs.*

Proof: See Appendix A.3.

The non-cooperative optimal tax rate under the origin principle is negative for convex demand. A subsidy on country 1's production increases domestic firms' profits, while it decreases country 2 firms' profits, causing exit of foreign firms and entry of domestic firms. Each of the domestic firms present in equilibrium will be producing more ($\partial y_1^O/\partial t_1 + \partial x_1^O/\partial t_1 < 0$) while imports will fall (see Table 3), leading to lower average costs and a large increase in the suboptimal consumption of the good.

When demand is concave, the optimal tax rate depends on the level of trade costs. For high trade costs the tax should be positive, as this will encourage some imports. The resulting decrease in the market power of domestic firms will outweigh any negative effects from increased trade costs and improve efficiency. Conversely, when trade costs are low the nationally optimal policy is a subsidy. This is because a subsidy will encourage entry of domestic firms, increase each domestic firm's production ($\partial y_1^O/\partial t_1 + \partial x_1^O/\partial t_1 < 0$) and increase consumption.

The following proposition compares the nationally optimal taxes under each of the tax principles.

Proposition 3 *(a) The nationally optimal tax rate is higher under the destination principle, if inverse demand is concave ($p'' < 0$). (b) The optimal tax* *rate is higher under the origin principle, if inverse demand is convex ($p'' > 0$) and trade costs are sufficiently high or sufficiently low.*

Proof: See Appendix A.4.

We cannot compare the tax rates for intermediate levels of trade costs if inverse demand is convex. However, we are able to determine the minimal trade cost levels under both tax principles which lead to zero exports. Let $\bar{s}^D$ and $\bar{s}^O$ denote this level for the non-cooperative optimal destination and origin principle tax rates, respectively. We find a clear relationship irrespective of the curvature of the inverse demand function.

Proposition 4 *The nationally optimal tax rate under the destination principle leads to no trade for a lower level of trade costs than the nationally optimal tax rate under the origin principle,* i.e., $\bar{s}^D < \bar{s}^O$.

Proof: See Appendix A.4.

Since the tax rate under the origin principle is positive for high trade costs but negative under the destination principle, there is a range of trade costs such that the origin principle will still allow for trade whereas the destination principle will imply no trade. This finding will also be important for the welfare analysis of both tax principles to which we turn now.

4 Economic integration and the choice of the tax principle

In this section the welfare levels that each country obtains when they set taxes non-cooperatively are compared. The criterion against which we compare the two tax principles is the optimal tax that would result from maximizing the combined welfare of the two countries. Under our assumption of identical countries we have a symmetric tax equilibrium, which means the tax levied on all units produced will be the same. This implies that maximization of aggregate welfare under the destination regime is equivalent to maximization under the origin regime. Here we use the destination principle since it is simpler. World welfare is measured as the sum of consumer surplus and tax revenue in both countries:

$$\widetilde{W} = U(Q_1) - p_1(Q_1)Q_1 + U(Q_2) - p_2(Q_2)Q_2 + t_1Q_1 + t_2Q_2.$$

Maximizing world welfare with respect to the tax rate chosen by both countries obtains the coordinated optimal tax rate (see Appendix A.5)

$$\begin{aligned} \widetilde{t} &= \frac{1}{dQ_1^D/dt_1 + dQ_2^D/dt_1} \left(\underbrace{p_1' \frac{dQ_1^D}{dt_1} Q_1}_{\text{(I)},-} + \underbrace{p_2' \frac{dQ_2^D}{dt_1} Q_2}_{\text{(II)},+/-} \underbrace{-Q_1}_{\text{(III)},+} \right) \\ &= -\frac{np''(y^2 + x^2)}{2}. \end{aligned} \tag{9}$$

The optimal tax rate takes into account the effect on both countries' consumer surplus [terms (I) and (II)] and weighs this against the positive tax revenue effect (III). This tax is negative when inverse demand is convex, while for concave inverse demand it is positive.

