GAINS FROM TRADE IN TAX REVENUE AND THE EFFICIENCY CASE FOR TRADE TAXES

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Abstract

The paper analyses the gains from trade in distortionary tax revenue between countries, focussing on the case where lump-sum reveue transfers are restricted. In this case, trade taxes can be used to transfer government revenue between countries, and such taxes will typically be used in Pareto-efficient international equilibria. Global production efficiency conditions are often, though not always, satisfied at Pareto-efficient allocations involving trade taxes, but the implications for international taxation differ from those that have been put forward on the basis of the Diamond-mirrlees production efficiency theorem.

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1 Introduction

When tax revenue is raised by means of distortionary taxes, the marginal cost of a unit of revenue will include the marginal efficiency cost, or deadweight loss, which represents the loss to taxpayers in excess of the revenue collected (Auerbach, 1985). These marginal efficiency costs may differ between countries, since they depend (for a given level of revenue) on the range of taxes available in a country and the compensated demand responses of taxpayers. If the marginal efficiency costs of tax revenue differ between countries, then intuition would suggest that the standard argument for gains from trade applies: all countries can gain by trading tax revenue. A first objective of this paper is to show that this intuition is correct by providing a general analysis of the gains from trade in distortionary tax revenue between countries, and the consequent policy implications.

A second objective of the paper is to use the concept of the gains from trade in tax revenue to clarify and extend the analysis of Keen and Wildasin (2000), who build on Wildasin (1978). Keen and Wildasin show that, in a standard competitive trade model, if there are no lump-sum revenue transfers between countries, (second-best) Pareto-efficiency for the international economy may require both that trade taxes are used and that global production is inefficient. This conclusion is at odds with much policy advice concerning international tax arrangements, which uses the Diamond-Mirrlees production efficiency theorem (Diamond and Mirrlees, 1971) as a basis for advocating the removal of taxes on trade, and the destination rather than the origin principle for the taxation of internationally traded commodities (Haufler, 2001, pp. 35, 50-1).[1] The present paper shows that, although the gains from

[1] The claim that the residence principle for capital income taxation is superior to the source principle

trade in distortionary tax revenue provide a general efficiency case for trade taxes, it is not generally true that global production inefficiency is a feature of Pareto-efficient international equilibria when lump-sum international transfers are restricted. Provided that a reasonable condition on the matrix of countries' net imports is satisfied, Pareto-efficient international tax arrangements will involve both global production efficiency and the use of trade taxes. However, as the paper shows, the policy implications of the fact that global production efficiency conditions are often, although not always, satisfied at Pareto-efficient allocations involving the use of trade taxes differ from those that have been put forward on the basis of the Diamond-Mirrlees theorem.

The plan of the paper is as follows. Section 2 sets out the model, which is one of competitive trade between countries that have to raise government revenue using distortionary taxes. It is assumed that there is a single household in each country, which means that a Pareto-efficient allocation can be described as one in which it is not possible to make one country better off without making another worse off. Furthermore, it is assumed that lump-sum taxes and transfers cannot be used within countries, implying that allocations described as Pareto-efficient are, strictly speaking, second-best Pareto-efficient. Section 2 also describes the approach used to characterise globally Pareto-efficient allocations, which involves maximising an arbitrary linear world welfare function subject to the constraints that world markets for traded goods clear and each country satisfies its national budget constraint. The Lagrange multipliers on these constraints, which play an important role in the subsequent analysis, are interpreted and discussed. Section 3 provides a simple exam-

because it satisfies production efficiency conditions is a particular application of this general argument.

ple that illustrates the way in which tax revenue can be traded between countries, and the role of trade taxes in achieving gains from this trade. It then provides a general analysis of how Pareto-efficient trade in tax revenue can take place between countries when there are restrictions on the use of lump-sum international revenue transfers, and shows that, if the marginal efficiency costs of government revenue differ across countries in the absence of trade taxes, then Pareto-efficient international equilibria will involve the use of trade taxes. Section 3 also characterises Pareto-efficient trade taxes, and points out that, in the circumstances in which Pareto-efficient international equilibria with trade taxes involve global production efficiency, the standard policy conclusions concerning international taxation that are drawn from the Diamond-Mirrlees production efficiency theorem do not apply. Section 4 shows that, if there are no restrictions on the use of lump-sum international transfers to trade revenue between countries, then trade taxes are not used in Pareto-efficient international equilibria, which always satisfy global production efficiency conditions. In these circumstances, the policy conclusions drawn from the Diamond-Mirrlees production efficiency theorem do apply. Section 5 concludes.

2 The model

2.1 International equilibrium

Consider a world of C countries with T traded private goods. In each country the vectors of consumer and producer prices for goods $1, ..., T$ are denoted respectively by $\mathbf{q}^c$ and $\mathbf{p}^c$, $c = 1, ..., C$.[2] The usual convention is adopted, that negative demand by a household represents the supply of a good, while negative supply by a firm represents demand for an

[2] All vectors are column vectors, with a prime indicating transposition.

input. There is a single household in each country with a budget constraint $\mathbf{q}^c \cdot \mathbf{x}^c = 0$, where $\mathbf{x}^c$ is the vector of household demands for goods $1, ..., T$. Private production in each country is carried out by a single competitive firm that has a strictly convex production set. The assumption of a decreasing-returns-to-scale technology is made solely for the analytical convenience of being able to work with private supply functions rather than correspondences: the results of the paper do not depend on this assumption. The private firm's profit function is $\pi^c(\mathbf{p}^c) = \mathbf{p}^c \cdot \mathbf{y}^c(\mathbf{p}^c)$, where $\mathbf{y}^c(\mathbf{p}^c)$ is the firm's vector-valued supply function for goods $1, ..., T$. In each country, the vector of government supply of private goods is $\mathbf{z}^c$, positive and negative components of which correspond respectively to outputs and inputs.

Each country's vector of net imports is $\mathbf{n}^c = \mathbf{x}^c - \mathbf{y}^c - \mathbf{z}^c$. Positive components of this vector correspond to imported goods, and negative components to exported goods. Countries trade with each other at world prices for goods $1, ..., T$, denoted by the vector $\mathbf{p}^W$. In addition there are lump-sum transfers between countries, which can be either positive or negative, and are denoted by S^c, $c = 1, ...C$. These lump-sum international transfers must satisfy the constraint that $\sum_{c=1}^{C} S^c = 0$. Each country's balanced trade constraint is therefore $\mathbf{p}^W \cdot \mathbf{n}^c = S^c$, $c = 1, ..., C$.

