Trade Policy, Cross-border Externalities and Lobbies: Do Linked Agreements Enforce More Cooperative Outcomes?

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January 2002

(First draft April 2000)

Abstract

If, in international agreements, governments "link" trade to environmental policy (or other issues with non-pecuniary externalities), will this promote more cooperation in both policies or will cooperation in one policy be strengthened at the expense of the other? We analyze this question in the context of self-enforcing agreements. We show that if the two policies are independent in the government's objective function then linkage – the ability to use both policies to punish non-compliance in either individual agreement – promotes cooperation in one policy at the expense of the other (e.g. strengthens environmental standards at the expense of higher tariffs). However, if the linked policies are not independent in the governments' objective function (e.g. a tariff on cars and an environmental tax on oil) and if these policies are strategic complements then linkage promotes more cooperation in both issues (higher environmental standards and lower tariffs) than no-linkage. The policies are strategic complements only if: (i) the production externality has cross-border effects; (ii) the weight on the externality cost is high; (iii) import competing lobbies are not "powerful".

JEL classification: F13; F18; F42; H23; H77.
Keywords: Trade; linkage; environment; labor; cross-border externality, repeated games.

*Author's email: limao@econ.umd.edu. I thank Stephanie Aaronson, Jagdish Bhagwati, Alessandra Casella, Gernot Doppelhoffer, Josh Ederington, Helen Milner, Rohini Pande, Eric Reinhardt, Mike Riordan, Xavier Sala-I-Martin, Giancarlo Spagnolo, David Weinstein and Gerald Willmann. I am also grateful for comments and suggestions from participants in seminars at the Econometric Society meeting (Atlanta), Georgetown, NYU (Inter-university Conference), Penn State, Stanford University, University of British Columbia, University of Maryland, World Bank and Yale University. I am particularly indebted to Kyle Bagwell and Don Davis for their support and encouragement. The usual disclaimer applies.

1 Introduction

In trade policy agreements, trade concessions are increasingly made conditional on cooperation in non-trade issues, what is known as "linkage". This trend is clear in multilateral, bilateral and regional trade agreements.[1] Multilaterally, compliance with intellectual property rights is now enforced through the threat of import barriers, sanctioned by the World Trade Organization (WTO). Moreover, the trend to link will surely intensify. At the end of the last multilateral trade liberalization round a long list of issues was proposed for similar treatment by the WTO including investment and competition policy as well as labor and environmental standards.[2] Therefore linkage has become one of the most important and contentious issues in trade policy both between developed and developing countries and also within developed countries.

To explain the motivation and welfare consequences of linkage we must first understand two key features of international cooperative agreements. First, the basic objective of such agreements is to internalize the costs of countries' actions. When countries set up import tariffs they do not internalize any costs inflicted on foreigners due for example to lower foreign export prices. Reciprocal trade liberalization agreements allow countries to internalize these costs by simultaneously lowering tariffs.[3] Environmental agreements (or agreements on other issues with non-pecuniary externalities) are required if a negative externality has a cross-border effect, since this effect implies that each country sets the domestic tax on the source of the externality below the global optimum.

The second key feature of international cooperative agreements is that they must be self-enforcing, given the absence of a supra-national authority to punish violators. That is, these agreements are subject to incentive constraints which balance the gains of deviating from the agreement against the ensuing losses from retaliation. If countries are not sufficiently patient then the cooperative first best is not feasible since the incentive constraints (IC) bind and therefore limit how much cooperation is possible. Now, since the relevant set of IC for an agreement depends on which policies are available for retaliation then so must the

[1] Bilaterally, the United States and the European Union have attached investment, environmental and labor clauses to the granting of trade preferences to developing countries (through the Generalized System of Preferences). Regionally, NAFTA includes both an environmental and a labor side agreement.

[2] These have not yet been accepted, GATT document MTN.TNC/45 [MIN], 12. In the 1999 Seattle ministerial conference there was again a strong pressure for environmental and labor standards to be included. The nominal inclusion of non-trade clauses in trade agreements is not an entirely new phenomenon (see Charnovitz 1996, 1998 for examples). The main difference is the willingness to enforce those clauses and the availability of effective mechanisms to do so, namely the dispute settlement system in the case of the WTO.

[3] Bagwell and Staiger (1999).

degree of cooperation.

Given these key features, the first question we address is the following. In an international agreement, does retaliation across two policies, instead of just policy-by-policy, promote more cooperation in both issues or must cooperation in one always be strengthened at the expense of less cooperation in the other? This question is motivated by a central objection to cross-retaliation in trade agreements, namely that it leads to a reallocation of enforcement. A **reallocation of enforcement** occurs if more cooperation on non-trade issues is achieved at the expense of higher tariffs. If the gains from the different policies are unevenly distributed, within and/or across countries, and if lump-sum transfers are unavailable, then this objection becomes important for two reasons. First, the redistribution may be undesirable. Second, even if cross-retaliation yields an aggregate welfare improvement, it may not be politically feasible if there are winners and losers, i.e. if it is only potentially Pareto improving within a country. It is important to know if reallocation occurs and which policy it benefits. However, an even more important question, which has so far been ignored in policy debates, is whether linkage creates enforcement. If linkage leads to the **creation of enforcement**–that is if more cooperation in both issues becomes feasible (e.g. lower tariffs and higher environmental standards)–then linkage can sustain a strictly higher welfare level without sacrificing cooperation in either issue.

To answer these questions we focus on a symmetric two country trade model with a negative production externality, which can have cross-border effects. The non-cooperative outcome features inefficiently high tariffs and low externality taxes (e-taxes henceforth) from a global perspective; governments overcome this through cooperative agreements. We assume a status quo of **no-linkage**, that is retaliation occurs policy-by-policy, so, for example, non-cooperation in e-taxes leads to a punishment in e-taxes but not in tariffs. We then contrast the set of subgame perfect equilibrium policies under no-linkage with those achieved under a **linkage** regime where non-cooperation in *either* issue can be met with punishment in *either* or *both* policies.[4]

Our first result is that whether linkage results in the creation of enforcement or must always lead to reallocation depends on the interaction between tariffs and e-taxes in the government's objective function.

[4] The TRIPs agreement in the WTO allows for the possibility of trade concessions being removed if there is an infringement of intellectual property. But the reverse is also explicitly allowed (art. 22.3, annex 2 of the Uruguay Round final act, p. 368). In fact Ecuador recently won authorization to ignore its TRIPs obligations towards the European Union as a form of retaliation against the E.U.'s trade policy on bananas (WTO Doc. WT/DS27/ARB/ECU on <http://www.wto.org>).

More specifically, linkage always leads to reallocation if the linked policies are independent in the objective function and there is an asymmetry in the individual enforceability of each issue. That is, if under no-linkage tariffs are relatively closer to their cooperative optimum than e-taxes, then linkage leads to higher e-taxes at the expense of higher tariffs and vice-versa. Policies are independent if their cross-effect in the objective function is zero before any strategic relation through linkage is present. Therefore unrelated issues–i.e. issues in which the policies yield distinct payoffs–typically give rise to independent policies, such as tariffs on automobiles and whaling regulations.[5]

However, an important number of issues considered for linkage are trade-related and the policies used to address them are not independent of trade policy even before linkage is considered. For example, tariffs on autos and environmental standards in the auto industry, such as carbon emissions targets, affect the price of cars. Since any sensible government objective for tariffs and e-taxes on cars factors in the price of that good, those two policies are not chosen independently. We show that the crucial condition for linkage to create enforcement is supermodularity of the objective function in the linked policies. Supermodularity is, in our paper, equivalent to requiring all linked tariffs and e-taxes to be strategic complements, so that an increase in tariffs raises the marginal benefit of e-taxes and vice-versa. Our result is not specific to this trade model. It can be applied to other economic problems with a similar structure where agents must enter self-enforcing contracts to repeatedly deal with a cooperation problem over multiple related issues using non-independent policies. The last characteristic distinguishes our linkage result from others in the literature and allows the analysis of an important extra set of economic problems, as we discuss below.

Briefly, the intuition is the following. If cross-retaliation is not allowed then enforcement cannot be optimally allocated across policies. By allowing cross-retaliation, linkage aggregates enforcement from different policies which can then be optimally allocated. When policies are independent this aggregation is equivalent to adding up the IC in the different policies, and thus any welfare improvement from a regime switch to linkage arises purely from a reallocation of enforcement. When policies are strategic complements this aggregation allows linkage to create enforcement. This occurs since, as we show, supermodularity is sufficient for the gains from simultaneous deviations in tariffs and e-taxes, which occur under linkage, to be lower than the sum of the gains from deviations in each individual policy. Moreover, for a number of

[5] For a special case of our model, in which the e-issue is clearly trade-related, the policies are nonetheless independent because the different components of the cross-effect exactly offset each other.

objective functions, including the one in our trade model, supermodularity is also sufficient to ensure that the gains from cooperating in both policies exceed the sum of the gains of cooperating in either.

Our other main goal is to show that the supermodularity conditions for the creation of enforcement can be satisfied by the trade model. In doing so we characterize the issues and countries in which linkage is likely to create enforcement. Moreover, we argue that recent changes in these determinants help explain why demands for linkage are now more pervasive and derive basic predictions regarding the actual adoption of linkage. We focus on three basic results from this analysis.

First, whether tariffs and e-taxes are strategic complements depends on the net effect of strategic pecuniary terms–due to revenue and terms of trade considerations–and a strategic non-pecuniary term–arising from the production externality. Cross-border spillovers and a sufficient weight on the production externality are necessary for supermodularity. We show that according to the strategic TOT effect alone foreign tariffs and foreign e-taxes are strategic substitutes in the home government's objective function. Therefore, for those policies to be strategic complements, it is necessary for the strategic externality effect to be present–requiring cross-border spillovers–and sufficiently valued to offset the TOT effect. This implies that for poor countries, which may place a low weight on the production externality, linkage is unlikely to create enforcement.

Second, in the absence of import sector lobbies, cross-border spillovers and a sufficient weight on the externality are also sufficient for supermodularity if the strategic externality effect is positive. In a simple version of the model we show that this condition is satisfied if the externality loss function is convex, which is a plausible case for environmental issues. However if import sector lobbies are "powerful" this result is overturned. This occurs because increases in domestic tariffs expand supply and thus lower the marginal benefit of increasing the domestic production tax. When lobbies are "powerful", i.e. given sufficient weight in the objective function, this effect dominates, the domestic tariffs and e-taxes become strategic substitutes and thus the sufficient conditions for linkage to create enforcement fail.

Finally, we model the governments' decision to switch to linkage explicitly in two simple extensions and show that even if aggregate welfare under no-linkage is strictly lower not all countries switch to linkage. One extension focuses on the role of transition costs and the other on redistribution problems, both highlight the potential importance of creation of enforcement on the adoption of linkage. Briefly, in the absence of the creation of enforcement linkage does not guarantee a strictly higher aggregate welfare level than no-linkage and thus may not offset any transition costs. Moreover, in the absence of creation, welfare is higher under linkage only if there is reduced cooperation in one of the policies, this can create a set of losers which vote against adopting it.

The structure of the paper is as follows. We start with a review of the literature. In section 3 we introduce the model and derive the non-cooperative and cooperative equilibria; in section 4 we derive the conditions under which linkage reallocates and creates enforcement; in section 5 we analyze when these conditions hold in the trade model and governments adopt linkage; in section 6 we extend the main results to a model with a more general pattern of production externalities and in section 7 we conclude.

2 Literature review

Despite the prominence of linkage in policy debates there is little economic theoretical support for (or against) such arrangements in terms of their impact on enforcement.[6] The majority of work focuses on different aspects of the static interaction between trade and non-trade issues in the context of standard trade models. Those papers typically address questions such as: what is the impact of harmonizing labor or environmental standards on factor/goods prices or welfare for different countries and economic agents?[7] The most frequent objections to linkage in this literature are summarized by Anderson:

> First, trade policy measures are usually not the best instruments for achieving social objectives...[S]econd... producer...and some environmental groups are finding it mutually advantageous to use environmental and worker rights arguments to support their claims for unilateral import restrictions.... Third...this activity can lead to an escalation in trade disputes...undermining the global trading system. (1998, p. 244)

The first concern is true from the perspective of optimal policy targeting in a static model. If foreign production creates an externality then increasing a tariff on that good is not the optimal policy to address

[6] Linkage has been analyzed in the political science literature, see for example Sebenius (1983).
[7] See for example Bhagwati and Hudec (1996), Blackhurst and Anderson (1992), Esty (1994).

that externality. However, we argue that the important question behind linkage is whether the *threat* of increasing a tariff is effective in *enforcing* more cooperation in another agreement and vice-versa. The targeting literature has no basic predictions regarding enforcement, so it cannot address this question.[8,9] The final concern may be important, as shown by the tripling in the number of WTO disputes involving non-trade issues from 1994-99 relative to the previous four years. The increase was largely driven by intellectual property issues, but it is too early to determine if the disputes will reduce cooperation in trade policy or if their number will fall once countries adapt their levels of cooperation in intellectual property.[10]

A more optimistic view of emerges from game-theoretic approaches to linkage. Abrego et al. (1997) use numerical simulation to compute the one-shot Nash bargaining solution to a game in which one country, "North", has a higher valuation for the environment than "South". They argue that the "southern" countries (holders of the environmental assets) should pursue joint trade-environmental agreements, as this would give them more leverage over "northern" countries' trade barriers. In the context of linkage the enforcement of cooperation, on which we focus, is at least as important as the bargaining of a particular solution. Moreover, the linkage proposals by "northern" governments have been opposed not only by southern ones but also by different groups *within* northern countries. This points to internal redistribution effects from switching to linkage and motivates our focus on the reallocation versus the creation of enforcement in the presence of import lobbies.[11]

Cesar and Zewe (1994) focus on the role of linkage as a side payment in a model where two agents face a prisoner's dilemma in two unrelated issues with symmetric payoffs. They show that if neither player values the same issue then no cooperation is sustainable when retaliations occur policy-by-policy. Linkage then improves cooperation in both issues since cooperation in one issue is rewarded (or punished) with cooperation in the other. This result hinges crucially on the impossibility to cooperate in either issue in the absence of linkage. We show that, for unrelated issues, if some cooperation is feasible in at least one

[8] Certain multilateral environmental agreements such as the Montreal Protocol on CFCs include the threat of trade restrictions in response to non-compliance. However, some of these measures are inconsistent with GATT rules and therefore according to the European Commission "...problems could arise if a country imposed a trade measure for environmental purposes on another WTO member which had not signed the multilateral environmental agreement. The E.U. wants WTO members to agree that this should not be allowed to happen." <http://trade.info.cec.int/europa/2001newround>

[9] Limão (2001a) analyzes Anderson's second concern and verifies it from an enforcement perspective.