In order to gain some intuition of the spillover effects of the optimal non-cooperative taxes levied by country 1 we evaluate their effect on country 2 welfare.[7] When taxes are levied under the destination regime, the effect on country 2's welfare is given by

$$\frac{\partial W_2^D}{\partial t_1} = -p_2' \frac{\partial Q_2^D}{\partial t_1} Q_2 + t_2 \frac{\partial Q_2^D}{\partial t_1} Q_2. \tag{10}$$

This expression also gives the marginal effect of a change in country 1's tax rate on world welfare since country 1 chooses its nationally optimal tax rate so that $\partial W_1^D/\partial t_1 = 0$. From the assumption of quasiconcavity of the welfare function it follows that if $\partial W_2^D/\partial t_1 > 0$ (the spillover is positive) the non-cooperative destination principle tax rate is less than the coordinated tax rate, while if $\partial W_2^D/\partial t_1 < 0$ (the spillover is negative) the non-cooperative tax rate is greater than the coordinated tax rate.

[7] A similar approach is used by Haufler and Pflüger (2004).

Additionally, we may also consider the effect on marginal world welfare if both countries agree on the destination principle. We find that

$$\frac{d\widetilde{W}}{dt_1}(t_1 = t_2 = \widehat{t}^D) = -\frac{np''yx(y+x)}{y(\Pi_{yx} + \Pi_{xy}) + x\Pi_{xx}}. \tag{11}$$

This expression is negative for concave inverse demand and positive for convex inverse demand.

We are now ready to discuss the the difference between the destination principle tax and the optimal tax. Consider equation (10). The first term represents the effect of a small tax rise in country 1 on country 2 consumer surplus, while the second term is the direct effect on the tax take of country 2. For concave demand both terms are negative (see Table 2), and so the destination principle tax is too high as it fails to take into account the negative spillovers. On the other hand, for convex inverse demand, the first term is positive and the second is negative. From the positive sign of (11) we see that the negative effect on the tax revenue of country 2 is outweighed by the positive effect on consumer surplus. The positive net spillovers imply that the non-cooperative destination tax will be too low. For the special case of linear demand, the nationally optimal destination principle tax rate is the same as the coordinated tax rate, as for linear demand a small change in the tax rate in country 1 has no effect on the price in country 2 for any level of trade costs (see Table 2). Then, from equation (10), the spillover effects of the tax are zero. Note that for nonlinear demand and non-prohibitive trade costs (*i.e.*, $x > 0$) equation (11) is nonzero (assuming there is some production), so the nationally optimal destination regime tax is not Pareto optimal for any level of trade costs at which trade takes place.

Next we consider non-cooperative taxation under the origin principle. The effect on welfare in country 2 is given by:

$$\frac{\partial W_2^O}{\partial t_1} = -p_2' \frac{\partial Q_2^O}{\partial t_1} Q_2 + t_2 \left(\frac{\partial n_2^O}{\partial t_1}(y_2 + x_2) + n_2 \left(\frac{\partial y_2^O}{\partial t_1} + \frac{\partial x_2^O}{\partial t_1} \right) \right) \tag{12}$$

Again, evaluating (12) at $t_2 = \widehat{t}^O$, positive values imply that the non-cooperative origin principle tax rate is too low, while negative values imply that it is too high. When we substitute the comparative statics results (see

Appendix A.5) and the nationally optimal origin regime tax rate (8) into equation (12) we find that $\partial\widetilde{W}/\partial t_1|_{t_1=t_2=\widehat{t}^O} > 0$ for concave demand, while for convex demand the sign depends on the level of trade costs. For convex demand and sufficiently high or low trade costs we have $\partial\widetilde{W}/\partial t_1|_{t_1=t_2=\widehat{t}^O} < 0$, while this expression may be positive for intermediate levels of trade costs.

The first term of (12) is the spillover effect on country 2's consumer surplus, which is positive (see Table 3). This positive effect is a result of a tax improving efficiency of consumption. The latter term takes the sign of the tax and represents the spillover effect on the country 2 tax base. When the country 2 tax is positive, a small rise in country 1's tax increases overall production in country 2 and leads to an increase in country 2's tax revenue. In this case a tax levied by country 1 will have positive spillovers, which are ignored when setting their tax, resulting in a non-cooperative optimal origin regime tax that is too low. However, with convex or linear inverse demand, country 2's nationally optimal tax is negative and so they will have to increase their subsidy payments as a result of country 1's tax increase. This negative effect on country 2's welfare is ignored when country 1 sets their tax. For convex demand and sufficiently low or high trade costs or for concave demand, this negative spillover outweighs any positive effects on efficiency and thus the non-cooperative origin tax rate is too high. For intermediate values of s and convex demand, it may be the case that the two spillovers exactly cancel each other out and the nationally optimal origin regime tax matches the Pareto efficient tax.

