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Maximum-Revenue versus Optimum-Welfare Export Taxes

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Abstract

In a game between two exporting countries, both countries may be better off if they both delegate to policymakers who maximise tax revenue rather than welfare. However, both countries delegating to policymakers who maximise revenue is not necessarily a Nash equilibrium. The game may be a prisoner's dilemma where both countries are better off delegating to policymakers who maximise revenue, but both will delegate to policymakers who maximise welfare in the Nash equilibrium. This result is obtained in the Bertrand duopoly model of Eaton and Grossman (1986) and the perfectly competitive model of Panagariya and Schiff (1995).

Keywords: Trade Policy, Export Taxes, Game Theory, Delegation.

JEL Classification: C72, F11, F12, F13.

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1. Introduction

Panagariya and Schiff (1994 and 1995) showed that two countries each setting export taxes to maximise tax revenue may obtain higher welfare in the Nash equilibrium in export taxes than if the countries were each setting export taxes to maximise national welfare. In their analysis, two countries both export the product of a perfectly competitive industry to a third-country market and each of the exporting countries uses an export tax to improve its terms of trade. The export taxes of the two exporting countries are strategic complements since when one country increases its export tax this increases the demand for exports facing the other country and leads the other country to increase its export tax. When a country maximises tax revenue, the export tax will be higher than when the country maximises welfare as Johnson (1951-52) has shown. Therefore, if both countries maximise tax revenue rather than national welfare then both countries will commit to set higher export taxes and, as a result, both countries may be better off. Yilmaz (1999) extends the analysis of Panagariya and Schiff (1994 and 1995) by using a computable general equilibrium model of the world cocoa market that concentrates upon Côte d'Ivoire and Cameroon. For both these countries, he finds that welfare in the Nash equilibrium in export taxes is higher when both countries maximise tax revenue than when they both maximise welfare.[1]

However, the analysis of Panagariya and Schiff (1994 and 1995) leaves a couple of questions unanswered. Firstly, how can a country credibly commit to maximise export tax revenue rather than welfare when it is really concerned to maximise welfare? Secondly, is it a Nash equilibrium for both countries to choose to maximise export tax revenue rather than welfare? This paper will attempt to answer these questions, in both the Eaton and Grossman

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[1] Piermartini (2004) shows that export tax revenue can be quite a significant source of government revenue for some developing countries (such as Ghana and Cameroon) and that export taxes are quite common on primary products (such as cocoa, coffee and sugar).

(1986) Bertrand duopoly model and the perfectly competitive model of Panagariya and Schiff (1995), which is analysed in the appendix. The two models are qualitatively similar, since in both models there are two countries exporting to a third-country market and export taxes are strategic complements, as was noted by Panagariya and Schiff (1995).

To answer the first question about a country credibly committing to maximise tax revenue rather than welfare, it will be assumed that a country can delegate the setting of the export tax either to a policymaker who maximises tax revenue or to a policymaker who maximises national welfare.[2] It will be shown that if both countries delegate to a policymaker who maximises tax revenue then they will be better off than if they both delegate to policymakers who maximise welfare when the products are close substitutes in the Eaton and Grossman (1986) model.

To answer the second question about whether both countries choosing to maximise tax revenue is a Nash equilibrium, the game will be extended by adding a first stage where the countries will choose either to delegate to a policymaker who maximises tax revenue or to delegate to a policymaker who maximises national welfare. It will be shown that the outcome of this extended game depends upon the degree of product substitutability in the Eaton and Grossman (1986) model. Although both countries delegating to policymakers who maximise tax revenue may yield higher welfare than both countries delegating to policymakers who maximise welfare, it is not necessarily a Nash equilibrium of the first stage of the game. This game may be a prisoner's dilemma where both countries would be better off delegating to revenue-maximising policymakers, but they both delegate to welfare-maximising

[2] Delegation of trade policy to a policymaker with different preferences to the government is analysed in strategic trade policy models by Trandel and Skeath (1996) and Collie (1997), where the policymaker puts more or less weight on the profits of the domestic firm than the government in its objective function. Tax revenue maximisation puts zero weight on the profits of the domestic firms in the objective function of the policymaker.

policymakers in the Nash equilibrium of the first stage of the game. It is shown that for a wide range of parameter values the game is a prisoner's dilemma, and that delegating to revenue-maximising policymakers is only a Nash equilibrium when the products are very close substitutes in the Eaton and Grossman (1986) model.

2. The Model

There are two exporting countries, labelled one and two, each with one firm that produces a differentiated good.[3] Both firms export to a third-country market where they compete in a symmetric Bertrand duopoly. The governments in both countries maximise national welfare by using export taxes, but each government delegates the setting of the export tax either to a policymaker who maximises tax revenue or to a policymaker who maximises national welfare.[4] This export tax policy game between the governments in the two countries can be modelled using a multi-stage game. At stage one of the game, the two governments each decide whether to delegate the setting of the export tax to a policymaker who maximises tax revenue or to a policymaker who maximises national welfare. Then, at the second stage of the game, the two policymakers chosen by the government in stage one each set their export taxes to maximise their objective function. Finally, in the third stage of the game, the two firms compete as Bertrand duopolists in the third-country market given the export taxes set by the two policymakers in stage two. As usual, the multistage game will be solved by backward induction to obtain the subgame perfect Nash equilibrium.

[3] A similar model with differentiated products and linear demand is used by Kikuchi (1998) and Clarke and Collie (2003, 2006a, and 2006b) to address various trade policy issues.

[4] Of course, each government could set the export tax itself rather than delegating to a policymaker who maximises national welfare.

Markets are assumed to be segmented and both firms have constant marginal cost c so the third-country market can be analysed independently of the markets in countries one and two. Firm one sets price p_1, and sells output y_1 while firm two sets price p_2, and sells output y_2. The policy-maker in country one (two) imposes a specific export tax of e_1 (e_2) per unit exported by firm one (two). It is assumed that there is a representative consumer in the third-country market with quasi-linear preferences that can be represented by a symmetric quadratic utility function:

$$U(\mathbf{y},z) = \sum_{i=1}^{2} \alpha y_i - \frac{1}{2}\sum_{i=1}^{2} \beta y_i^2 - \gamma y_1 y_2 + z \qquad \alpha,\beta,\gamma > 0; \quad \beta > \gamma \tag{1}$$

where z is consumption of a numeraire good and $\phi \equiv \gamma/\beta \in (0,1)$ is a measure of the degree of product substitutability ranging from zero when the products are independent to one when they are perfect substitutes. It is straightforward to show that the utility function (1) yields the following inverse and direct demand functions:

$$\begin{aligned} p_i &= \alpha - \beta y_i - \gamma\, y_j \\ y_i &= \frac{1}{F}\left[\alpha(\beta-\gamma) - \beta\, p_i + \gamma\, p_j\right] \end{aligned} \qquad i,j = 1,2 \quad i \neq j \tag{2}$$

where $F = \beta^2 - \gamma^2 > 0$.

The multistage game is solved by backward induction starting at the final stage when the firms compete as Bertrand duopolists given the export taxes set by the policymakers. Then, the profit functions of the two firms from exports to the third-country market are:

$$\pi_i = \left(p_i - c - e_i\right) y_i \qquad i = 1,2 \tag{3}$$

Assuming an interior solution, where both firms export positive quantities to the third-country market, it is straightforward to solve for the Bertrand equilibrium prices:

$$p_i = c + e_i + \frac{1}{H}\left[G(\alpha - c - e_i) - \beta\gamma(\alpha - c - e_j)\right] \tag{4}$$

where $G = 2\beta^2 - \gamma^2 > 0$ and $H = 4\beta^2 - \gamma^2 > 0$. Substituting these prices into the demand functions (2) yields the Bertrand equilibrium exports of the two firms:

$$y_i = \frac{\beta}{FH}\left[G(\alpha - c - e_i) - \beta\gamma(\alpha - c - e_j)\right] \tag{5}$$

From (4) and (5), it can be seen that an increase in the export tax of a country results in both firms increasing their prices, a decrease in exports for the firm in the country imposing the export tax and an increase in exports for its competitor.