[10] The share of disputes involving non-trade issues has also been rising since 1980. Author's calculations based on dispute data from Reinhardt (2000). For more details see Limão (2001a).

[11] See also Robles et al. (2000) for the effects of linkage in the context of Nash bargaining. Conconi and Perroni (2000) use a cooperative approach to study the effect of linkage on blocking coalitions in a three country model.

of the issues, as it is almost surely the case for trade, linkage does not lead to more cooperation in both but leads instead to a reallocation of enforcement. Moreover, in trade linkage debates the payoffs from the linked issues are typically asymmetric and not independent. Therefore we address these two aspects.

Our approach is motivated by the work on multimarket collusion by Bernheim and Whinston (1990) (BW). They show that, by aggregating incentive constraints from *unrelated* markets (so that profits in market A depend only on actions–i.e. prices–in that market), oligopolists can always achieve at least as much collusion in both markets by reallocating slack enforcement. Our approach differs in two ways. First, we interpret the oligopolists as countries and the markets as policy areas: trade and e-issues, which is sensible given the two key features of international agreements we explain in the introduction. The second and crucial difference is that we focus on *related* issues so that their payoffs cannot be written separately. This implies that the linked policies are generally not set independently during the stage game, that is even before any strategic relation through linkage. Thus we extend this literature by deriving sufficient conditions for the creation of enforcement, an outcome that is not possible in the original BW framework.[12]

Spagnolo (1999a) also explores the possibility of creation of enforcement through linkage in the framework of BW. In his work, "'Multigame contact' is shown to facilitate cooperation in supergames other than oligopolies as long as agents' objective function is submodular in material payoffs."[13] As we explain further in section 4, the key theoretical difference relative to our own result on the creation of enforcement is that in Spagnolo (1999a) each of the linked actions has its own material payoff during the stage game which is independent of the other action. The interaction between the material payoffs then occurs if agents value payoffs non-additively in their objective function. However, for an important number of cases where linkage is considered, the material payoffs cannot be written independently. Therefore we must extend and modify the basic result in a non-trivial way to analyze the case of trade and e-policies which interests us, as well as other cases in which the payoffs cannot be written independently, we provide examples in the conclusion.

Spagnolo (1999b) applies the framework and the main proposition in Spagnolo (1999a) and also interprets the actions of agents as international agreements between governments. The results are presented

[12] Phillips and Mason (1992) provide experimental evidence in support of BW. Moreover, they find an increase in cooperation in one "market" and a reduction in the other when comparing the "multimarket contact" outcome to the one with individual markets, i.e. there is reallocation of enforcement. As in BW, in the Phillips and Mason set-up creation of enforcement is not a possible outcome. This evidence for reallocation of enforcement further suggests the importance of finding conditions for the creation of enforcement.

[13] Spagnolo (1999a, p.127).

for “an extremely stylized two-country infinite horizon model with n policy issues” (p.4) as opposed to a specific model of trade and e-issues which is our focus. However, in the concluding remarks, trade and environmental issues (presumably ones with independent material payoffs) are suggested as possible applications.

Ederington (1998) builds on BW and analyzes a model where social welfare maximizing governments face a unique cooperation issue–a TOT externality–but have access to a tariff and a production tax, which are imperfect substitutes. He shows that linkage can deliver the same outcome as no-linkage because the tariff is the most effective instrument to address the TOT externality. This interesting result leaves unanswered one of the important questions we address, namely under which general conditions linkage *strictly* improves on no-linkage. In a recent independent paper Ederington (2001) incorporates a cross-border externality into a parametrized version of his earlier model. Computing the gain from deviating and cooperating in both policies and in the production tax alone *at* the first-best solution he finds that linkage and no-linkage sustain the first-best at the same discount factor when only import sector policies are available; no-linkage requires a higher discount if only export policies are available. The approach, focus and results of our paper differ in a number of important ways. With respect to the result just described the key distinction is that our analysis applies even if countries can never sustain the first-best. This is crucial because if no-linkage already sustains the first-best then countries have no incentive to switch to linkage.

3 Model

3.1 Setup and world prices

We focus on a two-country, two-good partial equilibrium model and allow for a production externality. This model has a general equilibrium analogue, which we describe below. We differentiate foreign from domestic variables by an asterisk and assume that the two goods, $i = x, y$ are produced both at home and abroad and we take x to be home's “natural” import good.

When countries trade, prices are determined in the following way. Consumer prices are given by $q_i = p_i^w + \tau_i$, where p_i^w is the “world” (or border) price and τ a specific import tariff. Producers receive $p_i =$

$p_i^w + \tau_i - e_i$, where e_i represents a unit production tax.[14] Home's excess demand is then $M_i = D_i(q_i) - S_i(p_i)$, and we make the standard assumptions on the slopes of the demand and supply functions.[15] The "world" prices are then determined by the market clearing conditions for each good, as a function of the policy variables in both countries for that good:

$$M_i(p_i^w, \tau_i, e_i) + M_i^*(p_i^w, \tau_i^*, e_i^*) = 0 \tag{1}$$

$$p_i^w = p_i^w(\underset{-}{\tau_i}, \underset{-}{\tau_i^*}, \underset{+}{e_i}, \underset{+}{e_i^*})$$

We rule out export taxes, τ_x^* and τ_y, so good x (y) does not depend on τ_x^* (τ_y). We assume that both countries have market power in trade and the sign of the partial effect of each policy on world prices is given below it.[16] It is simple to show that the world price is decreasing in tariffs and increasing in productions taxes. This occurs because tariffs depress the importer's excess demand and the production tax lowers world supply. Higher domestic tariffs raise domestic prices, for both consumers and producers. Production taxes raise domestic consumer prices but lower producer prices since the direct producer tax effect dominates the rise in world prices:

$$\frac{\partial q_i}{\partial \tau_i} = \frac{\partial p_i}{\partial \tau_i} > 0 \ ; \ \frac{\partial q_i}{\partial e_i} > 0 \ ; \frac{\partial p_i}{\partial e_i} < 0 \tag{2}$$

3.2 Aggregate welfare

Each government maximizes an objective function $W = W_x + W_y$, where W_i is a weighted measure of consumer and producer surplus, tax revenue and the externality cost in sector i. Throughout we also refer to the government's objective function as aggregate welfare.

One important aspect of import competing lobbies not yet fully examined in the literature is their impact on the enforcement of trade agreements when non-trade policies are also under negotiation. Given

[14] The choice of Pigouvian production taxes is compelling for two reasons. First, in the trade linkages debate higher standards in a sector are associated with a cost disadvantage and a production tax captures this effect clearly. Second, by choosing a first best instrument we preclude effects arising from second best arguments and can focus on the interaction of trade and e-policies in enforcement. We show the e-tax and tariff deliver a first-best outcome only if countries are sufficiently patient.

[15] That is $D_i' < 0, S_i' > 0$. We also assume these functions are linear.

[16] Evidence for market power in trade is found for example in the literature on pass-through exchange rates (Knetter 1993). Bagwell and Staiger (2000b) review this and other evidence. This evidence is not restricted to large developed economies. Chang and Winters (1999) find that Mercosur lowered the prices for non-members exporting into Mercosur. Notice also that transport costs create markets that are regionally circumscribed, which implies that even countries which are small on a world scale have some regional market power. This explains why Mexico initiated a dispute against Guatemala in the WTO over Guatemalan anti-dumping duties on Mexican cement exports. If the Guatemalan action had no effect on prices Mexico would not dispute it.

the scarce analysis of the effect of lobbies on enforcement when more than one policy is under negotiation, the first step is to ask if lobbies are relevant at all in the choice of enforcement regime. For this reason we leave the lobbying mechanism implicit and focus directly on a reduced form objective function which allows an extra weight to be placed on producer surplus in the import sector relative to consumer surplus and tax revenue. So, in the expression below we have $\lambda_i^p \geq 1$ in the import sector and $\lambda_i^p = 1$ in the export sector.[17]

$$W_i \equiv \int_{q_i}^{\infty} D_i(q_i)dq_i + \lambda_i^p \int_0^{p_i} S_i(p_i)dp_i + \tau_i M_i + e_i S_i - \bar{\Psi}_i \quad (3)$$

This objective function can be derived as the reduced form of a political contributions model such as Grossman-Helpman (1994) in the absence of production externalities.[18] The externality cost, $\bar{\Psi}_i$, is assumed to enter additively, for simplicity. The externality valuation may vary across sectors and countries. More specifically, $\bar{\Psi}_i \equiv \lambda_i^{\Psi} \Psi_i$ where λ_i^{Ψ} is a non-negative weight that reflects either the strength of environmental lobbies in sector i or the different valuation by each country of the externality. The externality we model is proportional to production and takes the following form:

$$\Psi_i = \Psi_i(S_i + \alpha_i S_i^*) \, , \Psi_i' \geq 0, \alpha_i \geq 0, \Psi_i(0) = 0 \quad (4)$$

We assume that Ψ is twice differentiable and convex. The (geographical) **scope of the externality** is captured by α. If the parameter is positive the externality has a cross-border effect, otherwise it is purely domestic. This parameter may be interpreted more broadly as the relative weight placed on the foreign source of the externality. For instance, it is argued that the existence of slave or child labor anywhere in the world generates per se a "psychological cost", for some of those aware of it. Then α can represent the weight placed on the existence of these conditions abroad relative to home. The weight and scope of the production externality are likely to change over time as scientific knowledge about the externality evolves or as we become aware of foreign practices that induce "psychological costs". In section 5 we analyze the

[17] It is straightforward to extend the model to include export lobbies.

[18] Staiger (1995). In Grossman-Helpman (1994) the government's objective function is given by $W^{GH} = a\bar{W} + c$ where $\bar{W}$ denotes aggregate welfare, c represents the political contributions from producer lobbies and a is the marginal rate of substitution between the two. In W_x the extra weight placed on producer surplus, $\lambda^p - 1$, can be directly interpreted as the inverse of a. Thus, underlying our partial equilibrium model is the basic general equilibrium structure used in Grossman-Helpman (1994). First, on the demand side, a utility function additively separable in a numeraire good n and two homogeneous goods x, y. Second, three CRS production processes with the numeraire good using labor alone and x and y using labor and a sector specific input, inelastically supplied. When the production of x and y create an externality that enters additively in utility and the e-tax revenues are distributed lump-sum we obtain eq.(3).

effects of such changes on the adoption of linkage.

To focus on one important motivation for linkage, the asymmetry in enforceability between trade and non-trade policies, we rule out other potential motivations for linking agreements. More specifically, we assume symmetry across countries such that home and foreign's import (and export) sectors are mirror images of each other, that is $W_i = W_j^*$ for $i \neq j$.[19] Moreover, for ease of exposition, we initially assume that domestic production in the export sector produces no externality, but foreign production does, so that we have $\Psi_y = \Psi_y(\alpha S_y^*)$ and, by symmetry, $\Psi_x = \Psi_x(S_x)$. This allows us to initially abstract from e-taxes in the export sectors.[20]

One crucial point is that, even in the simple version of the model, it is impossible to write any sub-components of the governments' objective, e.g. producer surplus or the production externality cost, in terms of only the tariff or the e-tax. The non-trade issue is inherently **trade-related** because changes in the tariffs change prices and therefore equilibrium supply levels. Thus, even before linkage is considered, a government sets its own static non-cooperative tariff and e-policies jointly. We now analyze this non-cooperative equilibrium that constitutes the threat point in the repeated game.

3.3 Non-cooperative Nash equilibrium

Governments use trade policies for internal redistribution, revenue and other purposes. Whenever countries have any market power in trade they do not fully internalize the cost of such policies because they neglect the effect on other countries' terms-of-trade (TOT). According to Bagwell and Staiger (1999, 2000b) the main goal of *reciprocal* trade liberalization agreements is precisely to internalize the costs that trade policies impose on other countries through changes in the TOT. Their theory is perfectly compatible with political economy motivations for the use of trade policies and provides a compelling economic rationale for the main rules in the WTO. Therefore, we focus on the TOT externality as the main motivation for the reciprocal trade liberalization agreement.

In addition to the cooperation problem in trade, in our model governments also face a cooperation

[19] Limão (2001b) analyzes the gains from linkage in an enforcement context when countries are asymmetric and have different bargaining powers.

[20] However, the case where the export sectors produce an externality is important in addressing some aspects of the debate surrounding the role of import lobbies. Therefore in section 6 we model the more general case to show that this simplifying assumption is not essential for the main results.

problem due to the presence of the negative production externality. If the externality is not purely domestic each of the governments will under-tax production from a global perspective.[21] Governments overcome these cooperation problems because they interact repeatedly and we now characterize the Nash equilibrium of the stage game that is repeated.

Governments choose taxes in the import sector to maximize the objective function given by eq.(3), taking the other country's policies as given.[22] We drop the commodity subscript, x, unless otherwise stated the policies refer to home's import sector. The results also apply to the foreign import sector since the countries are symmetric. The equilibrium Nash tariffs and e-taxes are implicitly given by the following joint solution:

$$\tau^N = \frac{p^w}{\varepsilon} \;\; ; \;\; e^N = \bar{\Psi}' - (\lambda^p - 1)\frac{S}{S'} \tag{5}$$

Where $\varepsilon \equiv p^w M^{*\prime}/M^*$ is the elasticity of the foreign excess demand curve evaluated at the equilibrium prices. In the absence of import lobbies, the optimal e-tax is a unit tax on production equal to the marginal cost of the externality, $\bar{\Psi}'$. However, if governments place extra weight on producers's welfare, $\lambda^p - 1$, the e-tax is lower than $\bar{\Psi}'$. The optimal tariff has the usual form, inversely related to the elasticity of the foreign excess demand. The tariff does not directly reflect the extra weight placed on producers since the producer tax is the most efficient instrument to transfer surplus to those producers.[23] Neither policy reflects the cross-border scope of the externality because foreign does not create an externality in home's import sector and home does not take into consideration the impact of its externality on the foreign country. Finally, note that generally the policies are jointly determined since both affect the world price as shown in section 3.1. This is true even before any strategic relation through linkage is present.[24]

To confirm the inefficiency of the Nash equilibrium we derive the global optimal policies.