While these results do not indicate any general welfare ranking of tax principles which depends on the degree of integration, we are able to say more if we consider the two special cases of no trade and zero trade costs. We start with the limiting case of trade costs that are so large that the optimal tax rates eliminate all trade. Let $\widetilde{s}$ denote this level for the coordinated tax rate. Substituting $x = 0$ into (6), (9) and (8) we find that

$$\widetilde{s} = \bar{s}^D \Rightarrow \widehat{t}^D|_{s=\widetilde{s}} = \widetilde{t}|_{s=\widetilde{s}} = -\frac{np''y^2}{2}, \widehat{t}^O|_{s=\bar{s}^O} = -\frac{np'p''y^2}{n(\Pi_{yy} + 2p') + 2p'}. \quad (13)$$

Hence, the destination principle tax equilibrium maximizes aggregate welfare.

This is because with prohibitive trade costs a small change in the tax levied in country 1 under the destination principle has no effect on country 2's consumption [see (10)] and so there are no spillovers. Therefore the optimal non-cooperative tax under the destination principle is the same as the Pareto efficient tax rate. These tax rates are the same as in the autarky case [see equation (4)].

Under the origin principle, there are still spillovers present. When inverse demand is concave the spillovers are positive and so the tax is too low, while the spillovers are negative when inverse demand is convex and so the tax is too high. When inverse demand is linear ($p'' = 0$) all the optimal tax rates are zero, $\widetilde{s} = \bar{s}^D = \bar{s}^O$, and non-cooperative taxation under both tax principles is Pareto efficient at prohibitive levels of trade costs.

Furthermore, Proposition 4 has shown that the destination principle implies a lower minimal level of trade costs for which exports become zero whereas the origin principle will still support trade. Expression (13) demonstrates that $\widetilde{s} = \bar{s}^D$, and hence we find that only the destination principle manages trade optimally for high trade costs unless inverse demand is linear.

Corollary 1 *The destination principle guarantees that countries do not trade when it is globally welfare-maximizing not to trade. If inverse demand is nonlinear, the origin principle implies socially excessive trade for high trade cost levels,* i.e., *if* $s \in [\widetilde{s}, \bar{s}^O]$.

Proof: Corollary 1 is a direct result of Proposition 4 and expression (13).

The other limiting case is that of zero trade costs. In contrast to the model with a fixed number of firms the division of output between countries is indeterminate when trade costs are truly zero because markets have become completely integrated.[8] However, we may instead consider trade costs as they become infinitesimally small. As this takes place the market share of exporters approaches that of the domestic producers, *i.e.*, x approaches y. Substituting $x = y$ into (6), (9) and (8) we get

$$\widehat{t}^D|_{s=0} = -\frac{2np''y^2(2p''y + 3p')}{3p''y + 4p'}, \widehat{t}^O|_{s=0} = 0, \widetilde{t}|_{s=0} = -np''y^2. \qquad (14)$$

[8]For $s = 0$, the Jacobian determinant of the system of first order conditions is zero.

So for nonlinear demand, both the optimal non-cooperative destination and origin regime taxes deviate from the cooperative tax when trade costs are zero. When inverse demand is concave the non-cooperative consumption tax is too large as the negative spillover effects are still present in the absence of trade costs [see equation (11)]. Conversely, when inverse demand is convex, the positive net spillovers are not taken into account resulting in a subsidy that is too small. In contrast, the non-cooperative production tax is too small. The origin principle tax rate is zero because as trade costs tend to zero, any marginal tax change would lead to infinite changes in quantities demanded, and infinite changes in the number of firms in each country.

Note that for the special case of linear demand and zero trade costs, all taxes are zero and so both the destination and origin principles lead to Pareto efficient outcomes. As noted earlier, this holds for all levels of trade costs under the destination principle as with linear demand a marginal change in country 1's tax rate has no effect on consumption in country 2. This is not the case under the origin principle. It turns out that although each of the spillovers are nonzero, when demand is linear and trade costs are zero they cancel each other out and therefore the origin principle tax equilibrium is Pareto efficient.

Based on these findings, we are now ready to present the main results of the paper.