In each country, the government produces a (local) pure public good g^c using private goods as inputs. A vector of destination-based commodity taxes $\mathbf{t}^c$ is imposed on household demands $\mathbf{x}^c$, $c = 1, ..., C$. The sign of the product $t_i^c x_i^c$ shows whether the demand for a particular good i is taxed or subsidised, so that a tax is indicated by $t_i^c > 0$ if $x_i^c > 0$, and by $t_i^c < 0$ if $x_i^c < 0$. A vector of trade taxes $\boldsymbol{\tau}^c$ is imposed on net imports $\mathbf{n}^c$, $c = 1, ..., C$, and similar sign conventions to those for commodity taxes apply, so that the sign of the product

$\tau_i^c n_i^c$ shows whether the net imports of good i are taxed or subsidised in country c. Thus $\tau_i^c > 0$ corresponds to a tariff if country c imports good i, but to an export subsidy if good i is exported, while $\tau_i^c < 0$ corresponds to a import subsidy if country c imports good i, but to an export tax if good i is exported. The government in country c receives a transfer S^c from other countries, taxes private sector profits π^c at a rate of 100 per cent, and transacts at producer prices for private goods, so that its net revenue is

$$R^c = \mathbf{t}^c \cdot \mathbf{x}^c + \boldsymbol{\tau}^c \cdot \mathbf{n}^c + \pi^c + \mathbf{p}^c \cdot \mathbf{z}^c + S^c \tag{1}$$

Note that the inputs necessary to produce g^c are included as negative elements of the vector $\mathbf{z}^c$.

The commodity and trade taxes mean that consumer and producer prices for goods $1, ..., T$ in country c are related to world prices as follows: $\mathbf{q}^c = \mathbf{p}^W + \boldsymbol{\tau}^c + \mathbf{t}^c$ and $\mathbf{p}^c = \mathbf{p}^W + \boldsymbol{\tau}^c$. Using these relationships in (1), together with the household budget constraint and the private firm's profit function, gives an alternative expression for government net revenue:

$$R^c = -\mathbf{p}^W \cdot \mathbf{n}^c + S^c \tag{2}$$

Equation (2) shows that the government budget constraint in a country is satisfied if its balanced trade constraint is satisfied. This equation also shows that the world prices of all goods must be non-negative. If some world prices were negative, the government of country c could, holding taxes and subsidies constant, obtain revenue by importing the relevant goods, and thus, by altering taxes and subsidies, use this revenue to improve the welfare of the household in country c.

Household preferences in each country are represented by the indirect utility function

$V^c(\mathbf{p}^W + \boldsymbol{\tau}^c + \mathbf{t}^c)$, and household demand functions are $\mathbf{x}^c(\mathbf{p}^W + \boldsymbol{\tau}^c + \mathbf{t}^c)$.[3] Hence the net import demand functions in each country are

$$\mathbf{n}^c(\mathbf{p}^W, \boldsymbol{\tau}^c, \mathbf{t}^c) = \mathbf{x}^c(\mathbf{p}^W + \boldsymbol{\tau}^c + \mathbf{t}^c) - \mathbf{y}^c(\mathbf{p}^W + \boldsymbol{\tau}^c) - \mathbf{z}^c \tag{3}$$

The constraints of international equilibrium are as follows. First, trade must be balanced in all countries:

$$\mathbf{p}^W \cdot \mathbf{n}^c(\mathbf{p}^W, \boldsymbol{\tau}^c, \mathbf{t}^c) = S^c, \;\; c = 1, ..., C \tag{4}$$

and second, world markets for traded goods $1, ..., T$ must clear:

$$\sum_{c=1}^{C} \mathbf{n}^c(\mathbf{p}^W, \boldsymbol{\tau}^c, \mathbf{t}^c) = \mathbf{0}_T \tag{5}$$

Let $\mathbf{N} = \left[\mathbf{n}^1 \; \mathbf{n}^2 \; ... \; \mathbf{n}^C\right]$ be the $T \times C$ matrix with columns given by the net import vectors of each country. The constraints (4) can be written as

$$\mathbf{N}'\mathbf{p}^W = \mathbf{S} \tag{6}$$

where $\mathbf{N}'$ is the $C \times T$ matrix given by the transpose of $\mathbf{N}$, and $\mathbf{S}$ is the $C \times 1$ vector with elements S^c. At any international equilibrium, world prices must solve (6). The necessary and sufficient condition for (6) to have a solution is that the rank of $\mathbf{N}'$ should equal the rank of the augmented matrix $[\mathbf{N}' \; \mathbf{S}]$. The maximal rank of $\mathbf{N}'$ is $Min(C-1, T)$, since the rows of $\mathbf{N}'$ sum to zero by (5), while the maximal rank of $[\mathbf{N}' \; \mathbf{S}]$ is $Min(C-1, T+1)$, since the rows of $\mathbf{S}$ also sum to zero. Thus if $T < C - 1$, (6) will only have a solution for $\mathbf{p}^W$ in special cases. It is therefore assumed that $T \geq C - 1$.[4]

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[3] For simplicity, the effects of the public good g^c on indirect utility and demand in country c are incorporated into the form of the functions V^c and $\mathbf{x}^c$.

[4] The case of primary interest for Keen and Wildasin (2000) is that in which all lump-sum international

2.2 Characterising Pareto-efficient allocations

The model makes the standard assumptions of optimal tax theory. Thus it assumes that there are no restrictions on the use of commodity taxes, and that pure profits do not appear in household budget constraints, so that these conditions of the Diamond-Mirrlees production efficiency theorem are fulfilled. The latter condition is ensured by the assumption that the pure profits which result from the decreasing returns to scale technology of private production are taxed at a rate of 100 per cent. An alternative assumption that achieves the same outcome - no pure profits in household budget constraints - is that private-sector production takes place under constant returns to scale. The following analysis therefore applies both to the case of decreasing returns to scale in private production with 100 per cent taxation of private-sector profits, and to the case of constant returns to scale in private production. As noted above, it is convenient to work with the former case. In this case, pure profits provide each country's government with a source of non-distortionary tax revenue. It is therefore assumed that g^c and $\mathbf{z}^c$, $c = 1, ..., C$, are parameters fixed at values such that all countries have to raise some revenue using distortionary taxes.

The other simplifying assumptions of the model - a single household in each country, and no non-traded private goods - can be relaxed at the cost of some additional complexity. The analysis that follows does not depend on them.

transfers are zero. In this case, the necessary and sufficient condition for (6) to have a non-trivial solution for $\mathbf{p}^W$ is that rank $\mathbf{N}' \leq T - 1$. If $T \geq C$, then rank $\mathbf{N}' \leq C - 1$, and hence rank $\mathbf{N}' \leq T - 1$, so that a non-trivial solution for $\mathbf{p}^W$ exists. But if $T < C$, then rank $\mathbf{N}' \leq T \leq C - 1$. In this case, when $\mathbf{N}'$ has maximal rank, the only solution to (6) is $\mathbf{p}^W = \mathbf{0}_T$. In order that some positive world prices exist when $T < C$ and there are no lump-sum international transfers, it is necessary for there to be at least one linear dependence between countries' net import vectors at an international equilibrium in addition to that implied by world market-clearing. Although these additional linear dependence(s) are certainly possible, they cannot be relied upon.

Pareto-efficient allocations can be characterised by examining the first-order necessary conditions for stationary points of the arbitrary linear world welfare function

$$W = \sum_{c=1}^{C} w^c V^c(\mathbf{p}^W + \boldsymbol{\tau}^c + \mathbf{t}^c), \;\; w^c \geq 0 \tag{7}$$

over the feasible set defined by the constraints of international equilibrium.[5] To characterise Pareto-efficient allocations, these first-order conditions must be stated in a form that is independent of the welfare weights w^c.