[21] The production tax also creates a pecuniary externality, similar to the tariff, if a country has monopoly power in trade since it affects prices.

[22] The necessary first order conditions are given in appendix A.2.

[23] Although λ^p has no direct effect on τ^N it affects its equilibrium value through its effect on the e-tax which affects the world price.

[24] In the general equilibrium model implicit in the analysis there is a numeraire good, which maintains the balance of payments (BOP) equilibrium. This allows us to focus on individual sectors in isolation. Otherwise home's policies in sector x would affect the BOP and therefore foreign supply in the export sector, S_y^*, thus allowing home to control the foreign source of the externality with the existing instruments.

3.4 Global optimal policies

The first best policies are found by choosing the cooperative tariffs and e-taxes, τ^c and e^c that maximize the joint objective function. This is equivalent to maximizing home's objective function after imposing the symmetry condition, $W^c = W_x(\tau^c, e^c) + W_y(\tau_y^* = \tau^c, e_y^* = e^c)$. The first order conditions (in appendix A.2) yield the following:

$$\tau^g = 0 \ ; \ e^g = \bar{\Psi}' + \alpha\bar{\Psi}^{*\prime} - (\lambda^p - 1)\frac{S}{S'} \tag{6}$$

The Nash tariffs are inefficiently high and the e-tax is also inefficient since it does not account for the marginal cost of domestic production on the foreign country due to the externality. These results are intuitive if we consider that from the world's perspective there exists only one type of distortion, which is proportional to the production of each good in each country. So, all that is required to achieve the first best is a unit tax on production in each sector.

The difference between the Nash and global cooperative policies confirms that the externalities which countries must resolve arise due to market power in trade and the cross-border scope of the externality. Therefore the underlying motivation for cooperative agreements is independent of the existence of import lobbies. However, we will show that lobbies can alter the benefits of cooperation in an agreement and will therefore be important in the comparison of the linkage and no-linkage enforcement regimes.[25]

Given the symmetry across countries we can collapse the analysis into a 2-dimensional diagram. Starting at the Nash point, N, in figure 1 home's aggregate welfare increases if both home and foreign reduce their tariffs (or increase their e-taxes), reaching a maximum at the global cooperative solution, C. Thus W^{c1} represents a cooperative iso-welfare contour. The curves $\tau^r(e)$ and $e^r(\tau)$ denote the Nash first order conditions and are independent of the foreign policies because the latter are set in the export sector. The slope of these curves is positive if the cross-partial of domestic tariffs and e-taxes in the objective function is positive, that is if they are strategic complements.[26] In section 5 we derive the conditions under which

[25] A cooperative agreement on e-taxes may be necessary even if the production externality is purely domestic because the production tax has a pecuniary externality through its effect on world prices. The WTO's agreement on subsidies deals precisely with domestic policies and tries to prevent market access concessions from being eroded through the use of secondary trade barriers. See Copeland (1990) and Bagwell and Staiger (2001) on this issue.

[26] Strictly speaking policies should be called *strategic* complements only if they are set by different agents. In the simple model we abuse the term slightly and refer to two policies as strategic complements if their cross-effect in welfare is positive, e.g. $\partial^2 W/\partial\tau\partial e > 0$. In the general model we will have to consider interactions between domestic tariffs and foreign e-taxes in the same sector so the standard use of the term strategic complements applies then.

this holds.[27]

The complementarity between the policies implies that increases in cooperation in one policy decrease the marginal benefit of cooperation in the other. That is, reductions in domestic (foreign) tariffs reduce the marginal benefit of increasing domestic (foreign) e-taxes and vice-versa. This will be an important condition in determining if linkage creates enforcement, as we show below when we introduce the repeated game and self-enforcing agreements.

4 Effects of linking trade to non-trade agreements

4.1 Two enforcement regimes: linkage and no-linkage

Governments overcome cooperation problems because they interact repeatedly and can therefore enter into cooperative agreements. However, in the absence of a supra-national authority to punish violators, international agreements must be self-enforcing. Therefore the outcome of such agreements depends on the enforcement regime, that is on which policies are available to enforce cooperation. We now analyze the effects of two important enforcement regimes: linkage and no-linkage.

The central question we address is whether aggregate welfare under linkage is strictly higher than no-linkage and if a switch to linkage must result in a reallocation of enforcement across issues, as some opponents of linkage fear, or if this trade-off can ever be avoided through the creation of enforcement. A **reallocation of enforcement** occurs if greater cooperation on non-trade issues occurs at the expense of higher tariffs or vice versa. If reallocation is inevitable then linkage may not be worth pursuing in the case where targeted lump-sum transfers are unavailable and the gains from trade and e-issues are unevenly distributed within and/or across countries, an argument we model more specifically in section 5.3. However, if linkage leads to the **creation of enforcement**, that is if more cooperation in both policies becomes feasible, then one of the main objections to this regime is removed.[28]

[27] Appendix A.2 contains the slopes of $\tau^r(e)$ and $e^r(\tau)$. These curves are linear as depicted and therefore the Nash equilibrium unique if Ψ is quadratic. Both curves intersect the vertical axis below C since at C a lower domestic e increases domestic welfare, similarly for higher τ. Note however that it is possible that e^r and τ^r intersect at a point such that $e^N > e^g$. However, this can only occur if the complementarity is sufficiently strong to offset the direct effects of the variables and α is small. Our discussion will focus on the empirically relevant case illustrated in figure 1.

[28] Considering the case where the gains from trade and e-issues are unevenly distributed *across* countries may appear odd in our symmetric model. Less so if one of the countries is the U.S. and the other "country" is the European Union. The

Cooperative self-enforcing agreements are well characterized by certain repeated games. The stage game that is indefinitely repeated is the simultaneous move one-shot Nash game previously described and we assume that each government observes the other governments actions at the end of each period.[29] We focus on symmetric, stationary Nash equilibria and require that they be subgame perfect. We adopt the simplest trigger strategies that maintain such equilibria–infinite Nash reversion–the exact trigger depends on whether the policies are linked or not.[30] The payoffs are given by the objective functions, W, discounted by each government at the similar rate $\delta = \overline{\delta}\rho$ where $\bar{\delta}$ reflects a proper discount factor and ρ the probability that the game continues for one more period. We now analyze the trigger strategies and equilibria under linkage.

4.1.1 Linkage

Under a **linkage regime** non-cooperation in *either* issue can be met with punishment in *either* or *both* issues.[31] That is, a government implements the cooperative level of a particular policy in period t as long as, in all previous periods, the history of play for all players in that policy was one of cooperation. Otherwise the government reverts to the Nash levels in *either* or *both* linked policies. In the most cooperative linkage agreement, if a government decides to deviate in any policy it finds it optimal to deviate in all linked policies (Abreu 1988). The reason for this is that the most cooperative policies will be sustained by the most painful punishment which entails punishment in both policies. Since we assume countries are symmetric they will prefer the most cooperative policies. This implies that a deviation only in e-taxes, for example, will not be observed because, after a deviation in e-taxes, a government knows it will be punished in both e-taxes and tariffs in the following period, so it deviates in tariffs also.[32]

European Commission corresponds to the "government" in our model and its objective function aggregates the different preferences *across* E.U. countries over trade and e-issues.

[29] In the context of tariff setting, self-enforcing agreements have been represented as repeated games first by Jensen and Thursby (1983) in finite time and extended by Dixit (1987) to infinitely repeated game where cooperative tariffs are sustained by the threat of Nash reversion. More recently this framework has been used to study trade agreements (Bagwell and Staiger, 1990 and Riezman, 1991) and environmental issues (Barret, 1994).

[30] More severe punishment schemes could potentially be used to attain higher levels of cooperation (Abreu 1988).

[31] In his historical review of issues linked in the framework of the GATT the former director of legal affairs of the WTO states that "...if market access and the protection of endangered species were to be successfully linked in WTO negotiations, trade concessions could be withdrawn to protect an endangered species and vice-versa." Roessler (1998, p. 226). See also footnote 4.

[32] The one period gain from deviating in either policy can not exceed the gain to deviating in both by the definition of a Nash best response. Stating that a government knows it will be punished in both policies implicitly assumes that the threat of punishment in both policies is a credible one. This threat achieves the most cooperative policies. However, ex-post the threat may not be realized. To deal with this issue we would have to introduce renegotiation proofness. We do not believe weak renegotiation proofness (Farrel and Maskin 1989) changes the qualitative nature of the results. It typically reduces the feasible degree of cooperation within linkage or no-linkage relative to the infinite Nash reversion solution given that the credible

In sum, although under linkage governments can deviate in any combination of policies and punish any deviation using either tariffs, e-taxes or both, it is not optimal for them to pursue deviations in individual policies. As a result, we need only consider three situations: cooperation, deviation or Nash in all policies. Recalling that symmetry allows us to express everything in terms of the home country variables the period payoffs for each of these cases is:

$$\begin{aligned} W^{C\tau e}(\tau_x^c, e_x^c) &\equiv W_x(\tau_x^c, e_x^c) + W_y(\tau_y^{*c} = \tau_x^c, e_y^{*c} = e_x^c) \\ W^{D\tau e}(\tau_x^c, e_x^c) &\equiv W_x(\tau_x^N, e_x^N) + W_y(\tau_y^{*c} = \tau_x^c, e_y^{*c} = e_x^c) \\ W^{N\tau e} &\equiv W_x(\tau_x^N, e_x^N) + W_y(\tau_y^{*N} = \tau_x^N, e_y^{*N} = e_x^N) \end{aligned} \tag{7}$$

In these expressions, (τ_x^c, e_x^c) denotes the policy values during a period of cooperation in both policies and (τ_x^N, e_x^N) the Nash values. The period gain from cooperation, $\omega^{\tau e}$, represents the difference between the cooperative and the Nash payoff that otherwise results. The period gain from deviation, $\Omega^{\tau e}$, is given by the difference between the deviation and cooperation payoffs.

$$\omega^{\tau e}(\tau_x^c, e_x^c) \equiv W^{C\tau e} - W^{N\tau e} \tag{8}$$

$$\Omega^{\tau e}(\tau_x^c, e_x^c) \equiv W^{D\tau e} - W^{C\tau e} \tag{9}$$

In choosing the cooperative policies, governments are constrained by the fact that the agreement must be self-enforcing, which implies that the following incentive constraint must be satisfied each period:

$$\Omega^{\tau e}(\tau_x^c, e_x^c) \leq \frac{\delta}{1-\delta}\omega^{\tau e}(\tau_x^c, e_x^c) \tag{10}$$

This condition, henceforth $IC^{\tau e}$, states that, for each country, the net gain from deviating in any one period must not exceed the discounted value of the net benefit from future cooperation. If governments are sufficiently patient $IC^{\tau e}$ does not bind at the global maximum. We assume that the discount factor is small enough that this incentive constraint binds at the global optimal policies in eq.(6) but large enough that cooperation always improves on the Nash values. This is the empirically relevant case since we do not

punishments are less severe. However, our interest is on the solution of linkage relative to no-linkage, thus if renegotiation has a similar effect on both regimes then our results would be unchanged.

observe full cooperation in either trade or e-policies.

4.1.2 No-linkage

In a **no-linkage regime** governments retaliate policy-by-policy, so, for instance, their response to a deviation in e-taxes is to revert to Nash in e-taxes but not in tariffs. If a deviation occurs in more than one policy then the response is to revert to Nash in each of the policies deviated in. Thus, governments have unconstrained deviation possibilities but constrained punishment possibilities. This corresponds to the current regime for environmental and labor standards in relation to the trade agreements in the context of the WTO.

The payoffs under cooperation, deviation and punishment in all policies are defined by eq.(7), as before. When the deviation and punishment occur only in the trade or e-policy we have the following payoffs (after imposing symmetry):

$$
\begin{aligned}
W^{D\tau}(\tau_x^c, e_x^c) &\equiv W_x(\tau_x^r, e_x^c) + W_y(\tau_x^c, e_x^c) \\
W^{De}(\tau_x^c, e_x^c) &\equiv W_x(\tau_x^c, e_x^r) + W_y(\tau_x^c, e_x^c) \\
W^{N\tau} &\equiv W_x(\tau_x^r(e_x^{n\tau}), e_x^{n\tau}) + W_y(\tau_x^r(e_x^{n\tau}), e_x^{n\tau}) \\
W^{Ne} &\equiv W_x(\tau_x^{ne}, e_x^r(\tau_x^{ne})) + W_y(\tau_x^{ne}, e_x^r(\tau_x^{ne}))
\end{aligned}
$$

Figure 2 clarifies at which points the payoff is being evaluated. Start at an arbitrary cooperative point such as NL. From NL a deviation in tariffs places home at D_x^τ with domestic tariffs given by the Nash reaction evaluated at the original cooperative e-tax and foreign policies at (τ_x^c, e_x^c).[33] Partial cooperation follows a deviation in tariffs. That is, countries stop cooperating in tariffs but continue to cooperate in e-taxes so that in the period following a deviation in tariffs the new equilibrium value for the e-taxes is found at N^τ, where countries choose e^c to maximize cooperative welfare given tariffs are set at τ^r. Graphically this corresponds to the tangency point of W^c and τ^r, if the IC for the e-tax does not bind.[34]

[33] Since the equilibrium values of the tariffs and e-policies are not independent a deviation in one policy must eventually lead to a change in the equilibrium value of the other. We assume that if this adjustment were to happen simultaneously with the deviation then foreign would consider that home deviated in the two policies. Therefore, in the period that home deviates in tariffs (e-taxes) it does not simultaneously adjust the level of its e-tax (tariff), unless it wishes to deviate in all policies.