Proposition 5 *(a) At prohibitively high levels of trade costs, the non-cooperative tax equilibrium under the destination principle is Pareto efficient. In the neighbourhood of $\widetilde{s}$, it weakly dominates the non-cooperative equilibrium under the origin principle. (b) When inverse demand is linear, the non-cooperative tax equilibrium under the destination principle is Pareto efficient for all levels of trade costs. It weakly dominates the non-cooperative equilibrium under the origin principle for all levels of trade costs.*

Proof: (a) See (13). (b) Substitute $p'' = 0$ into (6) and (9). Both the nationally optimal destination regime tax and the coordinated tax are zero, while the nationally optimal tax under the origin regime may not be [see (8)].

These results lend some support to the use of the destination principle when trade costs are near prohibitive or demand is linear. Proposition 5, however, tells us nothing about the *magnitude* of the destination principle equilibrium level of welfare compared to the origin principle equilibrium or whether there is some level of trade costs at which the origin principle dominates.

5 Concluding remarks

We have examined the role of trade costs in the choice between tax regimes in a reciprocal dumping model with free entry and non-cooperative tax setting. In this model, the nationally optimal tax is chosen to increase the domestic underconsumption of the traded good; to decrease the inefficiently high number of firms each incurring a fixed cost of setup and producing too little; and to alleviate the wasteful trade costs that arise from cross-shipping identical goods. In this framework we found support for the destination principle when trade costs are prohibitive. This replicates the result of the duopoly model investigated by Haufler *et al.* (2005). In their model with a fixed number of firms, however, they found that as trade costs tended toward zero the origin principle approached the coordinated tax rate and dominated the tax equilibrium under the destination principle. In the long run (*i.e.*, with free entry) this is no longer the case. In general neither of the non-cooperative tax equilibriums is Pareto efficient when trade costs are zero.

We do, however, obtain a strong result in favor of the destination principle when demand is linear, as in this special case the non-cooperative tax under this principle coincides with the Pareto efficient level for all levels of trade costs. Under the origin regime, however, the nationally optimal tax deviates from the Pareto efficient level for all intermediate levels of trade costs. Hence, endogenous market structures do not support the origin principle for low levels of trade costs as models with a fixed market structure do.

Overall, it seems unclear which tax principle is favorable. Even if the destination principle may have its merits with free entry and exit, it creates a high adminstrative burden when trade volumes are substantial. Furthermore, the results depend crucially on the type of competition, and this type will not be the same across the board of all markets. Typically, tax principles apply to all commodities and do not distinguish according to the type of the market environment under which these commodities are produced. Unless the type of competition is the same for all commodities produced in all countries, individual countries will balance the pros and cons of tax principles across all markets differently. This may explain disagreement among governments. Hashimzade *et al.* (2006) show in a duopoly model why countries may disagree on tax principles if they are asymmetric in terms of size or costs. Another source of disagreement could be the dominant type of competition which may differ across countries.

Appendix

A.1 Autarky

Totally differentiating the equilibrium conditions, we obtain

$$\begin{bmatrix} p' & p'+p''y & 0 \\ -p'y & p'y & 0 \\ -n & 1 & -y \end{bmatrix} \begin{bmatrix} dy \\ dQ \\ dn \end{bmatrix} = \begin{bmatrix} 1 \\ y \\ 0 \end{bmatrix} dt. \tag{A.1}$$

Solving (A.1) yields

$$\frac{dy}{dt} = -\frac{p''y}{p'(2p'+p''y)}, \frac{dQ}{dt} = \frac{2}{2p'+p''y}, \frac{dn}{dt} = \frac{2p'+np''y}{p'y(2p'+p''y)}, \tag{A.2}$$

which proves the tax effects as given by Table 1. Furthermore, substituting dQ/dt and dn/dt into (3) and setting $dW/dt = 0$ leads to the optimal autarky tax (4).

A.2 Destination principle

The first order condition w.r.t. the tax is given by

$$\frac{\partial W_1^D}{\partial t_1} = -p_1' \frac{\partial Q_1^D}{\partial t_1} + Q_1 + t_1 \frac{\partial Q_1^D}{\partial t_1} = 0. \tag{A.3}$$

Solving for t_1 leads to (5). Firm behavior is determined by

$$\begin{aligned} \Pi^D_{y_i} &= (p_i - c - t_i) + p'_i y_i = 0, \\ \Pi^D_{x_i} &= (p_j - c - s - t_j) + p'_j x_i = 0. \end{aligned} \tag{A.4}$$