3. Nash Equilibrium Export Taxes

There are four possible subgames at stage two of the multistage game, since the government in each country either delegates to a policymaker who maximises welfare or a policymaker who maximises tax revenue. The export tax best-reply functions and the Nash equilibrium of these four possible subgames are derived in this section.

The export tax revenue of each country is given by the export tax multiplied by the quantity of exports:

$$R_i = e_i y_i \qquad i = 1,2 \tag{6}$$

The welfare of each exporting country is given by the sum of the profits of its firm and its export tax revenue:

$$W_i = \pi_i + e_i y_i = (p_i - c) y_i \qquad i = 1,2 \tag{7}$$

When the government in the *i*th country chooses a policymaker who maximises welfare, the policymaker maximises (7), which yields the first-order condition:

$$\frac{\partial W_i}{\partial e_i} = (p_i - c)\frac{\partial y_i}{\partial e_i} + y_i \frac{\partial p_i}{\partial e_i} = 0 \qquad i = 1,2 \tag{8}$$

Solving the first-order condition for the optimal export tax given the export tax of the other country yields the export tax best-reply function for a welfare maximising policymaker:

$$e_i^W = r_i^W\left(e_j\right) = \frac{\gamma^2}{4\beta^2 G}\left[\left(\beta-\gamma\right)\left(2\beta+\gamma\right)\left(\alpha-c\right)+\gamma\beta e_j\right] \tag{9}$$

The export tax best-reply function for a welfare maximising policymaker is increasing in the export tax of the other country so export taxes are strategic complements.

When the government in the *i*th country chooses a policymaker who maximises export tax revenue, the policymaker maximises (6), which yields the first-order condition are:

$$\frac{\partial R_i}{\partial e_i} = y_i + e_i \frac{\partial y_i}{\partial e_i} = 0 \qquad\qquad i = 1,2 \tag{10}$$

Solving the first-order condition for the optimal export tax given the export tax of the other country yields the export tax best-reply function for a tax revenue maximising policymaker:

$$e_i^R = r_i^R\left(e_j\right) = \frac{1}{2G}\left[\left(\beta-\gamma\right)\left(2\beta+\gamma\right)\left(\alpha-c\right)+\gamma\beta e_j\right] \tag{11}$$

The best-reply function is increasing in the export tax of the other country so the export taxes are strategic complements. Note that the terms in square brackets in (9) and (11) are identical. Therefore, since $1/2G > \gamma^2/4\beta^2 G$, the optimal export tax of a country is larger with a revenue maximising policymaker than with a welfare maximising policymaker, $e_i^R > e_i^W$, and the slope of the best-reply function is steeper with a revenue maximising policy maker than with a welfare maximising policymaker. The four best-reply functions are shown in figure 1 and their intersections are the Nash equilibrium of the four subgames.[5]

In the subgame where both countries choose policymakers that maximise welfare, the Nash equilibrium of the subgame is given by the intersection of the two export tax best-reply

[5] The shape of the iso-welfare loci in figure 1 follows from the fact that the welfare of a country is always increasing in the export tax of the other country (assuming that the export taxes are positive).

functions for welfare maximising policy makers denoted (W,W) in figure 1. Using (4) and (5) together with (9) yields the Nash equilibrium export taxes of the two countries (where the superscript *WW* is used to denote the Nash equilibrium where policymakers in both countries maximise welfare):

$$e_i^{WW} = \frac{(\beta-\gamma)\gamma^2}{\beta(4\beta^2-2\beta\gamma-\gamma^2)}(\alpha-c)>0 \tag{12}$$

Substituting the export taxes of the two countries into the expression for welfare yields the welfare of the two countries when policymakers in both countries maximise welfare:

$$W_i^{WW} = \frac{2\beta G(\beta-\gamma)}{(\beta+\gamma)(4\beta^2-2\beta\gamma-\gamma^2)^2}(\alpha-c)^2 \tag{13}$$

In the subgame where both countries choose policymakers who maximise tax revenue, the Nash equilibrium of the subgame is given by the intersection of the two best-reply functions for revenue maximising policy makers denoted by (R,R) in figure 1. Using (4) and (5) together with (11) yields the Nash equilibrium export taxes of the two countries (where the superscript *RR* denotes the Nash equilibrium where policymakers in both countries are maximising tax revenue):

$$e_i^{RR} = \frac{(\beta-\gamma)(2\beta+\gamma)}{4\beta^2-\beta\gamma-2\gamma^2}(\alpha-c)>0 \tag{14}$$

Substituting the export taxes of the two countries into the expression for welfare yields the welfare of the two countries when policymakers in both countries maximise tax revenue:

$$W_i^{RR} = \frac{2\beta G(\beta-\gamma)(3\beta^2-\gamma^2)}{(\beta+\gamma)(2\beta-\gamma)^2(4\beta^2-\beta\gamma-2\gamma^2)^2}(\alpha-c)^2 \tag{15}$$

In the subgame where country one chooses a policy maker who maximises tax revenue and country two chooses a policymaker who maximises welfare, the Nash equilibrium is given by the intersection of the best-reply function for a revenue maximising policymaker in country one and the best-reply function for a welfare maximising policymaker in country two denoted by (R,W) in figure 1. Using (4) and (5) together with (9) and (11) yields the Nash equilibrium export taxes of the two countries (where the superscript *RW* denotes the Nash equilibrium where the policymaker in country one is maximising revenue and the policymaker in country two is maximising welfare):

$$
\begin{aligned}
e_1^{RW} &= \frac{H(\beta-\gamma)\left(4\beta^2+2\beta\gamma-\gamma^2\right)}{\beta\left(32\beta^4-32\beta^2\gamma^2+7\gamma^4\right)}(\alpha-c)>0 \\
e_2^{RW} &= \frac{\gamma^2(\beta-\gamma)(2\beta+\gamma)\left(4\beta^2+\beta\gamma-2\gamma^2\right)}{\beta^2\left(32\beta^4-32\beta^2\gamma^2+7\gamma^4\right)}(\alpha-c)>0
\end{aligned}
\tag{16}
$$

Substituting the export taxes of the two countries into the expression for welfare yields the welfare of the two countries when the policymaker in country one maximises tax revenue and the policymaker in country two maximises welfare:

$$
\begin{aligned}
W_1^{RW} &= \frac{2G(\beta-\gamma)\left(3\beta^2-\gamma^2\right)\left(4\beta^2+2\beta\gamma-\gamma^2\right)}{\beta(\beta+\gamma)\left(32\beta^4-32\beta^2\gamma^2+7\gamma^4\right)^2}(\alpha-c)^2 \\
W_2^{RW} &= \frac{2G(\beta-\gamma)(2\beta+\gamma)^2\left(4\beta^2+\beta\gamma-2\gamma^2\right)}{\beta(\beta+\gamma)\left(32\beta^4-32\beta^2\gamma^2+7\gamma^4\right)^2}(\alpha-c)^2
\end{aligned}
\tag{17}
$$

The final subgame is when the policymaker in country one maximises welfare and the policymaker in country two maximises tax revenue, but symmetry implies that the export taxes of the two countries are symmetric: $e_2^{WR}=e_1^{RW}$ and $e_1^{WR}=e_2^{RW}$; and that the welfare of the two countries are also symmetric: $W_2^{WR}=W_1^{RW}$ and $W_1^{WR}=W_2^{RW}$.