[34] If it does bind then N^τ is given by the intersection of the e-tax iso-incentive constraint and τ^r. The assumption that, when there is only partial cooperation in policy k, countries first choose policy k cooperatively and then set the other policy is

The period gains from joint cooperation and deviation are still given by eqs.(8, 9). The gains from cooperation and deviation in tariffs, assuming cooperation in e-taxes, are $\omega^{\tau}\ (.) \equiv W^{C\tau e} - W^{N\tau}$and $\Omega^{\tau}(.) \equiv W^{D\tau} - W^{C\tau e}$ respectively. The gains from cooperation and deviation in e-taxes are defined analogously. Under no-linkage governments are subject to three incentive constraints which now reflect the possibility of deviation in the tariff or e-tax individually, or in both simultaneously.

We can now compare the solutions under the alternative enforcement regimes.

4.2 Weak aggregate welfare improvement

In both enforcement regimes the governments' problem is to choose the cooperative levels of tariffs and e-taxes that maximize their joint objective function subject to the relevant set of incentive constraints. Given the symmetry of the model it is sufficient to focus on one country and, since the problem is stationary it is equal each period. Thus the solution set under linkage and no-linkage is respectively:

$$\Phi^{l} \equiv \arg\max_{\tau_x^c, e_x^c} \{\omega^{\tau e}(\tau_x^c, e_x^c) : IC^{\tau e}\} \tag{11}$$

$$\Phi^{nl} \equiv \arg\max_{\tau_x^c, e_x^c} \{\omega^{\tau e}(\tau_x^c, e_x^c) : IC^{\tau e}, IC^{\tau}, IC^{e}\} \tag{12}$$

Since the objective function is the same and under no-linkage an extra two incentive constraints must be met we have the following:

Proposition 1 *:*

All cooperative tariff and e-tax vectors feasible under no-linkage are also feasible under linkage. Thus, in a symmetric equilibrium, aggregate welfare under linkage is never lower than under no-linkage for either country.

The key to this result is that in a no-linkage regime a government can deviate in either or all policies, so there are unconstrained deviation possibilities but constrained punishment possibilities since only the policies deviated in are subject to punishment. By contrast, under linkage there are unconstrained deviation

the most reasonable one here because countries can always change the policy being set non-cooperatively. See also Copeland (1990) on this point.

possibilities and unconstrained punishment possibilities. Therefore, under linkage, we can always find punishments at least as painful as under no-linkage. This was the basic intuition underlying the results in BW in the context of multimarket collusion when markets are unrelated and their prices independent before linkage.

To better understand proposition 1 in the context of the trade model, we first consider a benchmark case where **tariffs and e-taxes are independent**, i.e. $\partial^2 W/\partial\tau_x\partial e_x = \partial^2 W/\partial\tau_y^*\partial e_y^* = 0$. As we show in section 5 this represents a special case of our model where the pecuniary and non-pecuniary strategic effects are exactly offsetting. This means that the e-policy can be independent of the tariff, according to the definition above, but the e-issue is still trade-related, since changes in tariffs continue to affect supply and thus the level of the externality directly. Independence can *also* represent situations where the e-issue is not trade-related so that payoffs for the policies can be written separately, e.g. tariffs on automobiles and e-taxes on power plants or on a non-traded good.[35] We now contrast what is feasible under linkage and no-linkage.

In figure 3a the points N and C represent the Nash and full cooperation outcomes previously found. The horizontal line, $\overline{IC}^e$, depicts the incentive frontier for the e-tax, that is the combinations of the policies that maintain the gain from deviation equal to the discounted gain from cooperation in e-taxes. Values of the e-tax between $\overline{IC}^e$ and the Nash level satisfy this incentive constraint. When policies are independent the gains from cooperation and deviation in e-taxes do not depend on tariff levels and thus $\overline{IC}^e$ is horizontal. For a similar reason $\overline{IC}^\tau$ is vertical.[36]

Recall that the linkage IC, in eq.(10), requires the gains from deviation in both issues not to exceed the discounted gains from cooperation in both issues. This is represented by the ellipse labelled $\overline{IC}^{\tau e}$, which intersects both the tariff and e-tax incentive frontiers at NL for the following reason. At NL the gains from deviation in tariffs equal the gains from cooperation in tariffs and similarly for e-taxes, therefore the gain from deviating in both policies must also equal the gain from cooperating in both if the policies are independent (we show this formally in section 4.4). Moreover, to understand why $\overline{IC}^{\tau e}$ is upward sloping at

[35] Clearly, depending on the general equilibrium setting and the particular non-traded good the tariff on automobiles and the e-tax may not be independent.

[36] In appendix A.2 we derive the slopes of the different incentive frontiers. We do not draw the trivial incentive frontiers for the individual policies parallel to the ones depicted but going through N. These ensure that the cooperative policies under no-linkage are bounded between NL and N. The linkage incentive frontier must therefore cross at N as well as directly above it and to its left at the intersection of those trivial incentive frontiers with the ones drawn.

NL, start at that point on the linkage incentive frontier. An increase in e^c implies that the gain to deviating in the e-tax now exceeds the gain to cooperating, violating the linkage IC. But if at the higher e-tax both countries increase τ^c towards its Nash level, the incentive to deviate in the e-tax remains unchanged, due to independence, but the incentive to deviate in tariffs and therefore the overall incentive to deviate is lowered. Thus, at a point such as L the linkage IC must again be satisfied. The shaded area in figure 3a represents the feasible policies under no-linkage which are a subset of those feasible under linkage, as stated in proposition 1.

Proposition 1 does not ensure that aggregate welfare under linkage is strictly higher than under no-linkage. Moreover, proposition 1 has nothing to say on whether a regime switch to linkage leads to a reallocation of enforcement and consequently whether linkage will lead to lower cooperation in tariffs or e-taxes. These are the questions we now address.

4.3 Strict aggregate welfare improvement via the reallocation of enforcement

To answer whether a switch to linkage leads to a reallocation of enforcement when policies are independent and which direction it goes we make use of the following definitions. The slope of the linkage incentive frontier in figure 3a represents the marginal change in tariffs required to maintain incentive compatibility given a marginal change in e-taxes, so we refer to this slope as the **marginal rate of substitution in enforcement**. We say that **tariffs are easier to enforce than e-taxes** if, under no-linkage, the discount factor required to sustain the global optimum in tariffs, δ_τ, is lower than δ_e. Thus δ_τ is defined by the individual policy IC evaluated at the global optimum for tariffs, $\Omega^\tau(\tau^g,.) = \frac{\delta_\tau}{1-\delta_t}\omega^\tau(\tau^g,.)$; δ_e is similarly defined. With these definitions, we can state the following proposition:

Proposition 2 *(Reallocation of enforcement):*

(a) If tariffs and e-taxes are independent and their MRS in cooperative welfare and enforcement are not equalized under no-linkage, then a switch to linkage leads to a reallocation of enforcement.

(b) If tariffs are easier to enforce than e-taxes under no-linkage, then linkage lowers cooperation in tariffs and raises cooperation in e-taxes for all $\delta \in [\ \delta_\tau\ , \delta_e)$ and some $\delta < \delta_\tau$. The opposite is true if e-taxes are easier to enforce.

Proof: See appendix A.1.

The first part of the proposition is illustrated in figure 3a. First, if the discount factor is low enough, i.e. if $\delta \leq \min(\delta_\tau, \delta_e)$ then both of the individual IC bind at the no-linkage solution, NL. The FOCs for the linkage solution, in eq.(11), require that the MRS of the policies in welfare and enforcement be equalized. Thus, if at NL the cooperative iso-welfare curve is not tangent to the incentive frontier then linkage leads to an aggregate welfare improvement by eliminating the individual IC. The regime switch requires a reallocation of enforcement because, as we explain above, $\overline{IC}^{\tau e}$crosses NL with a positive slope.[37]

To understand the second part of the proposition suppose that tariffs are easier to enforce than e-taxes. Moreover, assume that free trade is just feasible under no-linkage so that, in figure 3a, $\overline{IC}^{\tau}$ would coincide with the vertical axis. The no-linkage solution is then found at the the intersection of $\overline{IC}^{e}$ with the vertical axis where, for the arguments previously given, $\overline{IC}^{\tau e}$ crosses with a strictly positive slope. At this no-linkage solution a small increase in cooperative tariffs has no first order effect on welfare (from the FOC for the first best tariff, τ^g) and creates slack in the overall IC. This slack can be reallocated towards higher cooperative e-taxes under linkage. Since the increase in e-taxes creates a first order welfare gain, this reallocation is not just feasible but also optimal. By continuity of the functions there must also exist some δ lower than δ_τ for which this is true.

Tariff concessions have relatively more excludable benefits than some e-issues and it is therefore likely that it is easier to cooperate in tariffs. If a country does not accept the WTO rules then other countries will not extend tariff concessions to it. More importantly, that country does not benefit directly from tariff concessions among other countries so it has little incentive to free-ride on other countries' agreements. The opposite occurs with environmental policies, for example.[38] The benefits from reductions in greenhouse gases agreed to between countries A and B also benefit C thereby lowering C's incentive to cooperate.[39]

[37] In figure 3a we assume that W^c is globally concave in τ^c, e^c. Otherwise there may exist multiple linkage equilibria, which raise the possibility that the MRS in welfare and enforcement are equalized at NL but that linkage still leads to reallocation and an aggregate welfare improvement. So the non-equalization of the MRS at NL is sufficient but not necessary for reallocation of enforcement.

[38] Barret (1994). The WTO report on the environment is clear on this:

> "Another possible reason for political foot-dragging [on environmental policy] is that governments seek to free ride in the context of weak political institutions at the international level, including weak enforcement mechanisms. Indeed one reason why the WTO has become the focal point for environmental disputes is that the WTO has an integrated adjudication mechanism backed by trade sanctions as the ultimate enforcement tool." (1999, p.7)

[39] If the e-policy is not trade-related then the discount factor for the tariff incentive constraint, $\overline{\delta}\rho_\tau$, can be higher than the one for the e-tax, $\overline{\delta}\rho_e$, if the probability of continuing the tariff game, ρ_τ, exceeds that of the e-tax, ρ_e. This is an

If tariffs are indeed easier to enforce than e-taxes, then the analysis above provides a formal justification in terms of enforcement for the reallocation concerns put forth by opponents of linkage within the WTO. In our model when tariffs are easier to enforce a switch to linkage creates at least one group of losers: consumers of importable goods, who face higher consumer prices due to higher tariffs and e-taxes. In the absence of lump-sum transfers this redistribution can imply that linkage is not adopted, as we discuss below. However, the analysis applies to the linkage of independent policies and this is crucial in generating the trade-off in enforcement. Independence is a limit case when the e-issue is trade-related, as in our model. Therefore we must analyze the more general case when the linked policies are not independent.

4.4 Strict aggregate welfare improvement via the creation of enforcement

If the policies are not independent can the linkage IC hold with slack at the no-linkage solution, that is can linkage create enforcement? We now derive the conditions to answer this question in the affirmative so that linkage can always yield a strictly higher aggregate welfare than no-linkage. Moreover, because increased cooperation in both tariffs and e-taxes becomes feasible no trade-off in cooperation across the issues is necessary for the welfare improvement.

Suppose we find the optimal (and feasible) cooperative tariffs and e-taxes under no-linkage, Φ^{nl}. Then, linkage can sustain more cooperation in both policies if the linkage IC does not bind at Φ^{nl}. A *sufficient* condition for this is that the following inequalities hold at Φ^{nl}:[40]

$$\Omega^{\tau e} \quad \leq \quad \Omega^{\tau} + \Omega^{e} \tag{13}$$

$$\omega^{\tau e} \quad \geq \quad \omega^{\tau} + \omega^{e} \tag{14}$$

with at least one being strict. These are sufficient since they imply that:

$$\Omega^{\tau e} \leq \Omega^{\tau} + \Omega^{e} \leq \frac{\delta}{1-\delta}(\omega^{\tau} + \omega^{e}) \leq \frac{\delta}{1-\delta}\omega^{\tau e} \tag{15}$$

alternative reason for why cooperation in tariffs is easier to enforce. For certain environmental problems $\rho_\tau > \rho_e$ is plausible since technological progress will eliminate the problem, e.g. moving from coal to solar powered plants.

[40] This condition follows the approach in Spagnolo (1999a) for the case of independent stage game payoffs. We contrast our approach and results below.

with the middle inequality resulting from the fact that Φ^{nl} is implemented and therefore self-enforcing. Using the definitions for the different gains from cooperation and deviation we can rewrite eq.(13) and eq.(14) as:

$$W_x^{C\tau e} + W_x^{D\tau e} \quad \leq \quad W_x^{D\tau} + W_x^{De} \tag{16}$$

$$(W_x^{C\tau e} + W_x^{N\tau e}) + (W_y^{C\tau e} + W_y^{N\tau e}) \quad \leq \quad (W_x^{N\tau} + W_x^{Ne}) + (W_y^{N\tau} + W_y^{Ne}) \tag{17}$$

The proposition stating the conditions for the creation of enforcement relies on two lemmas establishing the conditions for eq.(13) and eq.(14) to hold. To do so we recall the definition of supermodularity. Intuitively supermodularity states that pairing the lowest strategies (e.g. low tariffs with low e-taxes) and the highest ones yields a higher payoff then when other combinations of those strategies is played. Therefore it captures the idea of complementarity between the variables.

Definition 1 *Supermodularity: A function $W(\mathsf{s})$ $R^n \rightarrow R$ is (strictly) supermodular in $\mathsf{s} \in S$ if:*

$$W(\mathsf{s}) + W(\tilde{\mathsf{s}}) \ (<) = W(\max(\mathsf{s}, \tilde{\mathsf{s}})) + W(\min(\mathsf{s}, \tilde{\mathsf{s}})) \quad \forall \ (\mathsf{s}, \tilde{\mathsf{s}}) \in S$$

Where the min and max operators apply pair-wise to each component of the vectors.

Lemma 1 *(Relative gains from deviation):*

If the objective function, W, is (strictly) supermodular in the linked domestic policies then $\Omega^{\tau e}(<) = \Omega^{\tau} + \Omega^{e}$.