Total differentiation yields

$$A \times \begin{bmatrix} dy_1 \\ dx_1 \\ dy_2 \\ dx_2 \\ dQ_1 \\ dQ_2 \\ dn_1 \\ dn_2 \end{bmatrix} = \begin{bmatrix} dt_1 \\ dt_2 \\ dt_2 \\ dt_1 \\ y_1 dt_1 + x_1 dt_2 \\ x_2 dt_1 + y_2 dt_2 \\ 0 \\ 0 \end{bmatrix} \tag{A.5}$$

where

$$A = \begin{bmatrix} p'_1 & 0 & 0 & 0 & p'_1 + p''_1 y_1 & 0 & 0 & 0 \\ 0 & p'_2 & 0 & 0 & 0 & p'_2 + p''_2 x_1 & 0 & 0 \\ 0 & 0 & p'_2 & 0 & 0 & p'_2 + p''_2 y_2 & 0 & 0 \\ 0 & 0 & 0 & p'_1 & p'_1 + p''_1 x_2 & 0 & 0 & 0 \\ -p'_1 y_1 & -p'_2 x_1 & 0 & 0 & p'_1 y_1 & p'_2 x_1 & 0 & 0 \\ 0 & 0 & -p'_2 y_2 & -p'_1 x_2 & p'_1 x_2 & p'_2 y_2 & 0 & 0 \\ -n_1 & 0 & 0 & -n_2 & 1 & 0 & -y_1 & -x_2 \\ 0 & -n_1 & -n_2 & 0 & 0 & 1 & -x_1 & -y_2 \end{bmatrix}.$$

To find the effect of a change in country 1's tax rate, we set $dt_2 = 0$, use symmetry to simplify and solve to obtain the equilibrium responses w.r.t. a change in the destination principle tax:

$$\frac{\partial y_1^D}{\partial t_1} = -\frac{p''[y(y+x)\Pi_{yy} + x^2(p''y - \Pi_{xx})]}{p'(y\Pi_{yy} + x\Pi_{xx})(\Pi_{yx} + \Pi_{xy})},$$

$$\frac{\partial x_1^D}{\partial t_1} = -\frac{2p''yx\Pi_{xy}}{p'(y\Pi_{yy} + x\Pi_{xx})(\Pi_{yx} + \Pi_{xy})},$$

$$\frac{\partial y_2^D}{\partial t_1} = -\frac{2p''yx\Pi_{yx}}{p'(y\Pi_{yy} + x\Pi_{xx})(\Pi_{yx} + \Pi_{xy})},$$

$$\frac{\partial x_2^D}{\partial t_1} = \frac{p''[y(y-x)\Pi_{yy} - x^2(\Pi_{yx} + \Pi_{xy})]}{p'(y\Pi_{yy} + x\Pi_{xx})(\Pi_{yx} + \Pi_{xy})},$$

$$\frac{\partial Q_1^D}{\partial t_1} = \frac{2[p''yx + [y\Pi_{yy} + x\Pi_{xx}]}{(y\Pi_{yy} + x\Pi_{xx})(\Pi_{yx} + \Pi_{xy})},$$

$$\frac{\partial Q_2^D}{\partial t_1} = \frac{2p''yx}{(y\Pi_{yy} + x\Pi_{xx})(\Pi_{yx} + \Pi_{xy})},$$

$$\frac{\partial n_1^D}{\partial t_1} = \frac{2y[np''x(y\Pi_{yy} - x\Pi_{xx}) + p'(y+x)\Pi_{yy}]}{p'(y-x)(y+x)(y\Pi_{yy} + x\Pi_{xx})(\Pi_{yx} + \Pi_{xy}))},$$

$$\frac{\partial n_2^D}{\partial t_1} = -\frac{2x[np''y(x\Pi_{xx} - y\Pi_{yy}) + p'(y+x)\Pi_{xx}]}{p'(y-x)(y+x)(y\Pi_{yy} + x\Pi_{xx})(\Pi_{yx} + \Pi_{xy}))}.$$

For convenience we have dropped unnecessary subscripts. Inserting these results into (5) gives (6). To sign the terms (see Table 2), first observe that $y - x = -s/p' \geq 0$ due to (A.4). Then, all of the comparative static effects but $\partial y_1^D/\partial t_1$, $\partial x_2^D/\partial t_1$ and $\partial n_1^D/\partial t_1$ can easily be signed by using strategic substitutability. To sign $\partial y_1^D/\partial t_1$, we subtract $\partial x_1^D/\partial t_1$ from $\partial y_1^D/\partial t_1$:

$$\frac{\partial y_1^D}{\partial t_1} - \frac{\partial x_1^D}{\partial t_1} = \frac{(y+x)(y-x)p''}{p'y\Pi_{yy} + x\Pi_{xx}}.$$