It is assumed that all world prices are strictly positive at Pareto-efficient allocations. Thus one of the world market-clearing conditions in (5) is redundant. The condition dropped is the one for good 1, so that (5) is replaced by

$$\sum_{c=1}^{C} \mathbf{n}^c_{-1}(\mathbf{p}^W, \boldsymbol{\tau}^c, \mathbf{t}^c) = \mathbf{0}_{T-1} \tag{8}$$

where $\mathbf{n}^c_{-1}(\mathbf{p}^W, \boldsymbol{\tau}^c, \mathbf{t}^c)$ is the vector of country c's net imports excluding the element for good 1. Since good 1 has a positive world price, equations (4) and (8) imply that the world market for good 1 also clears ($\sum_{c=1}^{C} n^c_1(\mathbf{p}^W, \boldsymbol{\tau}^c, \mathbf{t}^c) = 0$). The world price of good 1 is normalised to be 1. Without loss of generality, this good is taken to be untaxed in each country, so that $q^c_1 = p^c_1 = 1$, $c = 1, ..., C$.

In the general case, the control variables for the problem of finding the stationary points of (7) subject to the constraints (4) and (8) are the commodity taxes in each country $\mathbf{t}^c_{-1}$, the trade taxes in each country $\boldsymbol{\tau}^c_{-1}$, the lump-sum international transfers S^c, and world prices $\mathbf{p}^W_{-1}$. The subscript -1 means that these vectors exclude the element for good 1.

[5] See Panzar and Willig (1976).

Letting μ^c, $c = 1, ..., C$, be Lagrange multipliers on the constraints (4), v_i, $i = 2, ...T$, be Lagrange multipliers on the constraints (8), and γ be the Lagrange multiplier on the constraint $\sum_{c=1}^{C} S^c = 0$, the Lagrangean for this problem is

$$L = \sum_{c=1}^{C} w^c V^c(\mathbf{p}^W + \boldsymbol{\tau}^c + \mathbf{t}^c) - \sum_{i=2}^{T} v_i \left[\sum_{c=1}^{C} n_i^c(\mathbf{p}^W, \boldsymbol{\tau}^c, \mathbf{t}^c) \right]$$
$$- \sum_{c=1}^{C} \mu^c \left[n_1^c(\mathbf{p}^W, \boldsymbol{\tau}^c, \mathbf{t}^c) + \sum_{i=2}^{T} p_i^W n_i^c(\mathbf{p}^W, \boldsymbol{\tau}^c, \mathbf{t}^c) - S^c \right] - \gamma \sum_{c=1}^{C} S^c \quad (9)$$

Suppose initially that the control variables are the commodity taxes in each country and world prices, with trade taxes in each country and lump-sum international transfers being parameters. Denoting household income in country c by m^c, the first-order necessary conditions for the control variables are as follows:

$$t_j^c: \quad - w^c \frac{\partial V^c}{\partial m^c} x_j^c - \mu^c \frac{\partial x_1^c}{\partial q_j^c} - \sum_{i=2}^{T} \left(v_i + \mu^c p_i^W \right) \frac{\partial x_i^c}{\partial q_j^c} = 0 \qquad j = 2, ..., T, \; c = 1, ..., C \quad (10)$$

$$p_j^W: \quad - \sum_{c=1}^{C} w^c \frac{\partial V^c}{\partial m^c} x_j^c - \sum_{c=1}^{C} \mu^c \left(\frac{\partial x_1^c}{\partial q_j^c} - \frac{\partial y_1^c}{\partial p_j^c} \right)$$
$$- \sum_{c=1}^{C} \sum_{i=2}^{T} \left(v_i + \mu^c p_i^W \right) \left(\frac{\partial x_i^c}{\partial q_j^c} - \frac{\partial y_i^c}{\partial p_j^c} \right) - \sum_{c=1}^{C} \mu^c n_j^c = 0 \qquad j = 2, ..., T \quad (11)$$

2.3 The shadow value of government revenue

Recalling (2), the multipliers μ^c, $c = 1, ..., C$, measure the shadow value (in terms of the world welfare function (7)) of government revenue in country c.[6] At a Pareto-efficient allocation,

[6] The analysis in this subsection draws heavily on that of Wildasin (1978).

commodity taxes in country c will be set so that the shadow value of government revenue is the same whichever tax is used to raise additional revenue. Using the Slutsky equation, the conditions (10) imply that

$$\mu^c = -\frac{\left(w^c \frac{\partial V^c}{\partial m^c} - \sum_{i=2}^T v_i \frac{\partial x_i^c}{\partial m^c}\right) x_j^c + \sum_{i=2}^T v_i \frac{\partial \widehat{x}_i^c}{\partial q_j^c}}{\frac{\partial x_1^c}{\partial q_j^c} + \sum_{i=2}^T p_i^W \frac{\partial x_i^c}{\partial q_j^c}} \qquad j = 2, ..., T,\ c = 1, ..., C \tag{12}$$

where $\widehat{x}_i^c$ denotes the compensated demand for good i in country c. Recalling (2) and (3), $-1/\left(\frac{\partial x_1^c}{\partial q_j^c} + \sum_{i=2}^T p_i^W \frac{\partial x_i^c}{\partial q_j^c}\right)$ is the change in t_j^c required to raise an additional unit of government revenue. The two terms in the numerator of (12) are $\left(w^c \frac{\partial V^c}{\partial m^c} - \sum_{i=2}^T v_i \frac{\partial x_i^c}{\partial m^c}\right) x_j^c$, the net marginal world value of income in country c, and $\sum_{i=2}^T v_i \frac{\partial \widehat{x}_i^c}{\partial q_j^c}$, the marginal world cost of the compensated changes in demand due to the commodity tax on good j in country c.

The shadow value of government revenue will typically differ between countries because of differences in the two components of (12). The first component embodies equity considerations (as reflected in the weights w^c that enter the net marginal world value of income in country c), while the second embodies efficiency considerations (as reflected in the marginal world costs of raising revenue in different countries by distortionary taxes). The conditions that characterise all Pareto-efficient allocations must be stated in a form independent of the welfare weights w^c. For this purpose, differences between countries in the terms $-\left(w^c \frac{\partial V^c}{\partial m^c} - \sum_{i=2}^T v_i \frac{\partial x_i^c}{\partial m^c}\right) x_j^c / \left(\frac{\partial x_1^c}{\partial q_j^c} + \sum_{i=2}^T p_i^W \frac{\partial x_i^c}{\partial q_j^c}\right)$ are ignored, since such differences arise from distributional judgements. However, because the efficiency costs of taxation may differ between countries, differences in the terms $-\sum_{i=2}^T v_i \frac{\partial \widehat{x}_i^c}{\partial q_j^c} / \left(\frac{\partial x_1^c}{\partial q_j^c} + \sum_{i=2}^T p_i^W \frac{\partial x_i^c}{\partial q_j^c}\right)$ are relevant for Pareto-efficiency. In the analysis that follows, differences in the shadow values of government revenue between countries are assumed to arise solely from differences in the marginal efficiency costs of government revenue.