As in Panagariya and Schiff (1994, 1995), it is interesting to compare the Nash equilibrium in export taxes when policy makers in both countries maximise welfare (W,W) with that when policymakers in both countries maximise tax revenue (R,R). Clearly, figure 1 shows that the Nash equilibrium export taxes are larger at (R,R) than at (W,W) as one would expect.[6] To show how the relative size of the Nash equilibrium export taxes depends upon the degree of product substitutability divide (12) by (14) which yields:

$$\frac{e_i^{WW}}{e_i^{RR}} = \frac{\gamma^2\left(4\beta^2 - \beta\gamma - 2\gamma^2\right)}{\beta\left(8\beta^3 - 4\beta\gamma^2 - \gamma^3\right)} = \frac{\phi^2\left(4 - \phi - 2\phi^2\right)}{8 - 4\phi^2 - \phi^3} < 1 \tag{18}$$

This ratio only depends upon the degree of product substitutability and, since $0 < \phi \equiv \gamma/\beta < 1$, it is clearly always less than one. Figure 2 shows the ratio of the Nash equilibrium export taxes as a function of the degree of product substitutability and shows that it increases from zero when products are independent, $\phi = 0$, to one-third when products are perfect substitutes, $\phi = 1$. Note that when products are independent, $\phi = 0$, the Nash equilibrium export tax when policymakers in both countries maximise welfare is zero, $e_i^{WW} = 0$.

To compare the welfare when policymakers in both countries maximise tax revenue with welfare when policymakers in both countries maximise welfare, divide (15) by (13) which yields:

$$\Omega^* = \frac{W_1^{RR}}{W_1^{WW}} = \frac{\left(3\beta^2 - \gamma^2\right)\left(4\beta^2 - 2\beta\gamma - \gamma^2\right)}{\left(2\beta - \gamma\right)^2\left(4\beta^2 - \beta\gamma - 2\gamma^2\right)^2} = \frac{\left(3 - \phi^2\right)\left(4 - 2\phi - \phi^2\right)}{\left(2 - \phi\right)^2\left(4 - \phi - 2\phi^2\right)^2} \tag{19}$$

Again, this ratio depends only upon the degree of product substitutability and it is plotted in figure 3. If this ratio is greater than one then welfare is higher in the Nash equilibrium

[6] In conventional trade theory, Johnson (1951-52) showed that the maximum-revenue tariff exceeds the optimum-welfare tariff but Collie (1991) and Clarke and Collie (2006a) showed that this need not be the case under oligopoly. However, for an export tax, Clarke and Collie (2006b) showed that maximum-revenue export tax always exceeds the optimum-welfare export tax under oligopoly.

export taxes at (R,R) than at (W,W), and this is the case if $\phi > \phi^* \approx 0 \cdot 466$. This leads to the following proposition:

Proposition 1: *Welfare is higher in the Nash equilibrium in export taxes when policymakers in both countries maximise tax revenue (R,R) than when policymakers in both countries maximise welfare (W,W) if the degree of product substitutability* $\phi > \phi^* \approx 0 \cdot 466$.

Therefore, if the products are sufficiently close substitutes then welfare will be higher when policymakers in both countries maximise revenue than when policymakers in both countries maximise welfare. This case is shown in figure 1, where (R,R) is clearly on a higher iso-welfare locus than (W,W). The proposition is analogous to the results of Panagariya and Schiff (1994 and 1995), which they obtained in a perfectly competitive model.

4. Nash Equilibrium

In the first stage of the game, the governments in the two countries each choose whether to delegate the setting of the export tax to a policymaker who maximises welfare or to a policymaker who maximises tax revenue. These choices yield the welfare payoffs derived in the previous section, and the first stage of the game can be represented by the payoff matrix:

<table>
<tr><td colspan="2" rowspan="2">Payoff matrix
Countries delegate to a policy-maker who maximises:</td><td colspan="2">Country Two</td></tr>
<tr><td>Welfare (W)</td><td>Revenue (R)</td></tr>
<tr><td rowspan="2">Country One</td><td>Welfare (W)</td><td>W_1^{WW}, W_2^{WW}</td><td>W_1^{WR}, W_2^{WR}</td></tr>
<tr><td>Revenue (R)</td><td>W_1^{RW}, W_2^{RW}</td><td>W_1^{RR}, W_2^{RR}</td></tr>
</table>

Proposition 1 does not imply that both countries delegating to a policymaker who maximises revenue is a Nash equilibrium of the first-stage of the game as it may be a prisoner's dilemma type of game. In the case shown in figure 1, welfare is higher in the Nash equilibrium in export taxes at (R,R) than at (W,W), but welfare is even higher in the Nash equilibrium in export taxes at (W,R). Therefore, if country two delegates to a policymaker who maximises tax revenue then country one is better off delegating to a policymaker who maximises welfare rather than a policymaker who maximises tax revenue, $W_1^{WR} > W_1^{RR}$, so both countries delegating to a policymaker who maximises tax revenue is not a Nash equilibrium. In figure 1, the Nash equilibrium is for both countries to delegate to a policymaker who maximises welfare even though both countries would be better off if they both delegated to a policymaker who maximises tax revenue.

In general, the outcome of the first stage of the game will depend upon the degree of product substitutability. To find the Nash equilibria of the first stage of the game consider the best-replies of the two countries to the strategies of the other country. The best-reply of country one will be R when country two chooses R if $W_1^{RR} > W_1^{WR}$, which will be the case if:

$$\begin{aligned}\Omega^R = \frac{W_1^{RR}}{W_1^{WR}} &= \frac{\beta^2\left(3\beta^2-\gamma^2\right)\left(32\beta^4-32\beta^2\gamma^2+7\gamma^4\right)^2}{H^2\left(4\beta^2-\beta\gamma-2\gamma^2\right)^2\left(4\beta^2+\beta\gamma-2\gamma^2\right)^2} \\ &= \frac{\left(3-\phi^2\right)\left(32-32\phi^2+7\phi^2\right)^2}{\left(64-84\phi^2+33\phi^4-4\phi^6\right)^2} > 1\end{aligned} \tag{20}$$

This ratio is plotted in figure 3 and is greater than one if $\phi > \phi^R \approx 0\cdot 862$. The best-reply of country one will be R when country two chooses W if $W_1^{RW} > W_1^{WW}$, which will be the case if:

$$\Omega^W = \frac{W_1^{RW}}{W_1^{WW}} = \frac{\left(3\beta^2-\gamma^2\right)\left(16\beta^4-12\beta^2\gamma^2+\gamma^4\right)^2}{\beta^2\left(32\beta^4-32\beta^2\gamma^2+7\gamma^4\right)^2} = \frac{\left(3-\phi^2\right)\left(16-12\phi^2+\phi^4\right)^2}{\left(32-32\phi^2+7\phi^4\right)^2} > 1 \tag{21}$$

This ratio is plotted in figure 3 and it can be seen that it is greater than one if $\phi > \phi^W \approx 0 \cdot 983$. Since the game is symmetric the best replies of country two are just the same as for country one.