When inverse demand is concave, this expression is positive, implying $\partial y_1^D/\partial t_1 > \partial x_1^D/\partial t_1$. For concave inverse demand $\partial x_1^D/\partial t_1$ is positive and so $\partial y_1^D/\partial t_1$ is positive. If inverse demand is convex, the above expression and the term $\partial x_1^D/\partial t_1$ take a negative sign and so $\partial y_1^D/\partial t_1$ is negative. We can sign $\partial x_2^D/\partial t_1$ and $\partial n_1^D/\partial t_1$ easily when inverse demand is concave. However, for convex inverse demand, the signs of $\partial x_2^D/\partial t_1$ and $\partial n_1^D/\partial t_1$ depend on the level of trade costs. High (low) trade costs imply $\partial x_2^D/\partial t_1$ is positive (negative). $\partial n_1^D/\partial t_1$ is negative for sufficiently high or low trade costs, while it may be positive for intermediate values of s.

A.3 Origin principle

The first order condition w.r.t. the tax is given by

$$\frac{\partial W_1^O}{\partial t_1} = -p_1'\frac{\partial Q_1^O}{\partial t_1} + n_1(y_1+x_1) + t_1\left(\frac{\partial n_1^O}{\partial t_1}(y_1+x_1) + n_1\left(\frac{\partial y_1^O}{\partial t_1} + \frac{\partial x_1^O}{\partial t_1}\right)\right) = 0. \tag{A.6}$$

Solving for t_1 leads to (7). Firm behavior is determined by

$$\begin{aligned}\Pi^O_{y_i} &= (p_i - c - t_i) + p_i' y_i = 0, \qquad (A.7)\\ \Pi^O_{x_i} &= (p_j - c - s - t_i) + p_j' x_i = 0.\end{aligned}$$

Total differentiation yields

$$A \times \begin{bmatrix} dy_1 \\ dx_1 \\ dy_2 \\ dx_2 \\ dQ_1 \\ dQ_2 \\ dn_1 \\ dn_2 \end{bmatrix} = \begin{bmatrix} dt_1 \\ dt_1 \\ dt_2 \\ dt_2 \\ (y_1 + x_1)dt_1 \\ (y_2 + x_2)dt_2 \\ 0 \\ 0 \end{bmatrix} \qquad (A.8)$$

where the matrix A is the same as in (A.5). As before, we set $dt_2 = 0$, use symmetry to simplify and solve to obtain the equilibrium responses w.r.t. a change in the origin principle tax:

$$\frac{\partial y_1^O}{\partial t_1} = -\frac{p''[y^2(y+2x)\Pi_{yy} + x^3\Pi_{xx}] + 2p'x(y\Pi_{yy} + x\Pi_{xx})}{p'(y-x)(y\Pi_{yy} + x\Pi_{xx})(\Pi_{yx} + \Pi_{xy})},$$

$$\frac{\partial x_1^O}{\partial t_1} = \frac{p''[y^3\Pi_{yy} + x^2(2y+x)\Pi_{xx}] + 2p'y(y\Pi_{yy} + x\Pi_{xx})}{p'(y-x)(y\Pi_{yy} + x\Pi_{xx})(\Pi_{yx} + \Pi_{xy})},$$

$$\frac{\partial y_2^O}{\partial t_1} = \frac{2x(y+x)\Pi_{yx}\Pi_{xx}}{p'(y-x)(y\Pi_{yy} + x\Pi_{xx})(\Pi_{yx} + \Pi_{xy})},$$

$$\frac{\partial x_2^O}{\partial t_1} = -\frac{2y(y+x)\Pi_{yy}\Pi_{xy}}{p'(y-x)(y\Pi_{yy} + x\Pi_{xx})(\Pi_{yx} + \Pi_{xy})},$$

$$\frac{\partial Q_1^O}{\partial t_1} = \frac{2y(y+x)\Pi_{yy}}{(y-x)(y\Pi_{yy} + x\Pi_{xx})(\Pi_{yx} + \Pi_{xy})},$$