2.4 The multipliers on the world market-clearing constraints

The multipliers v_i, $i = 2, ..., T$, give the shadow values (in terms of the world welfare function) of an additional unit of good i becoming available to the world economy from a source that does not relax a particular country's balanced trade constraint, such as, for example, a supranational body.[7] In each country, by the theory of the competitive producer,

$$\frac{\partial y_1^c}{\partial p_j^c} + \sum_{i=2}^{T} \left(p_i^W + \tau_i^c\right) \frac{\partial y_i^c}{\partial p_j^c} = 0 \qquad j = 2, ..., T \tag{13}$$

so that, multiplying by μ^c,

$$\mu^c \frac{\partial y_1^c}{\partial p_j^c} + \sum_{i=2}^{T} \mu^c p_i^W \frac{\partial y_i^c}{\partial p_j^c} = - \sum_{i=2}^{T} \mu^c \tau_i^c \frac{\partial y_i^c}{\partial p_j^c} \qquad j = 2, ..., T \tag{14}$$

Using (10) in (11),

$$\sum_{c=1}^{C} \left(\mu^c \frac{\partial y_1^c}{\partial p_j^c} + \sum_{i=2}^{T} \mu^c p_i^W \frac{\partial y_i^c}{\partial p_j^c} \right) + \sum_{c=1}^{C} \sum_{i=2}^{T} v_i \frac{\partial y_i^c}{\partial p_j^c} = \sum_{c=1}^{C} \mu^c n_j^c \qquad j = 2, ..., T$$

which, using (14), can be written as

$$\sum_{i=2}^{T} v_i \sum_{c=1}^{C} \frac{\partial y_i^c}{\partial p_j^c} = \sum_{c=1}^{C} \mu^c n_j^c + \sum_{i=2}^{T} \sum_{c=1}^{C} \mu^c \tau_i^c \frac{\partial y_i^c}{\partial p_j^c} \qquad j = 2, ..., T$$

or

$$\left[\mathbf{Dy}'\right] \mathbf{v}_{-1} = \mathbf{N}_{-1} \boldsymbol{\mu} + \sum_{c=1}^{C} \left[\mathbf{Dy}^c\right]' \mu^c \boldsymbol{\tau}_{-1}^c$$

Here $[\mathbf{Dy}^c]'$ is the $(T-1) \times (T-1)$ matrix with typical term $\left\{\partial y_i^c / \partial p_j^c\right\}$, $i, j = 2, ..., T$, i.e., the transpose of the matrix of derivatives of private sector supply functions with respect to

[7] If a specific country made an additional unit of good i available, the shadow value would be $v_i + \mu^c p_i^W$, including the effect of the additional unit in relaxing the country's balanced trade constraint.

producer prices in country c; $\mathbf{v}_{-1}$ is the $(T-1)\times 1$ vector with elements v_i, $i=2,...,T$; $\mathbf{N}_{-1}$ is the $(T-1)\times C$ matrix with columns given by the vectors of each country's net imports of goods $2,...,T$; and $[\mathbf{Dy}'] \equiv \sum_{c=1}^{C}[\mathbf{Dy}^c]'$ is the $(T-1)\times(T-1)$ matrix with typical term $\left\{\sum_{c=1}^{C}\partial y_i^c/\partial p_j^c\right\}$, $i,j=2,...,T$. Assuming that $[\mathbf{Dy}']^{-1}$ exists, the values of the multipliers on the world market-clearing constraints are given by

$$\mathbf{v}_{-1}=[\mathbf{Dy}']^{-1}\left\{\mathbf{N}_{-1}\boldsymbol{\mu}+\sum_{c=1}^{C}[\mathbf{Dy}^c]'\,\mu^c\boldsymbol{\tau}_{-1}^c\right\} \tag{15}$$

To interpret (15), consider an example with only two traded goods, in which case it becomes

$$v_2=\frac{\sum_{c=1}^{C}\mu^c\left[n_2^c+\tau_2^c\left(\partial y_2^c/\partial p_2^c\right)\right]}{\sum_{c=1}^{C}\partial y_2^c/\partial p_2^c} \tag{16}$$

Suppose that, at the international equilibrium corresponding to the parametric values of τ_2^c, $c=1,...,C$, a unit of good 2 is made available to the world economy by a supranational body. World market equilibrium for good 2 can be maintained by a change in p_2^W that, with τ_2^c constant for all c, changes producer prices in all countries such that world production of good 2 falls by one unit, while t_2^c, $c=1,...,C$, are adjusted to keep the consumer price of, and thus the demand for, good 2 unchanged in all countries. Since these commodity taxes were initially chosen to satisfy (10), small changes in them have no welfare effects, and since pure profits are fully taxed, there are no effects on household welfare from the change in producer prices. The only welfare effects are those that occur via the changes in government net revenue due to the change in p_2^W. Recalling (2) and (3), in this two-good example the effect of a small change in p_2^W on government net revenue in country c when t_2^c

adjusts to keep q_2^c constant is $\left[(\partial y_1^c/\partial p_2^c) + p_2^W(\partial y_2^c/\partial p_2^c) - n_2^c\right]$, which can be written, using (13), as $-\left[n_2^c + \tau_2(\partial y_2^c/\partial p_2^c)\right]$. The change in p_2^W required to reduce world production of good 2 by one unit is $-\left(1/\sum_{c=1}^{C} \partial y_2^c/\partial p_2^c\right)$. Hence the change in p_2^W due to the extra unit of good 2 becoming available leads to a change in government net revenue in country c of $\left[\left(n_2^c + \tau_2(\partial y_2^c/\partial p_2^c)\right) / \sum_{c=1}^{C} \partial y_2^c/\partial p_2^c\right]$. Multiplying the revenue change in each country by μ^c and summing across countries gives the effect on world welfare: as (16) shows, this effect is equal to v_2.

When there are more than two traded goods, the interpretation of the multipliers v_i, $i = 2, ..., T$, is the same as in the two-good case. These multipliers measure the overall welfare effects of the changes in government revenue in each country resulting from the changes in world prices required to keep world markets in equilibrium when an additional unit of good i becomes available to the world economy. The only difference is that the computation of these effects is more complicated in the many-good case, as (15) shows.