Proof: $\Omega^{\tau e} \leq \Omega^{\tau} + \Omega^{e}$ is equivalent to eq.(16). Suppose NL in figure 2 represents the no-linkage solution. Then eq.(16) requires the sum of welfare in sector x evaluated at NL and N to be no higher than the sum of welfare at D^{τ} and D^{e}. The (strict) supermodularity of W in (τ_x, e_x) ensures that $W_x^{C\tau e} + W_x^{D\tau e}(<) = W_x^{I\tau} + W_x^{Ie}$, moreover $W_x^{I\tau} + W_x^{Ie} \leq W_x^{D\tau} + W_x^{De}$ since τ^r and e^r are the best responses to e^c and τ^c respectively. ¤

To understand the intuition behind lemma 1 first note that a continuously differentiable function is strictly supermodular in (τ_x, e_x) if and only if $\partial^2 W/\partial\tau_x\partial e_x > 0$.[41] So, strict supermodularity in the domestic linked policies reduces to a requirement that those policies are strategic complements. Assume this is the case, then a country incurs an extra cost when it deviates jointly, that is when it increases tariffs and reduces e-taxes, that is not present if it deviates only in one individual policy. When tariffs are increased the marginal benefit of deviating in e-taxes, i.e. decreasing them, falls. Thus linking, by "forcing" deviation in both policies, lowers the temptation to deviate in any given policy.[42]

Lemma 1 builds upon a result in Spagnolo (1999a) but differs in two respects. In Spagnolo (1999a) there exist two issues each with an independent prisoner's dilemma structure and material payoffs Π_1 and Π_2 which take different values depending on whether agents cooperate or not. These payoffs are evaluated according to $U(\Pi_1, \Pi_2)$ and it is shown that the gains from deviation under linkage are lower than the sum of the gains from deviation if U is submodular in (Π_1, Π_2). The first, trivial, difference occurs because, in our model, the deviations in the linked policies occur in opposite directions (higher tariffs, lower e-taxes); therefore, we require supermodularity as opposed to submodularity. The second, and more substantive, difference occurs because an important set of issues linked are intrinsically related and therefore we cannot write Π_1 and Π_2 separately. Because in our model the linked issues are intrinsically related, lemma 1 also shows that the "movement" from I^τ (I^e) to D^τ (D^e), in figure 2, is welfare improving. Such a movement would not take place if the issues were unrelated and the policies set independently during the stage game.

For ease of exposition we first establish a lemma for the gains from cooperation using the following **partial cooperation condition**: $W^{I\tau} + W^{Ie} \leq W^{N\tau} + W^{Ne}$. This condition, depicted in figure 2, states that the sum of the welfare level under partial cooperation in tariffs (W^{cNe}) and e-taxes $(W^{cN\tau})$ is no less than the sum of welfare levels evaluated at I^e and I^τ. Below we provide sufficient conditions for this condition to hold.[43]

Lemma 2a *(Relative gains from cooperation):*

If the objective function, W, is (strictly) supermodular in the linked domestic and foreign policies and the

[41] Topkis (1979).

[42] The gain from deviating under linkage is always at least as large as *either* of the gains from deviating in tariffs or e-taxes individually. This occurs because deviation under linkage requires countries to play their best response in both policies.

[43] Note that $W^{I\tau} + W^{Ie} \leq W^{N\tau} + W^{Ne}$ is different from $W_x^{I\tau} + W_x^{Ie} \leq W_x^{D\tau} + W_x^{De}$. The latter expression always holds since it is evaluated at $D\tau$ (De) home is setting its tariff (e-tax) at the best response.

partial cooperation condition holds then $\omega^{\tau e}(>) \geq \omega^{\tau} + \omega^{e}$.

Proof: $\omega^{\tau e} \geq \omega^{\tau} + \omega^{e}$ is equivalent to eq.(17). Suppose NL in figure 2 represents the no-linkage solution. Then eq.(17) requires that the sum of welfare at NL and N is no higher than the sum of welfare at N^{τ} and N^{e}, in both the x and y sectors. If W is (strictly) supermodular in (τ_x, e_x) and (τ_y^*, e_y^*) then $W^{C\tau e} + W^{N\tau e}(<) = W^{I\tau} + W^{Ie}$. The partial cooperation condition ensures that $W^{I\tau} + W^{Ie} \leq W^{N\tau} + W^{Ne}$.¤

The basic intuition for this result is similar to that for lemma 1. We require supermodularity in the domestic import policies and also in the foreign policies in the export sector. The intuition for the extra complementarity condition is the following. Suppose $\partial^2 W / \tau_y^* \partial e_y^*$ is zero, then a simultaneous move to higher foreign tariffs and lower e-taxes (i.e. the punishment phase under linkage) has the same welfare effect as the sum of the individual punishments. However, if the cross-effect of these policies in domestic welfare is positive, then a *simultaneous* increase in foreign tariffs and decrease in e-taxes (point N in figure 2) carries an extra cost which is not present *if* each of the punishments were carried out individually at points I^{τ} and I^{e}. This complementarity increases the severity of the Nash punishment under linkage.

The issue that arises when the linked issues are intrinsically related is that the Nash phase in tariffs occurs at N^{τ} not at I^{τ} and for e-taxes it occurs at N^{e} not at I^{e}, as we show in figure 2.[44] It is this "extra movement" from I^{τ} to N^{τ} and I^{e} to N^{e} that the partial cooperation condition highlights and which suggests that supermodularity *may* not be sufficient to establish the relative gains from cooperation. However, we now show that supermodularity is in fact sufficient for establishing the relative gains from cooperation for a non-trivial set of objective functions.

Lemma 2b *(Relative gains from cooperation):*

If the objective function, W, is supermodular in the linked domestic policies and strictly supermodular in the linked foreign policies then $\omega^{\tau e} > \omega^{\tau} + \omega^{e}$. Moreover, there exist objective functions, W, strictly supermodular in both the linked domestic and foreign policies such that $\omega^{\tau e} > \omega^{\tau} + \omega^{e}$.

Proof: In lemma 2a we show that if W is (strictly) supermodular in (τ_x, e_x) and (τ_y^*, e_y^*) then $W^{C\tau e} +$

[44] We also discuss this issues in page 17. This constitutes another important difference relative to earlier work. In the case of independent payoffs, studied by Spagnolo (1999a), the readjustment of policies after a deviation does not arise because the policies on different issues are not related during the stage game. In that case I^{τ} and I^{e} exactly coincide with N^{τ} and N^{e} in figure 2 and the partial cooperation condition is trivially satisfied with equality.

$W^{N\tau e}(<) = W^{I\tau} + W^{Ie}$. Thus we now need only show that under the conditions in lemma 2b the partial cooperation condition holds. W is supermodular in (τ_x, e_x) iff $W_{x\tau e} = 0$ (given that W is continuous and twice differentiable). If $W_{x\tau e} = 0$ then, in figure 2, τ^r and e^r are respectively vertical and horizontal and therefore $\tau^r(e^{n\tau}) = \tau^N$ and $e^r(\tau^{ne}) = e^N$. This implies that I^τ and N^τ (I^e and N^e) share the same tariff, τ^N, (e-tax, e^N). Now, if the individual IC for the e-tax (tariff) holds at I^τ (I^e), which we show in appendix A.1 is true, then I^τ (I^e) is feasible when countries choose N^τ (N^e). Therefore $W^{I\tau} + W^{Ie} \leq W^{N\tau} + W^{Ne}$, moreover this inequality is strict if W is strictly supermodular in (τ_y^*, e_y^*) since then the optimal cooperative e-tax (tariff) at I^τ (I^e) differs from that at NL.

To show the existence of W with $W_{x\tau^* e^*} > 0$ and $W_{x\tau e} \in (0, \varepsilon]$, i.e. strictly supermodular in (τ_y^*, e_y^*) and (τ_x, e_x), such that $\omega^{\tau e} > \omega^\tau + \omega^e$ note that $\lim_{\varepsilon -> 0^+} e^r(\tau^{ne}) = e^N$ and $\lim_{\varepsilon -> 0^+} \tau^r(e^{n\tau}) = \tau^N$. Given that W is continuous, a $\varepsilon > 0$ exists such that $W^{I\tau} + W^{Ie} \leq W^{N\tau} + W^{Ne}$ and therefore, from lemma 2a, $\omega^{\tau e} > \omega^\tau + \omega^e$ follows.¤

The basic intuition for the first part of the lemma is that if the objective function is supermodular in domestic policies then the deviation and Nash levels of a given policy coincide. However, the strict supermodularity of the domestic government's objective in the foreign policies implies that when foreign increases its tariff, home would like foreign to increase its e-tax as well. So for example, in figure 2 the individual best-response functions would be perpendicular and intersect at N. In this case the tariffs are identical at both I^τ and N^τ but, at N^τ, countries have optimally chosen the level of the cooperative e-tax for that tariff. A similar reasoning explains why welfare at I^e is strictly lower than at N^e and consequently why the partial cooperation condition is strictly satisfied. Given that the partial cooperation condition holds strictly when W is strictly supermodular in foreign policies and supermodular in domestic policies, it also holds for some positive levels of complementarity between the domestic policies, as shown in the second part of the lemma.

With lemmas 1 and 2b and the following definition we state the main proposition of this section.

Definition 2 *Creation of enforcement: Linkage creates enforcement if* $\Omega^{\tau e} < \frac{\delta}{1-\delta}\omega^{\tau e}$ *at* Φ^{nl}, *that is if it can enforce both lower tariffs and higher e-taxes than no-linkage.*

Proposition 3 *(Creation of enforcement):*

If the objective function, W, is supermodular in the domestic policies and strictly supermodular in the foreign policies then linkage creates enforcement. Moreover, there exist objective functions, W, strictly supermodular in both domestic and foreign policies such that linkage creates enforcement.

Proof: Follows directly from lemmas 1 and 2b and eq.(15).

The conditions above are sufficient for linkage to yield a strictly higher welfare than no-linkage such that no trade-off in cooperation across the issues is necessary. We illustrate this in figure 3b. At the no-linkage equilibrium, NL, the linkage IC holds with slack so that more cooperation in both tariffs and e-taxes is feasible and, in this case, also optimal, as shown by the linkage solution, L.[45]

This proposition does not rule out the possibility that the optimal linkage solution entails a reallocation of enforcement, which may happen if there is a strong asymmetry in the enforceability of the policies. However, the key point is that the creation of enforcement allows for a strictly higher welfare level without a need for the reallocation of enforcement since the direction of change for the cooperative policies is (locally) unrestricted. This can be an important determinant of whether governments actually switch to linkage, as we discuss in the next section.

Proposition 3 can be applied to other economic problems with a similar structure where *all* of the following are present: (i) a cooperation problem over multiple issues; (ii) agents interact repeatedly and resort to self-enforcing contracts and (iii) the linked issues are related so that the instruments that address them are generally not set independently of each other during the stage game, even before any linkage considerations. This third characteristic distinguishes proposition 3 from existing results in the literature that apply to situations in which the issues are not intrinsically related and thus the policies are set independently of each other during the stage game.[46] The extra set of economic problems which proposition 3 allows us to analyze is quite important and in the conclusion we discuss some specific examples.

[45] We derive the slopes of the incentive frontiers in appendix A.2. It is now clear why, when policies are independent, the linkage IC must cross at the intersection of the individual IC as in figure 3a. This occurs because at the no-linkage solution under independence we have $\Omega^{\tau e} = \Omega^{\tau} + \Omega^{e} = \frac{\delta}{1-\delta}(\omega^{\tau} + \omega^{e}) = \frac{\delta}{1-\delta}\omega^{\tau e}$. The middle equality results from the binding of each individual IC at NL. The outside equalities result from lemmas 1 and 2 when supermodularity is not strict.

[46] We refer in particular to the results in Bernheim and Whinston (1990) and Spagnolo (1999a) discussed in the literature review.

5 Supermodular objective functions and the adoption of linkage

We now show when the supermodularity conditions that are sufficient for the creation of enforcement hold in the model described in section 3 and when governments may optimally decide to switch to linkage. Our objective is to give guidelines as to what "types" of e-issues (i.e. with a national or a cross-border scope; highly valued or not) and countries (developed or developing; with powerful import lobbies or not) satisfy the complementarity conditions. We choose to analyze these dimensions, the scope of the spillover, the weight placed on the non-trade issue and power of the import lobbies, because of their importance in policy debates of linkage in the context of the WTO. After characterizing the countries and issues for which linkage creates enforcement we analyze how changes in those characteristics help explain why linkage has become more important. Finally, we model the governments' decision to switch to linkage explicitly in two simple extensions and show that even if aggregate welfare under no-linkage is strictly lower not all countries switch to linkage.

5.1 Strategic complementarity of domestic tariffs and e-taxes

The first condition we analyze is whether own tariffs and e-taxes are strategic complements. This would imply that increased domestic tariff protection induces higher domestic standards in the import sector. Differentiating the objective function in eq.(3) we have the following condition for home's import sector: $W_\tau = (1 + p^w_\tau)(\tau M' + (e - \bar{\Psi}')S') - p^w_\tau M + \Pi_\tau$, where the subscript for the good (x) is dropped and subscripts now denote partial derivatives (unless the function has only one argument in which case a prime is used). The first term, $(1 + p^w_\tau)$, represents the positive effect of the tariff on domestic prices. The term $\tau M'$ represents the fall in tariff revenue due to lower imports, eS' represents the increase in e-tax revenue due to higher production, $\bar{\Psi}'S'$, the increase in externality cost and $-p^w_\tau M$ refers to the change in the terms of trade (TOT), which is positive because the country imports this good. The final term, $\Pi_\tau = (\lambda^p - 1)(1 + p^w_\tau)S$, reflects the presence of import lobbies, if governments place an extra weight, $\lambda^p - 1$, on import producers relative to consumers then an increase in tariffs will have an extra benefit in the form of increased producer surplus. The cross-derivative is then:[47]

$$W_{\tau e} = \underset{+}{(1 + p_\tau^w)S\,'} + \underset{+}{(-p_\tau^w M_e)} + \underset{+}{(-\bar{\Psi}_{\tau e})} + \underset{-}{\Pi_{\tau e}} \tag{18}$$

The first term represents a strategic revenue effect; when domestic supply expands due to higher tariffs the marginal benefit of increasing e-taxes increases, so this effect is positive. The second term represents a strategic TOT effect and is unambiguously positive; higher e-taxes expand home imports, which is more valuable at the lower world prices delivered by the increased domestic tariff. The strategic externality effect, $-\bar{\Psi}_{\tau e}$, can be decomposed into two multiplicative factors, the change in the marginal cost of the externality due to higher e-taxes, $-(p_e^w - 1)S\,'\lambda^{\Psi}\Psi''$, and the domestic tariff effect on the externality, $(1 + p_\tau^w)S\,'$. The latter factor is positive since higher tariffs increase the domestic supply and thus the level of the externality. The domestic e-tax effect on the externality $(p_e^w - 1)S\,'$ is negative. Thus the strategic externality effect is positive since the loss function is convex.