There are four possible outcome of the game depending upon the degree of product substitutability. Firstly, if $0 < \phi < \phi^* \approx 0 \cdot 466$ then delegating to a policymaker who maximises welfare is a dominant strategy for both countries so both countries delegating to policymakers who maximise welfare is the unique Nash equilibrium of the game and it is Pareto-superior to both countries delegating to policymakers who maximise tax revenue. Secondly, if $\phi^* < \phi < \phi^R \approx 0 \cdot 862$ then delegating to a policymaker who maximises welfare is a dominant strategy for both countries. Therefore, both countries delegating to policymakers who maximise welfare is the unique Nash equilibrium, but it is Pareto-inferior to both countries delegating to policymakers who maximise tax revenue and so the game is a prisoner's dilemma type of game. Thirdly, if $\phi^R < \phi < \phi^W \approx 0 \cdot 983$ then both countries delegating to policymaker who maximise welfare and both countries delegating to policymakers who maximise tax revenue are both Nash equilibrium of the game, but both countries delegating to policymakers who maximise revenue is Pareto-superior to both countries delegating to policymaker who maximise welfare so there may be a coordination problem. Finally, if $\phi^W < \phi < 1$ then delegating to a policymaker who maximises tax revenue is a dominant strategy for both countries. Therefore, both countries delegating to policymakers who maximise tax revenue is the unique Nash equilibrium, and it is Pareto-superior to both countries delegating to policymakers who maximise welfare. This leads to the following proposition:

Proposition 2*: Both countries delegating to policymakers who maximise tax revenue is only a Nash equilibrium if the degree of product substitutability* $\phi > \phi^R \approx 0 \cdot 862$. *Therefore, the game is a Prisoner's dilemma if* $0 \cdot 466 \approx \phi^* < \phi < \phi^R \approx 0 \cdot 862$.

For a wide range of parameter values, the game is a prisoner's dilemma where both countries are better off delegating to policymakers who maximise tax revenue, but delegating to a policymaker who maximises welfare is a dominant strategy for both countries.

5. Conclusions

Panagariya and Schiff (1994 and 1995) and Yilmaz (1999), have shown that countries may be better off in the Nash equilibrium in export taxes when countries maximise tax revenue than when countries maximise welfare. However, their analysis left open a couple of questions that this paper has attempted to answer. Firstly, how can a country credibly choose to maximise tax revenue rather than welfare when the country is actually concerned about welfare? Secondly, is it a Nash equilibrium for both countries to choose to maximise tax revenue rather than welfare?

By delegating the setting of the export tax to a policymaker who maximises tax revenue, a country can credibly set an export tax that maximises tax revenue rather than welfare. It was shown that both countries delegating to revenue-maximising policymakers may be Pareto-superior to both countries delegating to welfare-maximising policymakers in both the Eaton and Grossman (1986) Bertrand duopoly model and the Panagariya and Schiff (1995) perfect competition model. In the Eaton and Grossman (1986) model it happens if the products of the two firms are close substitutes, and in the Panagariya and Schiff (1995) model if the slope of the demand curve relative to the slope of the supply curve is sufficiently large.

To answer the second question, the game was extended to include a first-stage where the each country could choose either to delegate to a policymaker who maximises tax revenue or a policymaker who maximises welfare. It was shown in both models that, for a wide range of parameter values, the game is a prisoner's dilemma where both countries are better off delegating to policymakers who maximise tax revenue, but that delegating to a policymaker who maximises welfare is a dominant strategy for both countries so both countries delegate to policymakers who maximise welfare in the Nash equilibrium. Both countries delegating to policymakers who maximise tax revenue will only be a Nash equilibrium if the products are very close substitutes in the Eaton and Grossman (1986) model or if the slope of the demand curve relative to the supply curve is very large in the Panagariya and Schiff (1995) model.

The policy implication of Panagariya and Schiff (1994 and 1995) and Yilmaz (1999) that countries would often be better off setting export taxes to maximise tax revenue rather than welfare, should be reconsidered in the light of this analysis.

Appendix

This appendix analyses the same policy-delegation game as in the paper, but set in the perfectly competitive model of Panagariya and Schiff (1995). The notation and the model are the same as in Panagariya and Schiff (1995) except that symmetry is assumed throughout the analysis and the export taxes are specific rather than *ad valorem*, which greatly simplifies the analysis of the Nash equilibrium. There are two countries, labelled one and two, exporting a homogeneous product to country three, which represents the world market for the product. The product is produced by perfectly competitive industries in countries one and two, but is only consumed in country three. Countries one and two impose specific export taxes, e_1 and e_2, on their exports of the product. Demand for the product in the world market (country three) is linear:

$$Q^D = A - BP \tag{A1}$$

where A and B are positive constants and P is the world price of the product. The domestic price of the product in the *i*th country is p_i, which is given by the world price minus the specific export tax, so $p_i = P - e_i$. Supply functions in countries one and two are also linear:

$$q_i^S = a + bp_i = a + b\left(P - e_i\right) \qquad i = 1,2 \tag{A2}$$

where a is negative and b is positive. Demand and supply curves are shown in Figure A1, which has country one imposing an export tax. Equating demand and supply, $Q^D = q_1^S + q_2^S$ yields the equilibrium world price as a function of the export taxes:

$$P = \frac{A - 2a + b\left(e_1 + e_2\right)}{2b + B} \tag{A3}$$

As expected, export taxes increase the world price and improve the terms of trade of the exporting countries. Substituting the equilibrium world price into the supply functions (A2) yields the supply of exports from countries one and two as functions of the export taxes:

$$q_i = \frac{Ab + aB - b\left(b+B\right)e_i + b^2 e_j}{2b+B} \qquad j \neq i, \quad i = 1,2 \tag{A4}$$

If exports are to be positive then the intersect of the demand curve with the price axis, A/B, must be above the intersect of the supply curves, $-a/b$, so it must be that: $Ab + aB > 0$. Clearly, an export tax reduces the exports of the country imposing the export tax and increases the exports of the other country.

As shown in figure A1, export tax revenue of a country is the specific export tax multiplied by the quantity of exports:

$$R_i = e_i q_i \qquad i = 1,2 \tag{A5}$$

The welfare of each exporting country is the sum of producer surplus, the area above the supply curve shown in figure A1, $\Pi_i = q_i^2 / 2b$, and the export tax revenue:

$$W_i = \frac{q_i^2}{2b} + e_i q_i \qquad i = 1,2 \tag{A6}$$

When the government in the *i*th country chooses a policymaker who maximises welfare, the policymaker maximises (A6), which yields the export tax best-reply function for a welfare maximising policymaker:

$$e_i^W = r_i^W\left(e_j\right) = \frac{\left(Ab + aB\right) + b^2 e_j}{\left(b+B\right)\left(3b+B\right)} \tag{A7}$$

When the government in the *i*th country chooses a policy maker who maximises tax revenue, the policy maker maximises (A5), which yields the export tax best-reply function for a revenue maximising policymaker:

$$e_i^R = r_i^R\left(e_j\right) = \frac{\left(Ab + aB\right) + b^2 e_j}{2b\left(b + B\right)} \tag{A8}$$

Both export tax best-reply functions are increasing in the export tax of the other country so export taxes are strategic complements. Note that the numerator is the same for both of the best-reply functions, but that the denominator is larger in (A7) than in (A8). Therefore, $e_i^R = r_i^R\left(e_j\right) > e_i^W = r_i^W\left(e_j\right)$ and $r_i^R\left(e_j\right)$ is steeper than $r_i^W\left(e_j\right)$ so the best-reply functions are just the same as those in figure 1.[7]

As in the paper, there are four subgame to be analysed. In the subgame where policymakers in both countries maximise welfare, the Nash equilibrium export taxes and welfare of the two countries are:

$$e_i^{WW} = \frac{Ab + aB}{2b^2 + 4bB + B^2} > 0 \qquad W_i^{WW} = \frac{\left(b + B\right)\left(3b + B\right)\left(Ab + aB\right)^2}{2b\left(2b^2 + 4bB + B^2\right)^2} \tag{A9}$$

In the subgame where policymakers in both countries maximise tax revenue, the Nash equilibrium export taxes and welfare of the two countries are:

$$e_i^{RR} = \frac{Ab + aB}{b^2 + 2bB} > 0 \qquad W_i^{RR} = \frac{\left(b + B\right)\left(5b + 3B\right)\left(Ab + aB\right)^2}{2b\left(2b + B\right)^2\left(b + 2B\right)^2} \tag{A10}$$

In the subgame, where the policy-maker in country one maximises revenue and the policy-maker in country two maximises welfare, the Nash equilibrium export taxes are:

$$\begin{aligned} e_1^{RW} &= \frac{\left(2b + B\right)^2\left(Ab + aB\right)}{b\left(5b^3 + 14b^2 B + 10bB^2 + 2B^3\right)} > 0 \\ e_2^{RW} &= \frac{\left(3b + 2B\right)\left(Ab + aB\right)}{5b^3 + 14b^2 B + 10bB^2 + 2B^3} > 0 \end{aligned} \tag{A11}$$

[7] Also, since the welfare of a country is always increasing in the export tax of the other country (assuming that the export taxes are positive), the shape of the iso-welfare loci is the same as in figure 1.