3 Restrictions on lump-sum international transfers, trade taxes, and Pareto-efficiency

3.1 An example of a Pareto-improvement achieved by trade taxes

To understand how Pareto-improving trade in government revenue between countries can occur, and the role of trade taxes in achieving such an outcome, consider a two-good, two-country example, in which good 1 is the untaxed numeraire. Assuming for simplicity that there are no lump-sum transfers between the two countries, the conditions of international equilibrium in this case are:

$$n_2^1(p_2^W, t_2^1, \tau_2^1) + n_2^2(p_2^W, t_2^2, \tau_2^2) = 0 \tag{17a}$$

$$n_1^1(p_2^W, t_2^1, \tau_2^1) + p_2^W n_2^1(p_2^W, t_2^1, \tau_2^1) = 0 \tag{17b}$$

$$n_1^2(p_2^W, t_2^2, \tau_2^2) + p_2^W n_2^2(p_2^W, t_2^2, \tau_2^2) = 0 \tag{17c}$$

Suppose that the initial equilibrium involves no trade taxes ($\tau_2^1 = \tau_2^2 = 0$), and the marginal efficiency cost of government revenue (in terms of good 1) is positive in country 2 but zero in country 1. Consider the following perturbation of the initial equilibrium: let there be offsetting changes dn_1^1 and dn_1^2 in the countries' net imports of good 1 ($dn_1^1 + dn_1^2 = 0$), combined with changes in the world price dp_2^W and each country's trade tax ($d\tau_2^1$ and $d\tau_2^2$) that keep consumer and producer prices in both countries constant, so that $dp_2^W = -d\tau_2^1 = -d\tau_2^2$. From (3), if consumer and producer prices are constant, the changes in net imports imply that $dn_1^1 = -dz_1^1$ and $dn_1^2 = -dz_1^2$. From (17b) and (17c), and noting from (3) that the partial derivatives of net imports with respect to p_2^W, τ_2^1 and τ_2^2 are identical, the required change in p_2^W is $dp_2^W = -(dn_1^c/n_2^c)$, $c = 1, 2$. Consequently the common change $d\tau_2 = (dn_1^c/n_2^c)$, $c = 1, 2$.

How does this perturbation affect each country's government net revenue? Since $\tau_2^1 = \tau_2^2 = 0$ at the initial equilibrium, the change in country c's government revenue is, from (1), $dR^c = n_2^c d\tau_2 + dz_1^c$, $c = 1, 2$. Recalling that $d\tau_2 = (dn_1^c/n_2^c)$ and $dn_1^c = -dz_1^c$, $dR^c = 0$, so that government net revenue in both countries is still zero at the international equilibrium after the perturbation. Let the perturbation involve an increase in country 1's net imports of good 1 ($dn_1^1 > 0$) and a corresponding decrease in country 2's net imports of good 1 ($dn_1^2 < 0$). Then government budget balance in country 1 is maintained by additional tax revenue $n_2^1 d\tau_2 = dn_1^1$ and reduced revenue from government supply $dz_1^1 = -dn_1^1$. Since the marginal efficiency cost of revenue (in terms of good 1) is zero in country 1, the changes that maintain budget balance have no net effect on welfare in country 1. Government budget balance in country 2 is maintained by reduced tax revenue $n_2^2 d\tau_2 = dn_1^2$ and increased revenue from government supply $dz_1^2 = -dn_1^2$. These changes have a positive net effect on welfare in country 2, because the marginal efficiency cost of revenue (in terms of good 1) is positive in country 2. Hence this perturbation is Pareto-improving. Note that the perturbation involves trade of good 1 for tax revenue: country 2 gives up some of good 1 to country 1 in exchange for having to raise a correspondingly lower amount of tax revenue, while country 1 receives some of good 1 in exchange for raising additional tax revenue. Note also that the perturbation involves the introduction of a (common) trade tax in each country.

This example illustrates the way in which trade in tax revenue can take place, and the possibility of making Pareto-improvements by using trade taxes. However, being an example, it has some special features, one of which is that changes in net imports of good 1 are assumed to be the result of changes in government supply of good 1. The general analysis in the next subsection dispenses with this and other special features of the example, and shows that there is an efficiency case for trade taxes when there are restrictions on lump-sum international transfers and differences in countries' shadow values of government revenue at international equilibria in the absence of trade taxes. To reiterate, differences in the shadow value of government revenue between countries are taken to arise solely from differences in the marginal efficiency costs of government revenue.

3.2 Pareto-efficient trade taxes and the shadow values of government revenue

The analysis in subsection 2.2 took trade taxes and lump-sum international transfers to be parameters. Now, with lump-sum international transfers continuing to be parameters, consider the effects of changes in trade taxes on world welfare when commodity taxes and world prices are chosen to satisfy (10) and (11) respectively. By the envelope theorem, the effect of changes $d\tau_j^c$ in country c's trade taxes from their parametric values is given by

$$dW = \sum_{j=2}^{T} \frac{\partial L}{\partial \tau_j^c} d\tau_j^c \qquad j = 2, ..., T, \; c = 1, ..., C \tag{18}$$

From (9),

$$\frac{\partial L}{\partial \tau_j^c} = -w^c \frac{\partial V^c}{\partial m^c} x_j^c - \mu^c \left(\frac{\partial x_1^c}{\partial q_j^c} - \frac{\partial y_1^c}{\partial p_j^c} \right) - \sum_{i=2}^{T} \left(v_i + \mu^c p_i^W \right) \left(\frac{\partial x_i^c}{\partial q_j^c} - \frac{\partial y_i^c}{\partial p_j^c} \right)$$

$$j = 2, ..., T, \; c = 1, ..., C$$

Using (10) and (14), this becomes

$$\frac{\partial L}{\partial \tau_j^c} = \sum_{i=2}^{T} \left(v_i - \mu^c \tau_i^c \right) \frac{\partial y_i^c}{\partial p_j^c} \qquad j = 2, ..., T, \; c = 1, ..., C \tag{19}$$

Using (19) in (18),

$$
\begin{aligned}
dW &= \sum_{j=2}^{T}\sum_{i=2}^{T}\left(v_i-\mu^c\tau_i^c\right)\frac{\partial y_i^c}{\partial p_j^c}d\tau_j^c \qquad j=2,...,T,\ c=1,...,C \\
&= \left(\mathbf{d}\boldsymbol{\tau}_{-1}^c\right)'\left[\mathbf{D}\mathbf{y}^c\right]'\left(\mathbf{v}_{-1}-\mu^c\boldsymbol{\tau}_{-1}^c\right) \qquad c=1,...,C \qquad (20)
\end{aligned}
$$

where $\mathbf{d}\boldsymbol{\tau}_{-1}^c$ is the $(T-1)\times 1$ vector with elements $d\tau_j^c$, $j=2,...,T$.

Equation (20) shows that, when commodity taxes and world prices are also control variables, the condition for trade taxes to yield a stationary point of (7) subject to the constraints of international equilibrium, and thus be Pareto-efficient, is that

$$
\left[\mathbf{D}\mathbf{y}^c\right]'\left(\mathbf{v}_{-1}-\mu^c\boldsymbol{\tau}_{-1}^c\right)=\mathbf{0}_{T-1} \qquad c=1,...,C
$$

Assuming that $[\mathbf{D}\mathbf{y}^c]'$ is nonsingular, this implies that Pareto-efficient trade taxes are characterised by

$$
\boldsymbol{\tau}_{-1}^c=\frac{1}{\mu^c}\mathbf{v}_{-1} \qquad c=1,...,C \qquad (21)
$$

Since (15) must hold for Pareto-efficient trade taxes, it can be written, using (21), as

$$
\mathbf{v}_{-1}=\left[\mathbf{D}\mathbf{y}'\right]^{-1}\left\{\mathbf{N}_{-1}\boldsymbol{\mu}+\left(\sum_{c=1}^{C}\left[\mathbf{D}\mathbf{y}^c\right]'\right)\mathbf{v}_{-1}\right\} \qquad (22)
$$