The last term in eq.(18) is the strategic lobby effect, $\Pi_{\tau e} = (\lambda^p - 1)(p_e^w - 1)(1 + p_\tau^w)S\,'$, it is unambiguously negative. It captures a basic intuition, likely to be present in other models with import competing lobbies. Namely, when production expands due to tariff protection, the marginal benefit of increasing direct taxes on the producers (the e-tax) is lower because it affects a higher volume of production.

With the following definition we can summarize the conditions for complementarity between domestic tariffs and e-taxes. We say that a country has **powerful import lobbies** if $\lambda^p \geq \bar{\lambda}^p$, where $\bar{\lambda}^p$ is defined by $W_{\tau e}(\bar{\lambda}^p, .) = 0$. That is a country has powerful import lobbies if the weight placed on producer surplus is at least as high as the critical value at which domestic tariffs and e-taxes are independent. We show that such a weight exists and is non-trivial, in the sense that it requires governments to actually give extra weight to import producers.

Proposition 4 *:*

Domestic tariffs and e-taxes are strategic complements in the domestic objective function, W, if and only if a country does not have powerful import lobbies.

[47] Recall that we assume linear demand and supply functions, which is standard in similar analysis of strategic effects of trade policies and implies that the cross derivative of world prices with respect to tariffs and e-taxes is zero.

Proof: See appendix A.1.

The existence of a threshold point, $\bar{\lambda}^p$, is simple to show since the extra weight on import producers affects only the strategic lobby effect and all of the other strategic terms depend only on exogenous parameters.[48] Thus if the weight is one the lobby effect disappears but if it is sufficiently large this effect dominates all others and domestic tariffs and e-taxes become strategic substitutes.

As we show in lemma 1 the condition in proposition 4 is sufficient to compare the incentives to deviate under the linkage and no-linkage regimes. Therefore, by determining when the domestic policies are complementary, import lobbies affect whether linkage creates enforcement. To compare the cooperation gains under linkage and no-linkage we must also analyze the interaction of the foreign policies in home's objective function.

5.2 Strategic complementarity of foreign tariffs and e-taxes

Once again we drop the subscripts, all conditions and variables now refer to home's export sector, y. Differentiating eq.(3) we find two negative effects of a foreign tariff increase on domestic welfare: $W_{\tau^*} = -p^w_{\tau^*}M + (-\bar{\Psi}'(1+p^w_{\tau^*})\alpha S^{*\prime})$. The first term represents the cost due to a reduction in home's export prices, the usual TOT effect. The second term represents the extra externality cost when there is a cross-border effect, since higher foreign tariffs lead to an expansion in foreign production. From this, τ^* and e^* are strategic complements in the home government's objective function if the following expression is positive:

$$W_{\tau^* e^*} = \underset{-}{(-p^w_{\tau^*} M_{e^*})} + \underset{+}{(-\bar{\Psi}_{\tau^* e^*})} \tag{19}$$

The strategic TOT effect, $-p^w_{\tau^*} M_{e^*}$, is negative. An increase in foreign's tariff reduces world prices for domestic's exports, thus an increase in foreign e-taxes becomes less valuable since it expands domestic exports at a reduced world price. The strategic externality effect is now $-\bar{\Psi}_{\tau^* e^*} = -(p^w_{e^*} - 1)\alpha S^{*\prime}\lambda^{\Psi}\Psi''(1 + p^w_{\tau^*})\alpha S^{*\prime}$. It consists of the change in marginal cost of the externality due to changes in the e-tax, $-(p^w_{e^*} - 1)\alpha S^{*\prime}\lambda^{\Psi}\Psi''$, weighted by the positive foreign tariff effect on the externality level, $(1 + p^w_{\tau^*})\alpha S^{*\prime}$.

[48] Assuming that $\Psi''' = 0$, which is the case if Ψ is quadratic for example.

We use the following definition to help characterize when the foreign policies are strategic complements: the **externality is sufficiently valued** if $\lambda^{\Psi} > \bar{\lambda}^{\Psi}$. Where $\bar{\lambda}^{\Psi}$ is defined by $W_{\tau^* e^*}(\bar{\lambda}^{\Psi}, .) = 0$.

Proposition 5 *:*

Foreign tariffs and e-taxes are strategic complements in the domestic objective function, W, if and only if the production externality is sufficiently valued and is not purely domestic.

Proof: See appendix A.1.

The key to this result is that when we focus on the pecuniary effects alone the foreign policies are strategic substitutes, which requires the externality effect in the export sector to be positive. This is the case because, when the loss function is convex, the marginal benefit from reducing the externality level is greater at higher levels of the externality. Since an increase in foreign tariffs increases the level of the externality, it also increases home's marginal benefit from a foreign increase in e^*, because the latter reduces S^*. When the externality is sufficiently valued this effect dominates the pecuniary one. More importantly, the proposition rules out purely domestic production externalities, since in that case no externality effect exists and therefore foreign policies are strategic substitutes.

The conditions for supermodularity in the last two propositions can be exactly satisfied by our trade model. In figure 4 we plot the loci of critical values along which the policies are independent and shaded the parameter areas under which the policies are complements. Thus the analysis of independent policies in section 4.1.2 also applies to this special case of our trade model, even though the production externality is trade-related since the costs of the externality are directly affected by tariffs. The conditions in propositions 4 and 5 suggest for which issues and countries linkage creates enforcement, but in practice establishing whether an externality is sufficiently valued or import lobbies are not powerful requires a case-by-case examination. Even determining which are the purely domestic externalities may prove difficult since it depends on the interpretation and knowledge of α, both of which are likely to change over time. Despite these caveats we now show that it is possible to derive basic predictions from our model regarding the adoption of linkage.

5.3 Adoption of linkage

Aggregate welfare under linkage is never lower and can be strictly higher then no-linkage, moreover linkage may create enforcement. This raises two obvious questions. First, why has no-linkage been the status quo and why has linkage become such an important issue only now? Second, does the model predict that all types of countries will adopt linkage?

A basic answer to the first question is that some of the issues now discussed for linkage represent recent concerns. The weight and the knowledge of the scope of the externality for such issues were previously close to zero, thus requiring no agreements. Recent increases in α and λ_i^{Ψ} for some of these externalities are changing this situation. Increasingly fewer issues are considered to have purely domestic effects. First, because of a broadening of the interpretation of the externalities to include "psychological costs" (e.g. child labor in other countries); second, in the case of environmental issues, because of the increased scientific knowledge of the interdependence of ecosystems. The increase of the weight, λ_i^{Ψ}, is a consequence of development since the abatement of a negative externality is likely to be a normal good. Alternatively the weight represents the strength of lobbies, e.g. environmentalists, which has also been on the rise.

The argument above provides one justification for no-linkage as the status quo and also for the recent proposals for linkage. However, is it possible that some countries do not switch even if aggregate welfare under linkage is strictly higher? Thus far we have implicitly assumed that governments switch to linkage if it yields the highest aggregate welfare level, which would imply that when linkage becomes an option governments are never worse off by adopting it. But we have also alluded to possible reasons why governments may not adopt linkage and we now address these explicitly. A full fledged model of regime switches is beyond the scope of this paper. But we provide two simple extensions to highlight how transition costs and redistribution problems may prevent switches to linkage and how the creation of enforcement can be important in those situations.

First, suppose the switch to linkage entails a fixed transition cost, T, representing negotiation or labor adjustment costs for example. One simple choice mechanism is for governments to switch if the discounted gains exceed the transition cost:

$$(W|_{\Phi^l} - W|_{\Phi^{nl}})/(1-\delta) \geq T \tag{20}$$

Countries with high transition costs do not switch. A less obvious point is that even if transition costs are arbitrarily small and welfare under linkage is higher than no-linkage, there exist both sufficiently impatient and patient countries that do not switch. This occurs because the linkage and no-linkage solution depend directly on how patient a country is. Patient countries, with discount factors above a critical level, δ_{NL}, required to sustain full cooperation under no-linkage, can also sustain full cooperation under linkage, as we know from proposition 1. This implies that a discount factor, δ_H, lower than δ_{NL} exists such that linkage does strictly better than no-linkage but not enough to offset the transition cost, even if that cost is arbitrarily small. Thus, sufficiently patient countries, with discount factors at or above δ_H, do not switch to linkage.[49]

Focusing on issues where there is creation of enforcement can be crucial when transition costs exist. If policies are independent, then even small transition costs may prevent countries from switching. Because, in the absence of creation, there is no guarantee that the aggregate welfare level under linkage is strictly higher. With the choice mechanism above, we can also predict the effect on the adoption of linkage due to changes in either the strength of import lobbies or the weight and scope of the externality. If a country is indifferent between the regimes we need only determine the partial effect of those parameters on the LHS of eq.(20).

Alternatively, linkage may not be adopted if it creates significant losses for certain groups (e.g. consumers of importables as we mention in section 4.3). The regime switch is then likely to be voted on, either directly by citizens or by a legislative body. In the U.S. for example, congress has voted on whether the president's fast-track authority for trade agreements extends to environmental and labor issues when included in the trade agreement.[50] We can model an "initial" stage (to be understood as the first time at which linkage becomes an option) in which a voter chooses whether to switch from the no-linkage to the linkage *solution* if the analogue of eq.(20) for that voter holds (e.g. a consumer, factor owner, environmentalist or their representative). In the absence of targeted lump-sum transfers, eq.(20) may fail to hold for particular voters

[49] A similar argument holds for impatient countries since if the discount factor is below a critical level no cooperation is sustainable under linkage nor, from proposition 1, under no-linkage. Technically, the result for the patient countries relies on the fact that the critical discount factor that sustains full cooperation is below unity. This and the continuity of the linkage and no-linkage solutions in δ assures that, as we increase the discount factor toward that critical level, the discounted gain from switching becomes arbitrarily small.

[50] The E.U. provides another example. The European Commission has the "exclusive competence" to negotiate trade agreements on behalf of the E.U. However, the European Court of Justice ruled that this "exclusive competence" does not apply if such agreements go beyond trade policy (Jackson p.80). Thus any such agreements are potentially subject to a vote by the member states' representatives.

or for a majority. Therefore, redistribution provides another important reason why we may not observe linkage, even if it leads to aggregate welfare improvements. [51]

The creation of enforcement can ameliorate the redistribution problem. Suppose the majority of voters can only gain when tariffs are lowered and production taxes increased, then linkage is adopted only if it creates enforcement. More generally, with creation the feasible direction of change for tariffs and e-taxes is (locally) unrestricted, thus making it more likely for the linkage solution to be supported by a majority.

To facilitate exposition, we assumed that production in each country's export sector did not create an externality. We now relax this assumption to show that it is not essential for the main results.

6 General model

A common concern surrounding import lobbies in debates over linkage is that "traditional protectionist groups will manipulate environmental concerns in order to reduce competition from imports."[52] This issue does not arise in the simple version of our model because the foreign country's production externality occurs only in home's export sector. Therefore a producer in the import competing sector does not benefit from a higher foreign e-tax, e_y^*, since it does not affect the price of home's imported good.[53] In this section we extend our model to cover such cases by allowing the externality and spillovers to occur in all sectors. We show how the main results generalize and provide the details of the analysis in appendix A.3.[54]

The basic change in the model is to allow for production externalities in both sectors in each country as given by eq.(4). Given the existence of externalities in the export sectors e_y and e_x^* become relevant instruments. The government's objective function, $\tilde{W}$, is obtained by not restricting the use of e-taxes in the export sector in the original expression in eq.(3).

[51] This initial stage represents a choice of rules and is therefore compatible with subsequently allowing the executive branch of the government to maximize a measure of aggregate welfare subject to the chosen enforcement regime. Note also that by restricting the vote to two choices, and assuming that both linkage and no-linkage have unique maximizers, we avoid the usual problems that arise in voting games due to multidimensionality of policies and non-single peakdness of agents preferences.

[52] Anderson and Blackhurst (1992, p.20).

[53] We are implicitly assuming that: (i) the owners of the specific factor used in the production of good x do not produce other goods and thus value only the surplus earned in selling x and (ii) the ownership of the specific factor is not evenly distributed across the whole population.

[54] Limão (2001a) provides a more thorough analysis of the issues in this section.