$$\frac{\partial Q_2^O}{\partial t_1} = -\frac{2x(y+x)\Pi_{xx}}{(y-x)(y\Pi_{yy} + x\Pi_{xx})(\Pi_{yx} + \Pi_{xy})},$$

$$\frac{\partial n_1^O}{\partial t_1} =$$

$$\frac{ny^2\Pi_{yy}[y(\Pi_{yx} + \Pi_{xy}) + 2x(2\Pi_{yx} + \Pi_{xy})] + nx^2\Pi_{xx}[x(\Pi_{yx} + \Pi_{xy}) + 2y(\Pi_{yx} + 2\Pi_{xy})]}{p'(y-x)^2(y+x)(y\Pi_{yy} + x\Pi_{xx})(\Pi_{yx} + \Pi_{xy})} +$$

$$\frac{2p'(y+x)(y^2\Pi_{yy}+x^2\Pi_{xx})}{p'(y-x)^2(y+x)(y\Pi_{yy}+x\Pi_{xx})(\Pi_{yx}+\Pi_{xy})},$$

$$\frac{\partial n_2^O}{\partial t_1} =$$

$$-\frac{ny^2\Pi_{yy}[y(\Pi_{yx}+\Pi_{xy})+6x\Pi_{xy}]+nx^2\Pi_{xx}[x(\Pi_{yx}+\Pi_{xy})+6y\Pi_{yx}]}{p'(y-x)^2(y+x)(y\Pi_{yy}+x\Pi_{xx})(\Pi_{yx}+\Pi_{xy})}-$$

$$-\frac{2p'yx(y+x)(\Pi_{yy}+\Pi_{xx})}{p'(y-x)^2(y+x)(y\Pi_{yy}+x\Pi_{xx})(\Pi_{yx}+\Pi_{xy})}.$$

Once again, we have dropped unnecessary subscripts. The first order conditions A.7 imply that $y \geq x$. Using symmetry and strategic substitutability, it is then straightforward to sign all of the comparative statics effects, except $\partial y_1^O/\partial t_1$ and $\partial x_1^O/\partial t_1$. Subtracting $\partial y_2^O/\partial t_1$ from $\partial x_1^O/\partial t_1$ leads to

$$\frac{\partial x_1^O}{\partial t_1} - \frac{\partial y_2^O}{\partial t_1} = \frac{(y+x)^2(y-x)p''^2 + 4p'y\Pi_{yx} + 4p'^2x}{p'(y\Pi_{yy}+x\Pi_{xx})(\Pi_{yx}+\Pi_{xy})}.$$

This expression is negative, implying $\partial x_1^O/\partial t_1 < \partial y_2^O/\partial t_1$. Since $\partial y_2^O/\partial t_1 < 0$, it follows that $\partial x_1^O/\partial t_1 < 0$. The sign of $\partial y_1^O/\partial t_1$ is positive for concave inverse demand. When inverse demand is convex, its sign depends on the level of trade costs – for high trade costs ($x \approx 0$) it is negative and for low trade cost ($x \approx y$) it is positive.

For the proof of part (a) of Proposition 2, we first sign the denominator of (7) which can be written as

$$\frac{\partial n_1^O}{\partial t_1}(y_1+x_1) + n_1\left(\frac{\partial x_1^O}{\partial t_1} + \frac{\partial y_1^O}{\partial t_1}\right) = \frac{\partial Q_1^O}{\partial t_1} + \frac{\partial (n_1x_1 - n_2x_2)^O}{\partial t_1}.$$

From Table 3, the first term on the RHS is negative. The second term can be calculated by using the comparative statics results:

$$\frac{\partial (n_1x_1 - n_2x_2)^O}{\partial t_1} = \frac{n[(y^2+3x^2)\Pi_{yx} + (3y^2+x^2)\Pi_{xy}] + 2p'x(y+x)}{p'(y-x)^2(\Pi_{yx}+\Pi_{xy})}$$

which is negative due to strategic substitutability. Thus the denominator is negative. For the numerator we find that

$$p_1'\frac{\partial Q_1^O}{\partial t_1}Q_1 - n_1(y_1+x_1) = -\frac{n(y+x)[y(p''y^2-2p'x)\Pi_{yy} - x^2\Pi_{xx}^2]}{(y-x)(\Pi_{yx}+\Pi_{xy})(y\Pi_{yy}+x\Pi_{xx})}.$$