Using the definition $[\mathbf{D}\mathbf{y}']\equiv\sum_{c=1}^{C}[\mathbf{D}\mathbf{y}^c]'$, (22) implies that when trade taxes are at Pareto-efficient values

$$
\mathbf{N}_{-1}\boldsymbol{\mu}=\mathbf{0}_{T-1} \qquad (23)
$$

If the rank of $\mathbf{N}_{-1}$ is $C-1$, then (23) has a unique solution for $\boldsymbol{\mu}$ (up to a factor of proportionality), which is $\mu^c=\mu$, $c=1,...,C$, so that the shadow value of government revenue is equated across countries. Since $\mathbf{N}_{-1}$ is a $T-1 \times C$ matrix, and its columns must sum to zero by the world market-clearing conditions, the maximal rank of $\mathbf{N}_{-1}$ is given by $Min(T-1, C-1)$. Hence if $T \geq C$ and $\mathbf{N}_{-1}$ has maximal rank, Pareto-efficiency will unambiguously involve equal shadow values of government revenue across countries. But if $T < C$, or if $T \geq C$ and $\mathbf{N}_{-1}$ does not have maximal rank (so that there is at least one linear dependence between countries' net import vectors in addition to that implied by world market-clearing), then (23) does not have a unique solution for $\boldsymbol{\mu}$ (up to a factor of proportionality). One possible solution is $\mu^c = \mu$, $c = 1, ..., C$, but there are others in which the values of μ^c differ between countries, and it is therefore ambiguous whether Pareto-efficiency will involve equal shadow values of government revenue across countries.

To understand the relationship between trade taxes and the shadow values of government revenue in different countries, and the reason that (23) holds if trade taxes are at Pareto-efficient values, consider the effect on world welfare if all countries' trade taxes on good j change from their parametric values by the same amount $d\tau_j$. From (9), this is (by the envelope theorem)

$$dW = \left\{ \sum_{c=1}^{C} \left[-w^c \frac{\partial V^c}{\partial m^c} x_j^c - \mu^c \left(\frac{\partial x_1^c}{\partial q_j^c} - \frac{\partial y_1^c}{\partial p_j^c} \right) - \sum_{i=2}^{T} \left(v_i + \mu^c p_i^W \right) \left(\frac{\partial x_i^c}{\partial q_j^c} - \frac{\partial y_i^c}{\partial p_j^c} \right) \right] \right\} d\tau_j \qquad j = 2, ..., T$$

which can be written, using (11), as

$$dW = \left\{ \sum_{c=1}^{C} \mu^c n_j^c \right\} d\tau_j \qquad j = 2, ..., T$$

A small change in the trade tax on good j that is the same in all countries thus has an effect on world welfare given by the weighted sum of each country's net imports of good j, where the weight for country c's net imports is the shadow value of government revenue in country c. There is no other effect on world welfare, because commodity taxes and world prices satisfy (10) and (11). A common perturbation of all countries' trade taxes on a good transfers revenue between countries according to the pattern of trade in this good. If the trade tax on good j is increased by the same small amount in all countries, government revenue will be transferred from the countries that export good j to those that import it. These transfers are pure redistributions, since the world market for good j clears. The effect of this common increase on world welfare is given by weighting the transfers by the relevant shadow values of government revenue and summing over countries.

If commodity taxes, trade taxes, and world prices are control variables, a stationary point of (7) subject to (4) and (8) will, therefore, require trade taxes to be at values such that small common perturbations $d\tau_j$, $j = 2, ..., T$, have no effect on world welfare, i.e., $\sum_{c=1}^{C} \mu^c n_j^c = 0$, $j = 2, ..., T$, which is the condition (23). To understand whether Pareto-efficient trade taxes will equate the shadow values of government revenue among countries, let $\mathbf{d\boldsymbol{\alpha}}$ be a $C \times 1$ vector, with its rows summing to zero, of desired small transfers of government revenue between countries. If these transfers have to be made by common perturbations in all countries' trade taxes, given by the $(T-1) \times 1$ vector $\mathbf{d\boldsymbol{\tau}}$ with elements $d\tau_j$, $j = 2, ..., T$, then it must be possible to solve the system of equations

$$\mathbf{N}'_{-1}\mathbf{d\boldsymbol{\tau}} = \mathbf{d\boldsymbol{\alpha}} \tag{24}$$

for $\mathbf{d\boldsymbol{\tau}}$, where $\mathbf{N}'_{-1}$ is the transpose of $\mathbf{N}_{-1}$. The necessary and sufficient condition for (24) to have such a solution is that both $\mathbf{N}'_{-1}$ and the augmented matrix $\left[\mathbf{N}'_{-1}\ \mathbf{d\boldsymbol{\alpha}}\right]$ have the same rank. If $\mathbf{N}_{-1}$ has rank $C-1$, then the rank of $\mathbf{N}'_{-1}$ is also $C-1$ and its rows sum to zero.

Since the rows of $\mathbf{d}\boldsymbol{\alpha}$ also sum to zero, the augmented matrix has the same rank as $\mathbf{N}'_{-1}$, and so (24) has a solution for any desired $\mathbf{d}\boldsymbol{\alpha}$. Thus if $\mathbf{N}_{-1}$ has rank $C-1$ at a Pareto-efficient allocation, the corresponding trade taxes must be such that the shadow value of government revenue is the same in all countries. If these shadow values differed among countries, then whatever small transfers of revenue between countries were required to move towards equal shadow values could be achieved by suitable common perturbations of trade taxes, as given by (24).

However, if the rank of $\mathbf{N}_{-1}$ is less than $C-1$ at a Pareto-efficient allocation, it will not be possible to solve (24) for an arbitrary vector of transfers $\mathbf{d}\boldsymbol{\alpha}$ that satisfies only the restriction that the sum of its rows is zero, because the condition that $\mathbf{N}'_{-1}$ and $\left[\mathbf{N}'_{-1}\ \mathbf{d}\boldsymbol{\alpha}\right]$ have the same rank will, in general, not hold. Pareto-efficient trade taxes may then be such that the shadow value of government revenue differs between countries, because the revenue transfers that would be required to move towards equal shadow values cannot be achieved by common perturbations of trade taxes. Trade taxes may, however, succeed in equating the shadow values of government revenue even if the rank of $\mathbf{N}_{-1}$ is less than $C-1$ at a Pareto-efficient allocation. Suppose that the revenue transfers required to move towards equal shadow values are such that $\mathbf{d}\boldsymbol{\alpha}$ satisfies some restrictions in addition to the sum of its rows being zero, such that the rank of $\left[\mathbf{N}'_{-1}\ \mathbf{d}\boldsymbol{\alpha}\right]$ is the same as that of $\mathbf{N}'_{-1}$. Then common perturbations in trade taxes can still achieve the desired transfers, and hence a Pareto-efficient allocation must have shadow values of government revenue that are the same in all countries.[8]

[8] Suppose, for example, that the rank of $\mathbf{N}_{-1}$ is $C-2$ because one country does not trade, so that its net import vector is the zero vector. If the desired transfers between countries are such that there is to be no change in this country's revenue, it is possible to achieve these transfers by perturbations of world prices.