Welfare of the two countries in the Nash equilibrium in export taxes are:

$$W_1^{RW} = \frac{(b+B)(2b+B)^2(5b+3B)(Ab+aB)^2}{2b(5b^3+14b^2B+10bB^2+2B^3)}$$
$$W_2^{RW} = \frac{(b+B)(3b+B)(3b+2B)^2(Ab+aB)^2}{2b(5b^3+14b^2B+10bB^2+2B^3)} \tag{A12}$$

The final subgame is where the policy-maker in country one maximises welfare and the policy-maker in country two maximises export tax revenue, but symmetry implies that $e_2^{WR} = e_1^{RW}$, $e_1^{WR} = e_2^{RW}$, $W_2^{WR} = W_1^{RW}$ and $W_1^{WR} = W_2^{RW}$.

To compare the Nash equilibrium in export taxes when policy makers in both countries maximise welfare (W,W) with that when policymakers in both countries maximise tax revenue (R,R), divide the export tax in (A9) by that in (A10), which yields:

$$\frac{e_i^{WW}}{e_i^{RR}} = \frac{b(B+b)}{B+4bB+2b^2} = \frac{\theta(2+\theta)}{1+4\theta+2\theta^2} < 1 \tag{A13}$$

This ratio is a function only of the slope of the demand curve relative to the supply curve, $\theta = b/B$. Clearly, the Nash equilibrium export tax when policymakers in both countries maximise tax revenue exceeds that when policymakers in both countries maximise welfare, $e_i^{RR} > e_i^{WW}$, as this ratio is less than one. Figure A2 shows this ratio as a function of $\theta = b/B$ and shows that it increases from zero when $\theta = 0$ to one-half as θ tends to infinity.

To compare the welfare in the Nash equilibrium when policymakers in both countries maximise revenue with welfare when they maximise welfare divide welfare in (A10) by that in (A9), which yields:

$$\Omega^* = \frac{W_1^{RR}}{W_1^{WW}} = \frac{(3+5\theta)(1+4\theta+2\theta^2)^2}{(2+\theta)^2(1+2\theta)^2(1+3\theta)} \tag{A14}$$

Again, this ratio depends only upon the slope of the demand curve relative to the supply curve, $\theta \equiv b/B$, and it is plotted in figure A3. Therefore, welfare is higher when both policy-makers maximise revenue if $\theta > \theta^* \approx 0 \cdot 32$. This leads to the following proposition:

Proposition A1*: Welfare is higher in the Nash equilibrium in export taxes when policymakers in both countries maximise tax revenue (R,R) than when policymakers in both countries maximise welfare (W,W) if the slope of the demand curve relative to the supply curve* $\theta > \theta^* \approx 0 \cdot 32$.

This proposition is basically the same as the result in Panagariya and Schiff (1995) except that they used *ad valorem* export taxes and used numerical simulations to solve the model. From their Table 1, with $B = 10$, it can be seen that the critical value occurs between $b = 3$ or $\theta = 0 \cdot 3$ and $b = 4$ or $\theta = 0 \cdot 4$, which is consistent with the critical value in proposition A1, $\theta^* = 0 \cdot 32$.

To find the Nash equilibria of the first stage of the game consider the best-replies of the two countries to the strategies of the other country. The best-reply of country one will be R when country two chooses R if $W_1^{RR} > W_1^{WR}$, which will be the case if:

$$\Omega^R = \frac{W_1^{RR}}{W_1^{WR}} = \frac{(3+5\theta)(2+10\theta+14\theta^2+5\theta^3)^2}{(2+\theta)^2(1+2\theta)^2(1+3\theta)(2+3\theta)^2} > 1 \quad \text{(A15)}$$

This ratio is plotted in figure A1 and it can be seen that it is greater than one if $\theta > \theta^R \approx 1 \cdot 78$. The best reply of country one will be R when country two chooses W if $W_1^{RW} > W_1^{WW}$, which will be the case if:

$$\Omega^W = \frac{W_1^{RW}}{W_1^{WW}} = \frac{(1+2\theta)^2(3+5\theta)(1+4\theta+2\theta^2)^2}{(1+3\theta)(2+10\theta+14\theta^2+5\theta^3)^2} > 1 \quad \text{(A16)}$$

This ratio is plotted in figure A1 and it can be seen that it is greater than one if $\theta > \theta^{W} \approx 3 \cdot 84$. Since the game is symmetric, the best-replies of country two are the same as those of country two.

There are four possible outcome of the game depending upon the slope of the demand curve relative to the supply curve. Firstly, if $0 < \theta < \theta^{*} \approx 0 \cdot 32$ then delegating to policymaker who maximises welfare is a dominant strategy for both countries so both countries delegating to policymakers who maximise welfare is the unique Nash equilibrium and it is Pareto-superior to both countries delegating to policymakers who maximise tax revenue. Secondly, if $\theta^{*} < \theta < \theta^{R} \approx 1 \cdot 78$ then delegating to a policymaker who maximises welfare is a dominant strategy for both countries so both countries delegating to policymakers who maximise welfare is the unique Nash equilibrium, but it is Pareto-inferior to both countries delegating to policymakers who maximise tax revenue so the game is a prisoner's dilemma. Thirdly, if $\theta^{R} < \theta < \theta^{W} \approx 3 \cdot 84$ then both countries delegating to policymakers who maximise welfare and both countries delegating to policymakers who maximise tax revenue are both Nash equilibria, but both countries delegating to policymakers who maximise tax revenue is Pareto-superior to both delegating to countries who maximise welfare so there may be a co-ordination problem. Finally, if $\theta > \theta^{W}$ then delegating to policymaker who maximises tax revenue is a dominant strategy for both countries so both countries delegating to policymakers who maximise tax revenue is the unique Nash equilibrium, which is Pareto-superior to both countries delegating to policymakers who maximise welfare.

Proposition A2*: Both countries delegating to policymakers who maximise tax revenue is only a Nash equilibrium if the slope of the demand curve relative to the slope of the supply curve* $\theta > \theta^{R} \approx 1 \cdot 78$. *Therefore, the game is a Prisoner's dilemma if* $0 \cdot 32 \approx \theta^{*} < \theta < \theta^{R} \approx 1 \cdot 78$.

For a wide range of parameter values, the game is a prisoner's dilemma where both countries are better off delegating to policymakers who maximise tax revenue, but delegating to a policymaker who maximises welfare is a dominant strategy for both countries. Note that in Table 1 of Panagariya and Schiff (1995), with $B = 10$, the range of values for $b = 1, 3, 4, 8, 10$ or $\theta = 0 \cdot 1, 0 \cdot 3, 0 \cdot 4, 0 \cdot 8, 1 \cdot 0$ so $\theta^R \approx 1 \cdot 78$ and $\theta^W \approx 3 \cdot 84$ are well outside the parameter values that they consider. Therefore, both countries delegating to policymakers who maximise tax revenue is never a Nash equilibrium for the parameter values considered by Panagariya and Schiff (1995).