Due to strategic substitutability, the numerator of (7) is positive if inverse demand is convex, *i.e.*, $p'' > 0$. Next, we sign the numerator for different levels of trade costs. For sufficiently high trade costs ($x \approx 0$) we obtain

$$p_1' \frac{\partial Q_1^O}{\partial t_1} Q_1 - n_1(y_1 + x_1) \approx -\frac{np''y^2}{\Pi_{yx}}$$

which is negative for $p'' < 0$. Thus, for sufficiently high trade costs, the tax is positive. For sufficiently small trade costs, $x \approx y$ and consequently

$$p_1' \frac{\partial Q_1^O}{\partial t_1} Q_1 - n_1(y_1 + x_1) \approx \frac{8np'y^3\Pi_{yy}}{(y-x)(\Pi_{yx} + \Pi_{xy})(y\Pi_{yy} + x\Pi_{xx})}$$

which is positive which proves that the tax is negative for sufficiently low trade costs and which completes the proof of part (b) of Proposition 2.

A.4 Comparison of tax principles

We evaluate the (11) at the equilibrium tax rate under the origin principle. Due to quasiconcavity, it follows that $\widehat{t}^D > (<) \widehat{t}^O$ when $\partial W_1^D / \partial t_1|_{t_1 = \widehat{t}^O} > (<)0$. For the proof of part (a) of Proposition 3, we calculate $\partial W_1^D / \partial t_1|_{t_1 = \widehat{t}^O}$ using the comparative statics results of Appendix A.2 and (8) in (11) which results in $\partial W_1^D / \partial t_1 (t_1 = t_2 = \widehat{t}^O) > 0$, implying that $\widehat{t}^D > \widehat{t}^O$. For the proof of part (b) of Proposition 3, we use $x = 0$ to obtain

$$\frac{\partial W_1^D}{\partial t_1}(t_1 = t_2 = \widehat{t}^O) = \frac{n^2 p'' y^2 (4p' + p''y)}{(2p' + p''y)[n(4p' + p''y) + 2p']}$$

which is negative for $p'' > 0$. Hence, $\widehat{t}^D < \widehat{t}^O$ for sufficiently high trade costs and convex inverse demand. When trade costs are small, using $x = y$ yields

$$\frac{\partial W_1^D}{\partial t_1}(t_1 = t_2 = \widehat{t}^O) = \frac{np''y^2(3p' + 2p''y)}{(2p' + p''y)(p' + p''y)}$$

which is also negative for $p'' > 0$, implying that $\widehat{t}^D < \widehat{t}^O$ also for sufficiently small trade costs and convex inverse demand. This completes the proof of part (b) of Proposition 3.

As for the proof of Proposition 4, it is first useful to determine the effect of a tax rise on total exports. From the comparative statics results of both

Appendix A.2 and Appendix A.3 we obtain

$$\frac{\partial(n_1x_1+n_2x_2)}{\partial t_1}=\frac{np''(y-x)(y^2+x^2)+2p'x(y+x)}{p'(y+x)(y\Pi_{yy}+x\Pi_{xx})}.$$

This expression is negative if inverse demand is concave, implying that aggregate exports are monotonously falling in t_1 under both tax principles. For convex demand and high trade costs ($x \approx 0$), this expression is positive such that aggregate exports will monotonously rise with t_1 for that case. Proposition 3 shows that $\widehat{t}^O < \widehat{t}^D$ for all levels of trade costs if inverse demand is concave. Since aggregate exports are monotonously falling in t_1 in this case, we conclude that $\widehat{s}^D < \widehat{s}^O$. Proposition 3 also shows that $0 > \widehat{t}^O > \widehat{t}^D$ for high levels of trade costs if inverse demand is convex. Since aggregate exports are monotonously rising in t_1 in that case, we conclude that $\widehat{s}^D < \widehat{s}^O$. Hence, $\widehat{s}^D < \widehat{s}^O$ in all conceivable cases which completes the proof of Proposition 4.

A.5 Global welfare maximization

Maximizing global welfare warrants

$$\frac{\partial\widetilde{W}}{\partial t_1}=-p_1'\frac{\partial Q_1^D}{\partial t_1}Q_1+Q_1+t_1\frac{\partial Q_1^D}{\partial t_1}-p_2'\frac{\partial Q_2^D}{\partial t_1}+t_2\frac{\partial Q_2^D}{\partial t_1}=0.$$

Rearranging and using symmetry ($t_1 = t_2$) yields (9).

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