3.3 Pareto-efficient trade taxes and global production efficiency

From (21), an international equilibrium with no trade taxes will be Pareto-efficient if $\mathbf{v}_{-1} = \mathbf{0}_{T-1}$ at such an equilibrium. Using (22), this requires that (23) should hold at an international equilibrium with no trade taxes. Hence there are two cases in which an international equilibrium without trade taxes is Pareto-efficient. One is when the shadow value of government revenue is the same in all countries at such an equilibrium. The other is when the shadow value of government revenue differs across countries at such an equilibrium, but the constraints do not permit transfers of revenue between countries because the rank of $\mathbf{N}_{-1}$ is less than $C-1$. However, if the shadow value of government revenue differs between countries at an equilibrium without trade taxes, and the constraints allow transfers of revenue among countries to be made, such an equilibrium will be Pareto-inefficient. A necessary, but not sufficient, condition for a Pareto-efficient allocation to involve trade taxes is thus that the shadow value of government revenue should differ among countries at the international equilibrium without trade taxes because of differences between countries in the marginal efficiency costs of government revenue (recall the discussion of (12) above). Note that, if each country can raise government revenue using lump-sum taxes, there are no differences between countries in the marginal efficiency costs of raising revenue domestically, since with lump-sum taxes there are no such costs. Thus there is no efficiency case for the use of trade taxes to transfer revenue between countries when lump-sum taxes are available in all countries.

The Pareto-efficient trade tax on a particular good $i = 2, ..., T$ will, from (21), take the sign of v_i at a Pareto-efficient allocation, and thus be the same in all countries. This means that, at a Pareto-efficient international equilibrium, it will be the case that the producer price of a particular good will either be above the world price in all countries, or below it in all countries. It cannot be Pareto-efficient for the producer price to be above the world price in some countries and below it in others. Recalling the convention that the sign of the product $\tau_i^c n_i^c$ shows whether the net imports of good i are taxed or subsidised in country c, the fact that the Pareto-efficient trade tax on a good has the same sign in all countries means that if, for example, the Pareto-efficient τ_i^c is negative, countries which import good i subsidise imports and those which export it tax exports.

Although Pareto-efficient trade taxes on goods take the same sign in all countries, (21) shows that the level of these trade taxes in each country will depend on the relationship between the shadow value of government revenue in each country. For any two countries c, $d = 1, ..., C$, (21) implies that

$$\frac{\tau_i^c}{\tau_i^d} = \frac{\mu^d}{\mu^c} \qquad i = 2, ..., T$$

If the solution to (23) is such that $\mu^c = \mu$, $c = 1, ..., C$, then the Pareto-efficient trade tax on any given good will be the same in all countries. Thus, if the constraints allow transfers of revenue between countries by trade taxes to equate the shadow value of government revenue across countries, Pareto-efficiency will also involve equal trade taxes across countries. But if the shadow value of government revenue cannot be equated among countries, the level of Pareto-efficient trade taxes will differ between countries, with the level being lower in countries with higher shadow values of government revenue. However, even when the levels of Pareto-efficient trade taxes differ across countries, Pareto-efficient relative trade taxes will be the same in all countries, since (21) also implies that

$$\frac{\tau_i^c}{\tau_j^c} = \frac{v_i}{v_j} \qquad c = 1, ..., C,\ i, j = 2, ..., T$$

The vector $\mathbf{p}_{-1}^c = \mathbf{p}_{-1}^W + \boldsymbol{\tau}_{-1}^c$ gives the relative producer prices of goods $2, ..., T$ in country c, $c = 1, ..., C$. Hence when the shadow values of revenue and trade taxes are the same in all countries at Pareto-efficient allocations, relative producer prices are also the same in all countries. In these circumstances, i.e. when rank $\mathbf{N}_{-1} = C - 1$, Pareto-efficiency involves global production efficiency. In each country, private producers face the same relative prices, which implies that, since private production is assumed to be competitive, for the world as a whole private production is on the boundary of the world private production set. But when the shadow values of revenue and trade taxes differ across countries at Pareto-efficient allocations, as they may do if rank $\mathbf{N}_{-1} < C - 1$, relative producer prices also differ across countries. Thus Pareto-efficiency does not necessarily imply global production efficiency. It is also the case that global production efficiency does not necessarily imply Pareto-efficiency, because the existence of an international equilibrium with trade taxes and relative producer prices that are the same in all countries does not ensure that (23) holds and, even if it does hold, does not guarantee that its only solution has an equal shadow value of revenue in all countries. Global production efficiency is thus neither necessary nor sufficient for Pareto-efficiency when countries raise government revenue by distortionary taxes and there are restrictions on the use of lump-sum international transfers. Consequently policies cannot be adequately justified solely in terms of their consistency with production efficiency.

Even when global production efficiency is consistent with Pareto-efficiency, because trade taxes are the same in all countries, this does not mean that a general presumption in favour of destination- rather than origin-based commodity taxes is justified. A positive trade tax on a good is equivalent to imposing equal rates of a destination-based commodity tax and an origin-based production subsidy on the good, while a negative trade tax is equivalent to equal rates of a destination-based commodity subsidy and an origin-based production tax. Hence there are two alternative ways of describing the distortionary taxes that are consistent with a Pareto-efficient international equilibrium which satisfies global production efficiency conditions when lump-sum international transfers are restricted. One way is to say that trade taxes are the same in all countries, while destination-based commodity taxes may differ between countries. The other is to say that origin-based commodity taxes (and subsidies) are the same in all countries, while destination-based commodity taxes may differ between countries. The equivalence between trade taxes and destination- and origin-based taxes means that, in the particular circumstances when it is Pareto-efficient for there to be no trade taxes in any country, the use of destination-based commodity taxes alone, with no origin-based commodity taxation, is consistent with global production efficiency. But in the circumstances when Pareto-efficiency involves trade taxes that are the same in all countries, global production efficiency is consistent with the use of origin-based as well as destination-based commodity taxation.

4 Unrestricted lump-sum international transfers and Pareto-efficiency

The previous section analysed the efficiency case for using trade taxes when lump-sum international transfers are fixed at parametric values. Suppose that trade taxes, together with commodity taxes and world prices, are at Pareto-efficient values conditional on the parametric values of lump-sum international transfers. Will small changes in these transfers from their parametric values result in a Pareto-improvement?