The Nash equilibrium policies are implicitly given by:

$$\tilde{\tau}_x^N = \frac{p_x^w}{\varepsilon_x} + \frac{\alpha_x S_x^{*\prime} \bar{\Psi}_x^{\prime}}{-M_x^{*\prime}} \ ; \ \tilde{e}_x^N = \bar{\Psi}_x^{\prime} - (\lambda^p - 1)\frac{S_x}{S_x^{\prime}} \ ; \ \tilde{e}_y^N = \bar{\Psi}_y^{\prime} - \tilde{\tau}_y^N \frac{M_y^{*\prime}}{M_y^{*\prime} + D_y^{\prime}} \tag{21}$$

The expression for the domestic e-tax, e_x, is unchanged. The first term in the tariff expression reflects the TOT motive. The second term is due to foreign's production externality, if the externality has a cross-border spillover then the tariff is set higher to depress the world price and reduce foreign production, which is the source of the externality. Finally, in $\tilde{e}_y^N$, the first term reflects the domestic marginal cost of the production externality whereas the second term reflects the following two effects. *If* we allowed for an export tax, it would take the value, $\tilde{\tau}_y^N$, analogous to $\tilde{\tau}_x^N$.[55] In the absence of cross-border spillovers $\tilde{\tau}_y^N$ is negative–to raise the world price of home's exports. However, if cross-border spillovers exist and are sufficiently costly then the Nash solution would yield a positive $\tilde{\tau}_y^N$, to depress world prices and lower the foreign externality. Since we rule out export taxes, $\tilde{e}_y^N$ (partially) fulfills that role and, in the latter case, $\tilde{e}_y^N$ is set below the domestic marginal cost of the externality. That is the case we focus on since export taxes are not frequently observed and we are interested in the more empirically relevant case where e-taxes are set below the global optimum.[56]

The optimal cooperative policies are again chosen to maximize the (modified) cooperative objective function, yielding:

$$\tilde{\tau}^g = 0 \ ; \ \tilde{e}_x^g = \bar{\Psi}_x^{\prime} + \alpha_x^* \bar{\Psi}_x^{*\prime} - (\lambda^p - 1)\frac{S_x}{S_x^{\prime}} \ ; \ \tilde{e}_y^g = \bar{\Psi}_y^{\prime} + \alpha_y^* \bar{\Psi}_y^{*\prime} \tag{22}$$

These results are intuitive if we consider that, from the world's perspective, there exists only one type of distortion, which is proportional to the production of each good in each country. A comparison of the cooperative and Nash policies shows that the difference between them is due to market power in trade and the cross-border effect of the externality. As in the simple model this difference is not directly affected by the existence of import lobbies so, in the presence of a cooperative agreement in e-policies, the underlying motivation for a reciprocal trade agreement is still to internalize the TOT effect.

[55] Thus the value of $\tilde{e}_y^N$ in terms of the primitives of the model is obtained by replacing $\tilde{\tau}_y^N$ with the same expression as $\tilde{\tau}_x^N$ but where the variables refer to home's export sector.

[56] In our setup a sufficient condition for $\tilde{\tau}_y^N > 0$ (an export subsidy) is that $M_y^*/S_y^{*\prime} < \alpha_y \lambda_y^\Psi \Psi_y^{\prime}$. So cross-border spillovers are "sufficiently" costly if $\alpha_y \lambda_y^\Psi > M_y^*/S_y^{*\prime}\Psi_y^{\prime}$. Clearly if $\alpha_y = 0$ the condition can not be satisfied since $M_y^*/S_y^{*\prime} > 0$.

6.1 Creation of enforcement in the general model

The results in lemmas 1 and 2 and the proposition on the creation of enforcement in section 4.4 extend to the general model with the modifications we now point out.

Each government has access to three policies, an import tariff and e-taxes in both sectors, thus there exist four possible scenarios for linkage. We focus only on one, the linkage of all policies.[57] We define the expressions for the period gains from cooperation, $\tilde{\omega}^{\tau_x e_x e_y}$, and deviation, $\tilde{\Omega}^{\tau_x e_x e_y}$ in all policies, analogously to the expressions in eqs.(8, 9) but including the export sector policies.

The definition of a non-linked agreement is unchanged from section 4.1.2. Under no-linkage countries sign a trade agreement, as before, and an agreement that encompasses the e-policies in both sectors.[58] Thus, under no-linkage, governments are subject to incentive constraints which reflect the possibility of deviation in either the trade policy: $\tilde{\Omega}^{\tau_x} \leq \frac{\delta}{1-\delta}\tilde{\omega}^{\tau_x}$, or in both e-policies: $\tilde{\Omega}^{e_x e_y} \leq \frac{\delta}{1-\delta}\tilde{\omega}^{e_x e_y}$, or in both trade and e-policies simultaneously: $\tilde{\Omega}^{\tau_x e_x e_y} \leq \frac{\delta}{1-\delta}\tilde{\omega}^{\tau_x e_x e_y}$. These are the three constraints we had in the simple model after modifying the objective functions to allow for export sector policies. Therefore, to analyze the conditions under which linkage creates enforcement, we can follow the approach of the simple model. That is to show when $\tilde{\Omega}^{\tau_x e_x e_y} \leq \tilde{\Omega}^{\tau_x} + \tilde{\Omega}^{e_x e_y}$ and $\tilde{\omega}^{\tau_x e_x e_y} \geq \tilde{\omega}^{\tau_x} + \tilde{\omega}^{e_x e_y}$ hold under no-linkage. These inequalities are analogous to eq.(13) and eq.(14).

Lemma 1 applies directly here. That is, if τ_x and e_x are complements in the modified objective function then the gains of deviation under linkage are lower than the sum of the gains from deviation under no-linkage.[59] As we show in appendix A.3, to obtain the equivalent of lemma 2b, we must augment the strategy space in the supermodularity definition to include e_y and e_x^*. We must also ensure that the deviations of the e-tax in the export sector entail a lower e_y, as occurs in the import sector.[60]

[57] The alternatives are linking tariffs with e-taxes in either sector, linking e-taxes across sectors or link all. Two possible justifications for choosing the latter are: (i) linkage of all possible trade and e-policies always leads to at least as cooperative an outcome as the linkage of any subset of policies. This follows directly from proposition 1; (ii) If the production externality in both sectors is of the same type, e.g. CO2 emissions, then, when linking trade and e-policies, it would seem most natural to include both sectors.

[58] That is the e-policies are already linked across sectors but not with the trade policy. Thus, if governments were to deviate in e-policies it would be optimal to deviate in both e_x and e_y independently of whether they are linked to the trade policy. If linking trade and e-policies creates enforcement in this case then it must also create enforcement relative to an alternative scenario where the e-policies were not initially linked, e.g. if there was an agreement to deal with e-policies sector-by-sector, as is clear from proposition 1.

[59] The e-policy in the export sector plays no role here because the policies are independent across sectors and thus the gain from deviating in e_y is independent of any deviations in the x sector.

[60] That is we require the main source of distortion in the non-cooperative setting of e_y and e_x^* to be the production externality rather than the TOT motivation. As we discuss in page 35 a necessary condition for this is for spillovers to be present in the export sector.

When this last condition is satisfied we can state the equivalent of proposition 3 for the general model: if the objective function, $\tilde{W}$, is supermodular in $(\tau_x, e_x), (\tau_x, e_x^*), (\tau_y^*, e_y)$ and strictly supermodular in (τ_y^*, e_y^*) then linkage creates enforcement. Moreover, there exist objective functions, $\tilde{W}$, strictly supermodular in $(\tau_x, e_x), (\tau_x, e_x^*), (\tau_y^*, e_y)$ and (τ_y^*, e_y^*) such that linkage creates enforcement.

The basic result on the creation of enforcement holds in this more realistic setting which allows production externalities in all sectors. The only questions that remain are whether the sufficient conditions for the creation of enforcement can be satisfied in the general model and if the weight placed on import sector producers has an important role.

6.2 Supermodular objective functions in the general model

In addition to the two complementarity conditions examined in the simple model we must also ensure that both (τ_x, e_x^*) and (τ_y^*, e_y) are strategic complements with respect to $\tilde{W}$. In the expression for the cross-effect of (τ_x, e_x) all of the pecuniary strategic effects are equal to those in eq.(18). The strategic externality term, given in appendix A.3, is modified to account for the effect of the policy changes on the total supply of that externality, $S_x + \alpha_x S_x^*$.[61] In appendix A.3 we provide the exact conditions arising from the new policy instruments, $\tilde{W}_{x\ \tau e^*}$ and $\tilde{W}_{y\ \tau^* e}$, which again reflect both strategic pecuniary effects and the strategic externality effect.

There are two key points. First, the strategic lobby term in $\tilde{W}_{x\ \tau e}$, is equal to $\Pi_{\tau e}$ in eq.(18), and therefore negative. This implies that if the initial parameters support the sufficient conditions for the creation of enforcement then increased lobbying eventually destroys them. Thus import lobbies can have a negative effect on the ability of linkage to create enforcement since, when the lobby effect dominates, domestic tariffs and e-taxes become strategic substitutes. Second, there exist parameters such that the modified objective function is strictly supermodular in the linked policies, as we show in appendix A.3. Therefore, the sufficient conditions for linkage to create enforcement hold even if we allow for externalities and production taxes in both import and export sectors.

[61] Since tariffs and e-taxes affect domestic and foreign producer prices in opposite ways the magnitude of the cross-border effect, α_x , is now important in determining if the strategic externality effect is positive. An analogous change applies to eq.(19).

7 Conclusion

We started by asking if linking trade policy to other cooperative agreements can ever result in the creation of enforcement rather than always leading to the reallocation of enforcement. Our first contribution is to show that the fear of reallocation of enforcement is justified if the linked issues are independent and asymmetric in their enforceability. Moreover, if under no-linkage it is relatively easier to cooperate on tariffs than on e-taxes, the reallocation entails more cooperation on non-trade issues at the expense of higher tariffs. Thus, the model helps explain both the recent demands for linkages with trade policy by lobbies for different e-issues and the respective opposition. If the main goal of the WTO remains multilateral trade liberalization then our result also lends support to this institution's current practice which, except in the area of intellectual property, avoids retaliation across independent issues.[62]

However, in switching to a linkage regime, reallocation is not inevitable if policies are not independent to begin with. Our second contribution is to show that linkage creates enforcement if the objective function is supermodular in linked policies. This result can be applied to a number of economic problems where agents must enter self-enforcing contracts to repeatedly deal with a cooperation problem over multiple related issues using non-independent policies. Obvious candidates are other international cooperative agreements, e.g. on health issues, transport infrastructure. Other applications include firm collusive behavior across interdependent markets (e.g. due to economies of scope or vertical integration) or when there is more than one instrument of collusion in the same market (e.g. price and advertising). Self-enforcing contracts are also pervasive in developing countries where the lack of rule of law often renders binding legal contracts too costly.

Our analysis is particularly relevant for regional integration agreements. First, one of our basic assumptions–a country's market power in trade–is most plausible in regional markets, since transport costs segment markets implying that even producers that are small worldwide can have regional market power. Second, more issues have regional rather than global cross-border effects. Thus there is more scope for the creation of enforcement through linkage regionally.[63]

[62] Article 22.3 a.

[63] This may explain why linkage in regional integration agreements has been more frequent and less contentious than in the WTO.

In the simple trade model we show that the issues for which linkage creates enforcement must have cross-border effects and be sufficiently valued to offset strategic pecuniary effects. These conditions are sufficient when import lobbies are not "powerful". We believe that both the increase in the weight placed on environmental (and other non-trade issues) and the broader interpretation of the scope of their externalities, are changing the strategic relation between policies. This partially explains the increasing demands for linkage as well as their origin in developed countries. If the externality weight rises with income our result suggests that this phenomenon will intensify. We also show that even if aggregate welfare under no-linkage is strictly lower not all countries switch to linkage due for example to redistribution costs. These costs are reflected in the opposition to linkage by specific groups within developed countries and they can be ameliorated when linkage creates enforcement.

Enforcement is not the only factor in the decision to link agreements, but it is certainly an important one. By analyzing linkage from an enforcement perspective we show that one of the main objections to linkage with trade policy, the reallocation of enforcement, can be overcome. One practical concern in implementing linkages is that institutions, such as the WTO, are not equipped to decide on certain non-trade issues. However, in our model, linkage would require only that WTO rules allow the threat to use trade sanctions to enforce certain specific agreements and vice-versa. This is compatible with a world order where there exist functional clubs to deal with each specific issue, e.g. the environment, with one or more global coordinating clubs to deal with linkages among issues.[64] Potential drawbacks from linkage may arise from redistribution problems due to within and across country asymmetries and from different degrees of imperfect monitoring of compliance with different agreements. Both of these issues should be fully addressed in the enforcement context used in this paper. However, it is clear that demands for linkage will not soon fade. So, rather than allow the unilateral abuse of trade sanctions, we must understand how to use multilateral threats of non-cooperation, in both trade and other issues, in order to promote more cooperative outcomes.[65]

[64] As suggested for example by Lawrence et al. 1996 (p. 107).

[65] See Hufbauer et al. (1990) for a thorough review of the U.S.'s use of trade sanctions.

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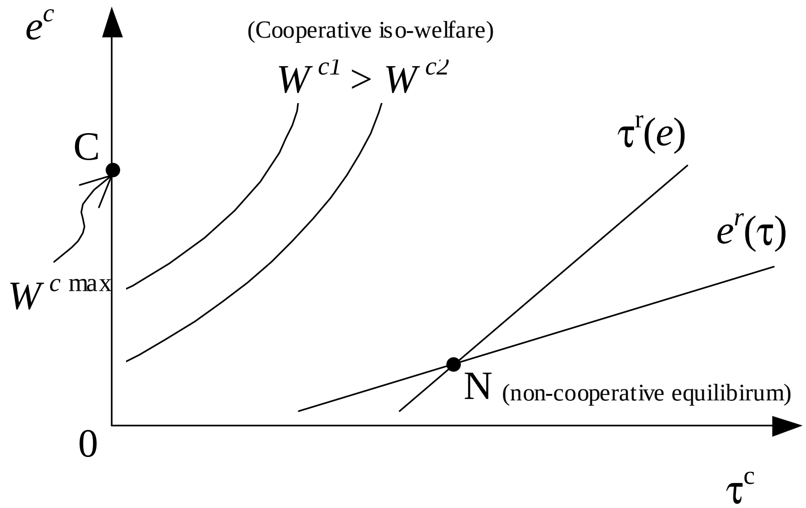
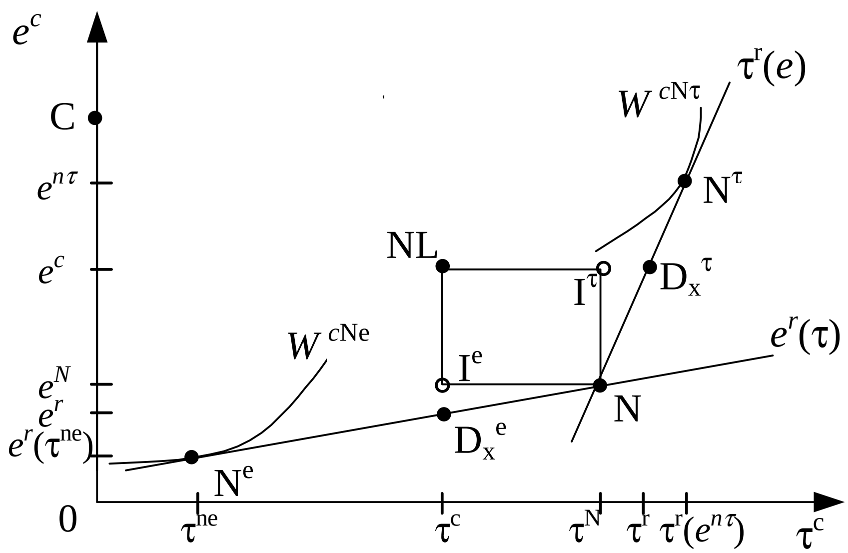
Figure 1. Nash (N) and global cooperative solution (C) in tariffs and e-taxes



Note:
The line τ^r (e^r) denotes the "best response" in tariffs (e-taxes) taking e (τ) as given.