References

Clarke, Roger and David R. Collie (2003). 'Product differentiation and the gains from trade under Bertrand duopoly', *Canadian Journal of Economics 36*, pp. 658-673.

Clarke, Roger and David R. Collie (2006a). 'Optimum-welfare and maximum-revenue tariffs under Bertrand duopoly', *Scottish Journal of Political Economy 53*, pp. 398-408.

Clarke, Roger and David R. Collie (2006b), 'Export taxes under Bertrand duopoly', *Economics Bulletin*, Vol. 6, No. 6, pp. 1-8.

Collie, David R. (1991). 'Optimum welfare and maximum revenue tariffs under oligopoly', *Scottish Journal of Political Economy 38*, pp. 398-401.

Collie, David R. (1997), 'Delegation and strategic trade policy', *International Economic Journal 11*, pp. 35-46.

Eaton, Jonathan and Gene Grossman (1986). 'Optimal trade and industrial policy under oligopoly', *Quarterly Journal of Economics 101*, pp. 383-406.

Johnson, Harry G. (1951-52). 'Optimum welfare and maximum revenue tariffs', *Review of Economic Studies 19*, pp. 28-35.

Kikuchi, Toru (1998). 'Strategic export policy in a differentiated duopoly: a note', *Open Economies Review 9*, pp. 315-325.

Panagariya, Arvind and Maurice Schiff (1994). 'Can revenue maximizing export taxes yield higher welfare than welfare maximizing export taxes?', *Economics Letters 45*, pp. 79-84.

Panagariya, Arvind and Maurice Schiff (1995). 'Optimum and revenue maximizing trade taxes in a multicountry framework', *Revista de Analisis Economico 10*, pp. 19-35.

Piermartini, Roberta (2004). *The Role of Export Taxes in the Field of Primary Commodities*, WTO Discussion Paper, No. 4, World Trade Organisation.

Trandel, Gregory A. and Susan Skeath (1996). ‘Playing favorites: welfare effects when strategic trade policy is set to favour producers’, *Southern Economic Journal 63*, pp. 163-171.

Yilmaz, Kamil (1999). ‘Optimal export taxes in a multi-country framework’, *Journal of Development Economics 60*, pp. 439-465.