Let dS^c, $c = 1, ..., C$, denote a small change in the lump-sum transfer to country c, with $\sum_{c=1}^{C} dS^c = 0$. By the envelope theorem, the effect of the changes dS^c on world welfare is

$$dW = \sum_{c=1}^{C} \frac{\partial L}{\partial S^c} dS^c$$

From (9)

$$\frac{\partial L}{\partial S^c} = \mu^c - \gamma \qquad c = 1, ..., C$$

and hence

$$dW = \sum_{c=1}^{C} (\mu^c - \gamma)\, dS^c \tag{25}$$

Since $\sum_{c=1}^{C} dS^c = 0$, (25) can be written $dW = \sum_{c=1}^{C} \mu^c dS^c$. Thus, if the shadow value of government revenue has been equated across countries by Pareto-efficient trade taxes ($\mu^c = \mu$, $c = 1, ..., C$), $dW = 0$: the ability to use lump-sum international transfers rather than trade taxes for a small part of the transfer of revenue between countries does not change world welfare, and thus does not result in a Pareto-improvement. However, if the shadow value of government revenue has not been equated across countries by Pareto-efficient trade taxes, the use of lump-sum international transfers instead of trade taxes does permit a Pareto-improvement. Thus it is only when trade taxes cannot equate the shadow value of government revenue across countries that restrictions on the use of lump-sum international transfers impose an efficiency cost on the international economy.

If there are no restrictions on the use of lump-sum international transfers, is there an efficiency case for trade taxes? To answer this question, suppose that the control variables for the problem of finding stationary points of (7) subject to the constraints of international equilibrium are the commodity taxes in each country, world prices, and lump-sum international transfers, while trade taxes in each country are parameters. The first-order necessary conditions for the control variables are (10), (11), and,

$$S^c : \quad \mu^c - \gamma = 0 \qquad c = 1, ..., C \tag{26}$$

The first-order conditions (26) show that, with no restrictions on lump-sum international transfers, a Pareto-efficient international equilibrium will involve these transfers being set to equate the shadow value of government revenue in different countries. In these circumstances, there is no efficiency case for the use of trade taxes. In the absence of trade taxes ($\boldsymbol{\tau}^c_{-1} = \mathbf{0}_{T-1}$), the shadow value of government revenue will be the same in all countries, and thus (23) will be satisfied. Hence, from (15), $\mathbf{v}_{-1} = \mathbf{0}_{T-1}$, and thus, from (21), $\boldsymbol{\tau}^c_{-1} = \mathbf{0}_{T-1}$ is Pareto-efficient. With no restrictions on lump-sum international transfers, Pareto-efficiency implies that producer prices in all countries should equal world prices, and thus that global production should be efficient, irrespective of the rank of $\mathbf{N}_{-1}$. Thus if lump-sum transfers can be used as a means of trading distortionary tax revenue, global production efficiency does imply that neither trade nor origin-based commodity taxes should be used. In these circumstances, the policy conclusions concerning international taxation that have been drawn from the Diamond-Mirrlees production efficiency theorem are correct, since unrestricted lump-sum international transfers merge the separate national revenue constraints into a single international one.

5 Conclusion

This paper has analysed the implications of the fact that, when the marginal efficiency costs of government revenue differ between countries, it is possible for all countries to gain by trading tax revenue for other goods. It has shown that, in these circumstances, if lump-sum international transfers of revenue are restricted and the matrix of countries' net imports satisfies a suitable condition, Pareto-efficient international equilibria require trade taxes to be used in order to exploit the gains from trade in tax revenue, even in a framework of competitive trade with no restrictions on the use of domestic commodity taxes and full taxation of any pure profits.

If lump-sum international transfers are restricted, and the matrix of countries' net imports of taxed traded goods always has rank equal to the number of countries minus one, then Pareto-efficient trade taxes are able to equate the marginal efficiency costs of government revenue across countries, and hence to achieve the same outcomes as would be possible if there were no restrictions on lump-sum international transfers. In these circumstances, Pareto-efficient trade taxes are such that the producer price of a particular good is, in all countries, either above the world price by the same amount, or below it by the same amount. Relative producer prices are thus the same in all countries, and so Pareto-efficient international equilibria are characterised by global production efficiency. But global production efficiency in these circumstances involves the use of trade taxes, which can alternatively be interpreted as a combination of destination- and origin-based commodity taxes and subsidies: it implies neither that trade taxes should not be used, nor that destination-based commodity taxes are superior to origin-based ones.

If lump-sum international transfers are restricted, and the matrix of countries' net imports of taxed traded goods has rank less than the number of countries minus one, then Pareto-efficient trade taxes cannot, in general, equate the marginal efficiency costs of government revenue across countries. In these circumstances, Pareto-efficient international equilibria are typically not characterised by global production efficiency, and the outcomes achievable by means of trade taxes are typically Pareto-inferior to those that would be possible with unrestricted lump-sum international transfers.

The case for using trade taxes when lump-sum international transfers are restricted is stronger than the case for sacrificing global production efficiency in these circumstances. It is Pareto-efficient to use trade taxes if countries have different marginal efficiency costs of revenue at international equilibria with no trade taxes, and a reasonable condition on the matrix of countries' net imports holds. Provided that this requirement holds, Pareto-efficiency requires trade taxes to be the same in all countries, so that global production efficiency conditions are satisfied. For Pareto-efficient international equilibria to be globally production-inefficient, it is necessary that this condition on the matrix of countries' net imports does not hold.

However, if lump-sum international revenue transfers are unrestricted, Pareto-efficient international equilibria do not involve any trade taxes, since these transfers can equate the marginal efficiency costs of government revenue across countries in the absence of trade taxes. In these circumstances, globally Pareto-efficient allocations always involve global production efficiency, and the desirability of global production efficiency implies both that trade taxes should not be used and that destination-based commodity taxes are superior to origin-based ones.

The efficiency case for trade taxes thus depends critically on whether unrestricted lump-sum international revenue transfers can be used as a means of trading distortionary tax revenue. The feasibility of such transfers is a subject that requires further research. It is not clear whether the asymmetric information problems that standard optimal tax analysis uses to explain why lump-sum redistribution between individuals is not possible also rule out lump-sum revenue transfers between countries. The Pareto-efficient trade taxes that have been analysed in this paper take a very particular form, and it is not obvious that, if such taxes were introduced, they would long survive distortion by rent-seeking interests. Hence there are reasons to be cautious about the efficiency case for trade taxes and for arguing that, if possible, trade in tax revenue should take place via lump-sum transfers. But it is important to recognise that, in the absence of unrestricted lump-sum international transfers, an efficiency case for trade taxes does exist.

References

Auerbach, A.J. (1985), 'The Theory of Excess Burden and Optimal Taxation', in A.J. Auerbach and M.S. Feldstein (eds), *Handbook of Public Economics*, Vol I (North-Holland, Amsterdam).

Diamond, P.A. and J.A. Mirrlees (1971), 'Optimal Taxation and Public Production I: Production Efficiency', *American Economic Review*, 61, 1-27.

Haufler, A. (2001), *Taxation in a Global Economy*, (Cambridge University Press, Cambridge).

Keen, M.J. and D.E. Wildasin (2000), 'Pareto Efficiency in International Taxation', CESifo Working Paper No. 371.

Panzar, J.C. and R.D. Willig (1976), 'Vindication of a "Common Mistake" in Welfare Economics', *Journal of Political Economy*, 84, 1361-3.

Wildasin, D.E. (1978), 'Production Efficiency in Tax-Distorted Economies with Multiple Revenue Constraints', unpublished paper, University of Illinois at Chicago Circle.

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