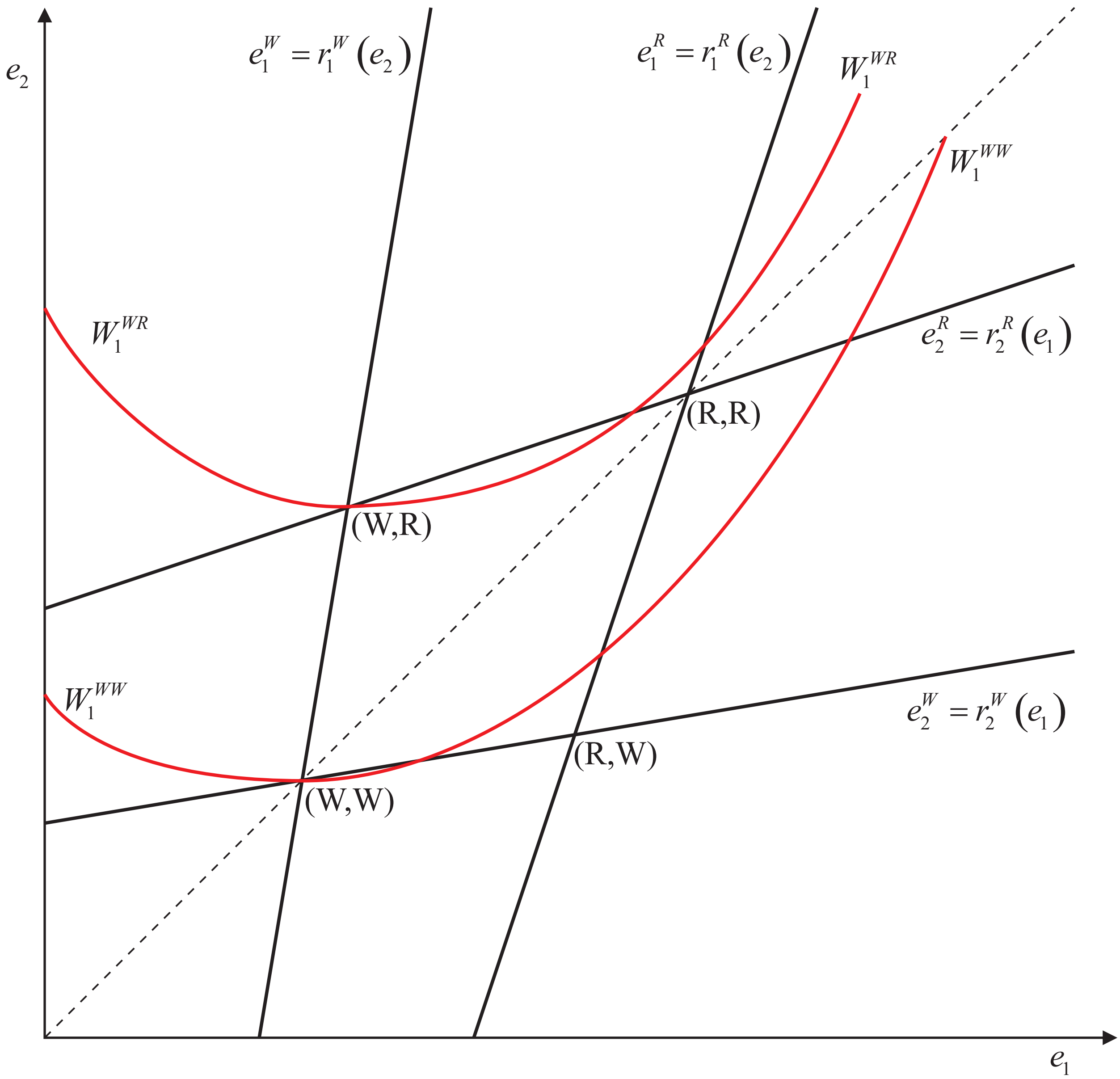

Figure 1: Export tax best-reply functions and Nash equilibrium welfare

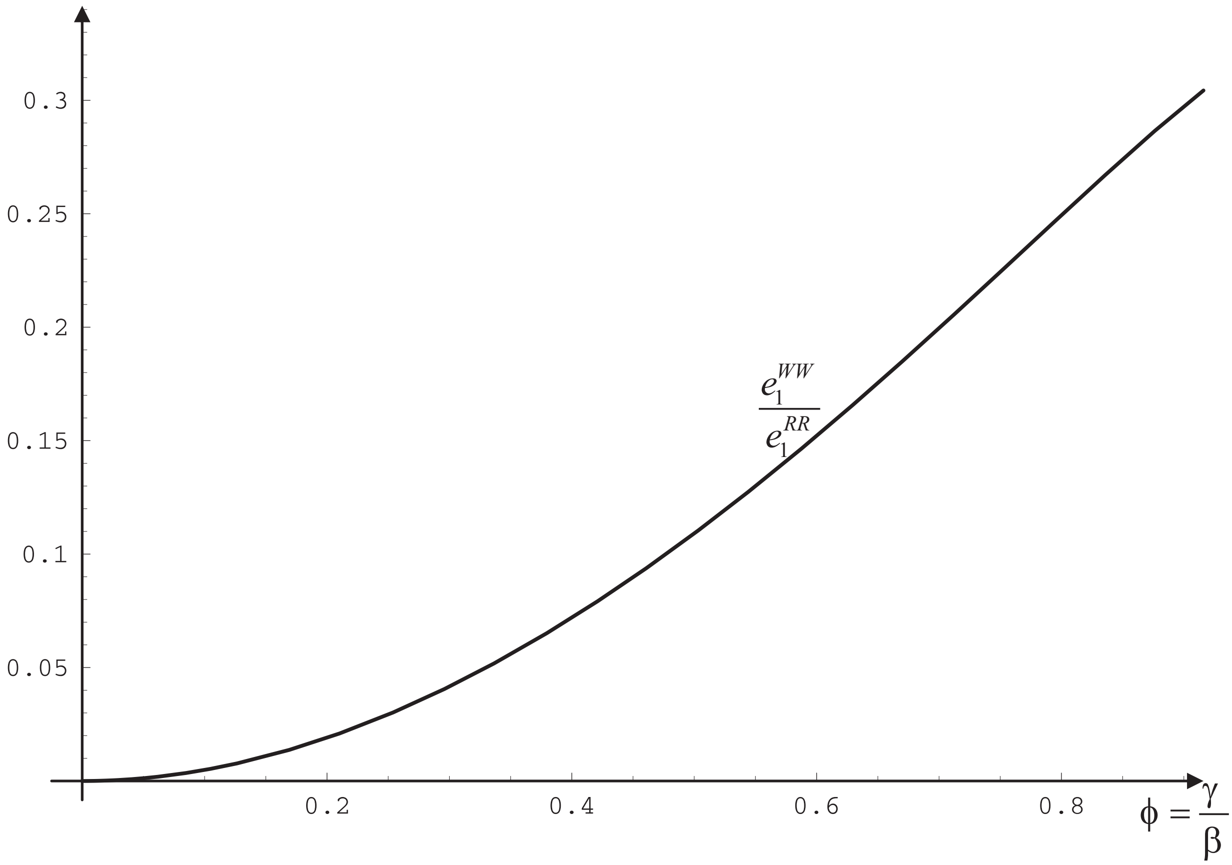

Figure 2: Comparison of Nash equilibrium export taxes under Bertrand duopoly

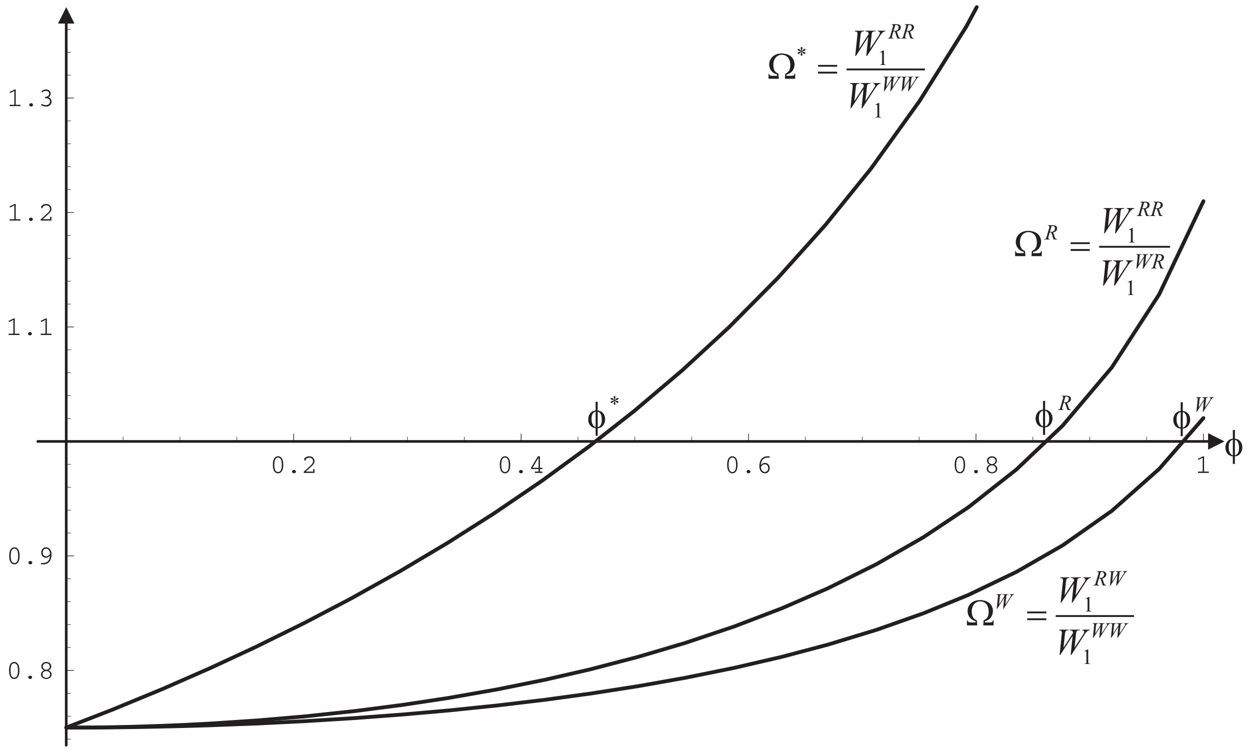

Figure 3: Comparison of Nash equilibrium Welfare under Bertrand duopoly

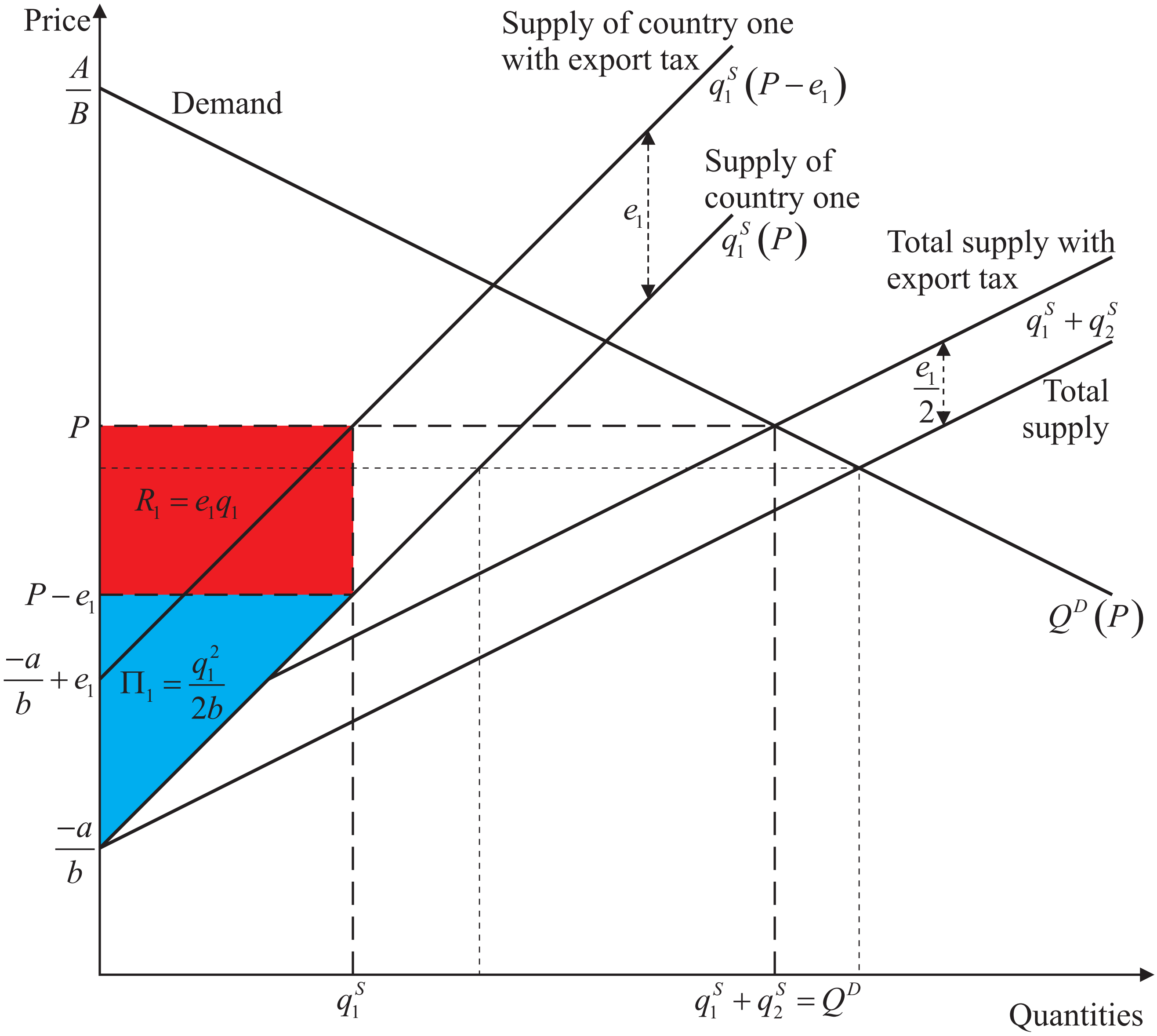

Figure A1: Demand and supply under perfect competition with export tax

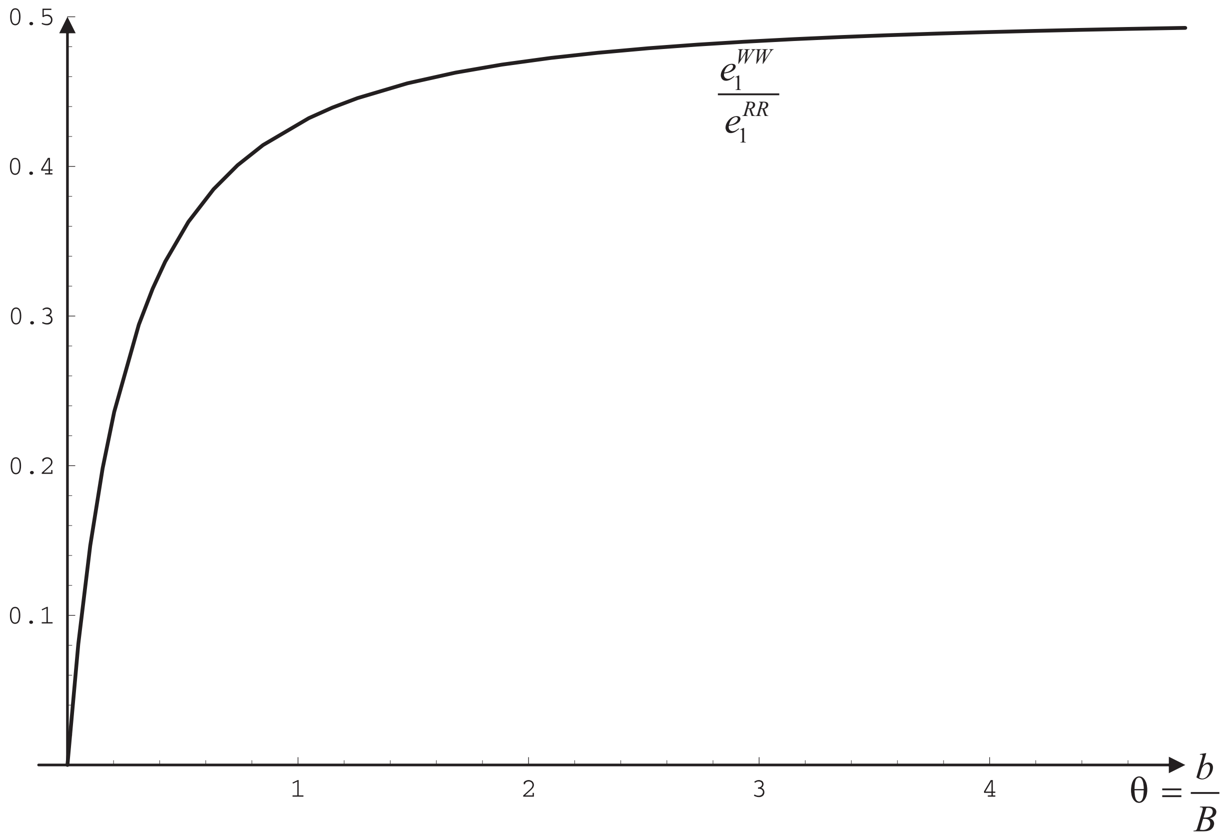

Figure A2: Comparison of Nash equilibrium export taxes under perfect competition

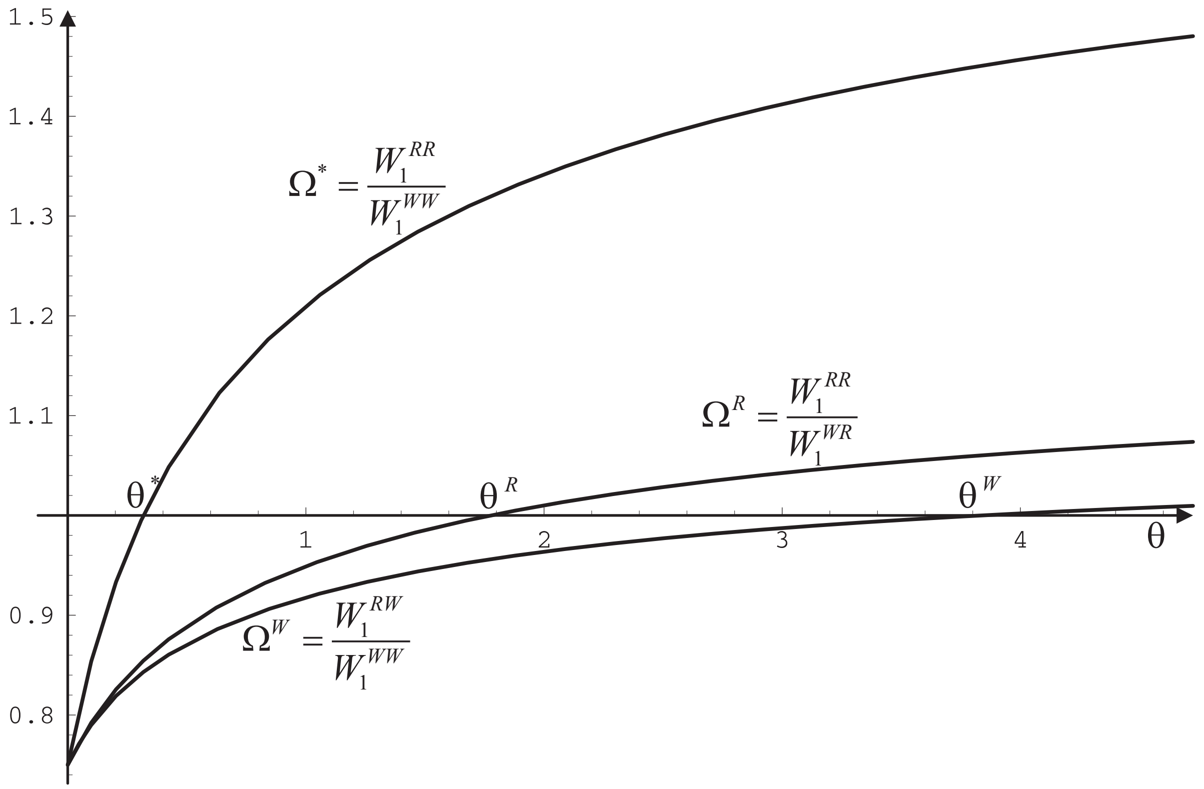

Figure A3: Comparison of Nash equilibrium welfare under perfect competition