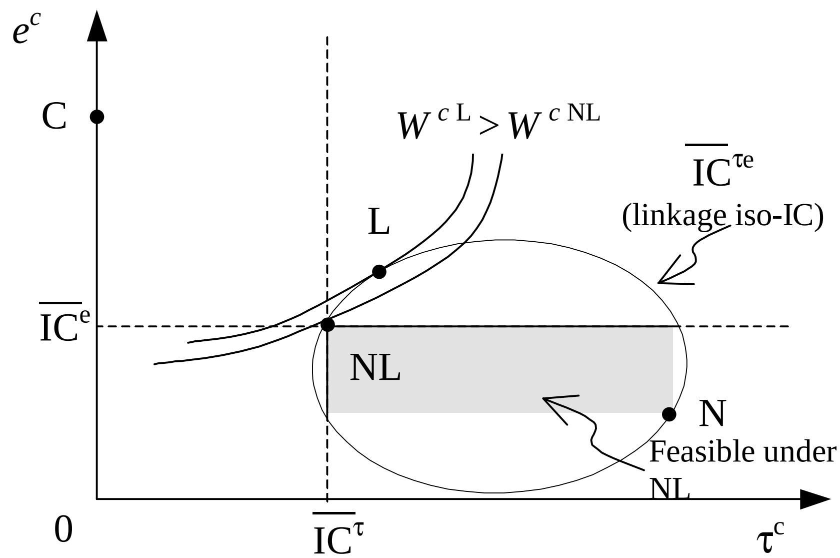
Figure 2. Cooperation and deviation strategies under no-linkage



Notes:
Point N denotes the Nash equilibrium in both policies; N^τ (N^e) denotes the Nash point when there is cooperation in e but not in $\tau(e)$; D_x^τ (D_x^e) denotes the deviation point in τ_x (e_x) in a period where the policies were initially set at *NL*, all policies except τ_x (e_x) remain at *NL* in the deviation period; I^τ and I^e do not represent equilibrium strategy points when the policies are strategic complements.

Figure 3. Impact of linkage on enforcement

3a. Reallocation of enforcement under independent policies



Notes:
(i) There exists a trivial iso-incentive constraint for each of the individual IC that is parallel to the ones drawn and goes through the Nash point. This ensures that the feasible self-enforcing policies under no-linkage are within the rectangle enclosed by points *N* and *NL*.
(ii) Taking *NL* as the origin, the first and third quadrant represent areas of re-allocation of enforcement (i.e. moving from *NL* towards higher (lower) e-taxes enforced by higher (lower) tariffs) whereas the second represents an area of creation of enforcement.

3c. Creation of enforcement under non-independent policies

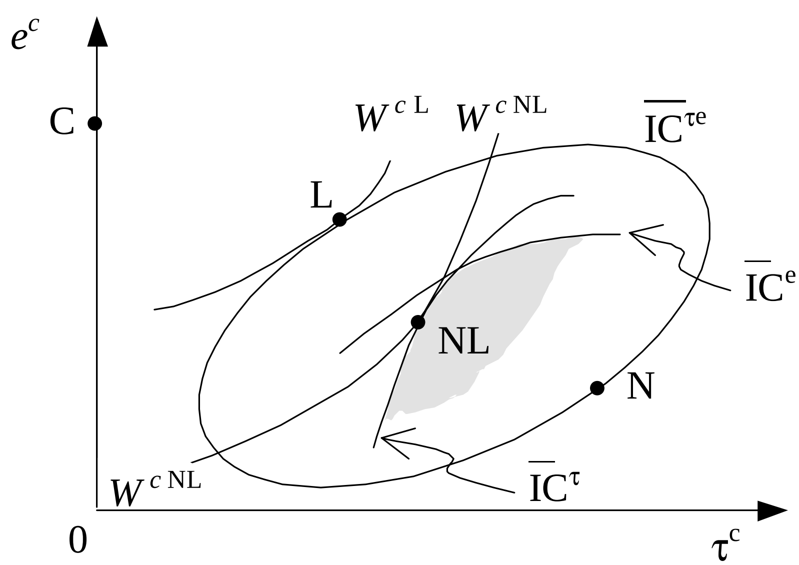
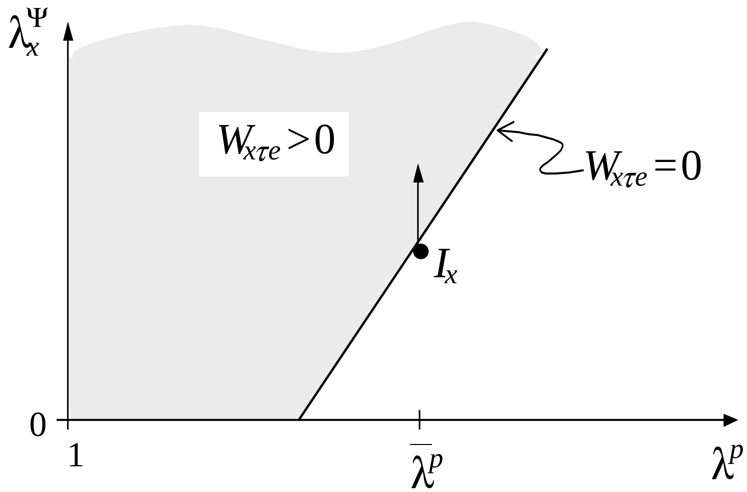
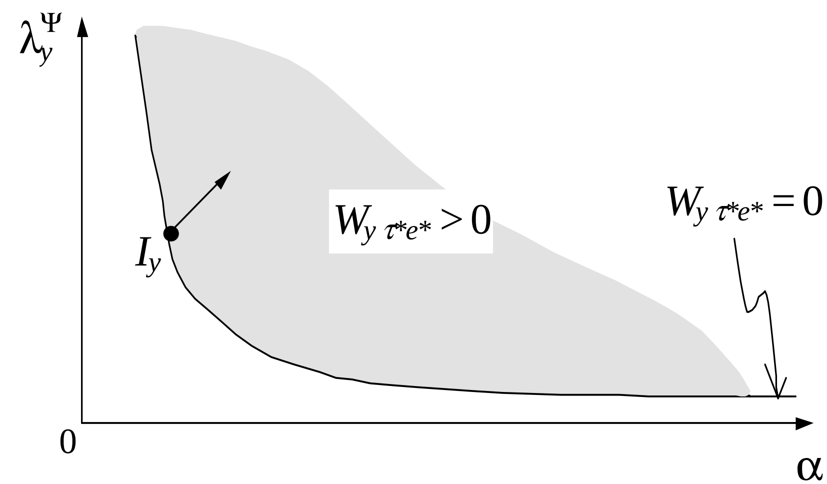


Figure 4. Conditions for supermodular welfare

4a. Weight on externality vs. importance of lobbies
in domestic import sector



4b. Weight vs. scope of externality
in domestic export sector



Notes:

(i) The shaded areas correspond to the combinations of parameters under which the objective function is strictly supermodular in all linked policies, e.g. $W_{x\tau e}$ denotes the cross-derivative of domestic tariffs and e-taxes in domestic welfare.

(ii) We assume that the production externality loss function, Ψ, is strictly convex in both figures.

(iii) The movement from the points on the independence loci, I_i , to the shaded areas illustrates the effect of changes in the scope and externality weight over time on the strategic relation between tariffs and e-taxes, when we assume $\Psi''' = 0$.

A Appendix

A.1 Proofs

Proposition 2

(a) If $\delta \leq \min(\delta_\tau, \delta_e)$ then the necessary FOC for the interior linkage solution, Φ^l, are $\frac{W_\tau + W_{\tau*}}{W_e + W_{e*}} = \frac{W_\tau + \delta W_{\tau*}}{W_e + \delta W_{e*}}$ and $\Omega^{\tau e}(\tau^c, e^c) = \frac{\delta}{1-\delta}\omega^{\tau e}(\tau^c, e^c)$. Thus, if the MRS are not equalized at NL it is not a linkage solution. Reallocation must occur since, at NL, we have $\Omega^{\tau e}(\tau^c, e^c) = \frac{\delta}{1-\delta}\omega^{\tau e}(\tau^c, e^c)$ and $\overline{IC}^{\tau e}$ has a positive slope (as shown in the analysis of figure 3a).

(b) If $\delta = \delta_\tau$ then $\tau^c = 0$ and $W_\tau + W_{\tau*} = 0$ whereas $-\frac{W_\tau + \delta W_{\tau*}}{W_e + \delta W_{e*}} > 0$ and an increase in τ and e until $\frac{W_\tau + W_{\tau*}}{W_e + W_{e*}} = \frac{W_\tau + \delta W_{\tau*}}{W_e + \delta W_{e*}}$ is optimal. By continuity of W and of the incentive frontier $\exists\ \delta < \delta_\tau$ such that the reallocation still occurs from tariffs to e-taxes. The same argument holds if at NL there is slack in IC^τ, i.e. $\delta_\tau < \delta < \delta_e$.¤

Lemma 1

$\Omega^{\tau e} \leq \Omega^\tau + \Omega^e \iff W_x^{C\tau e} + W_x^{D\tau e} \leq W_x^{D\tau} + W_x^{De}$ where $C\tau e, D\tau e, D\tau, De$ are defined at points $NL, N, D^\tau$and D^e in figure 2. Adding and subtracting both $W_x(\tau^N, e^c)$ and $W_x(\tau^c, e^N)$ to the RHS of the equivalence relation above we have $s_x + a_x \leq 0$, where:

$$s_x \equiv \{W_x(\tau^c, e^c) + W_x(\tau^N, e^N)\} - \{W_x(\tau^N, e^c) + W_x(\tau^c, e^N)\} \quad \text{(A1.1)}$$
$$a_x \equiv \{W_x(\tau^N, e^c) - W_x(\tau^r, e^c)\} + \{W_x(\tau^c, e^N) - W_x(\tau^c, e^r)\} \quad \text{(A1.2)}$$

As we show in sections 3.3 and 3.4 $\tau^c < \tau^N$ and $e^c > e^N$. Thus $\max((\tau^c, e^c), (\tau^N, e^N)) = (\tau^N, e^c)$ and $\min((\tau^c, e^c), (\tau^N, e^N)) = (\tau^c, e^N)$. Therefore if W is (strictly) supermodular in τ, e (or, what is equivalent, $W_{x\tau e}(>) = 0$) then $s_x(<) = 0$. Moreover $a_x \leq 0$ since τ^r is the best response to e^c and similarly for e^r relative to τ^c.¤

Lemma 2a

$\omega^{\tau e} \geq \omega^\tau + \omega^e \iff W^{C\tau e} + W^{N\tau e} \leq W^{N\tau} + W^{Ne}$. Rewriting this expression as $s + a \leq 0$ where:

$$s \equiv \{W(\tau^c, e^c) + W(\tau^N, e^N)\} - \{W(\tau^N, e^c) + W(\tau^c, e^N)\} \quad \text{(A1.3)}$$
$$\begin{aligned} a &\equiv W(\tau^c, e^N) + W(\tau^N, e^c) - \{W(\tau^{ne}, e^r(\tau^{ne})) + W(\tau^r(e^{n\tau}), e^{n\tau})\} \quad \text{(A1.4)} \\ &= W^{Ie} + W^{I\tau} - (W^{Ne} + W^{N\tau}) \end{aligned}$$

(Strict) supermodularity ensures $s(<) = 0$ and the partial cooperation condition states that $a \leq 0$ so $s + a \leq 0$.¤

Lemma 2b

To conclude the proof in the text we show that IC^τ and IC^e are satisfied at I^e and I^τ respectively. First note that when there is partial cooperation in one policy the other policy's IC becomes irrelevant. Intuitively, IC^τ holds at I^e because it held at NL and, since $e^N < e^c$, we have that at NL the gains from deviation are at least as high and the gains from cooperation lower than at I^e. We now show this for the two different cases in the lemma.

Case 1: W is supermodular in domestic policies and strictly supermodular in foreign policies.

$\Omega^\tau(\tau^c, e^c) = \Omega^\tau(\tau^c, e^N)$. By expanding and rearranging we have $\Omega^\tau(\tau^c, e^c) - \Omega^\tau(\tau^c, e^N) = -s_x = 0$ where s_x is defined in eq.(A1.1) and the last equality is proved in lemma 1 above.

$\omega^\tau(\tau^c, e^c) < \omega^\tau(\tau^c, e^N)$. By expanding and rearranging we have $\omega^\tau(\tau^c, e^c) - \omega^\tau(\tau^c, e^N) = s < 0$, where the inequality is proved in lemma 2a above.

Thus, under case 1, IC^{τ} does not bind at I^e and therefore $W^{Ie} < W^{Ne}$, since at N^e the countries have chosen the optimal cooperative tariff given $e = e^N$. A similar proof applies to show that IC^e does not bind at I^{τ} and therefore $W^{I\tau} < W^{N\tau}$.

Case 2: W is strictly supermodular in both domestic and foreign policies.

$\Omega^{\tau}(\tau^c, e^c) > \Omega^{\tau}(\tau^c, e^N)$. By expanding and rearranging we have $\Omega^{\tau}(\tau^c, e^c) - \Omega^{\tau}(\tau^c, e^N) = -\{s_x + W_x(\tau^N, e^c) - W_x(\tau^r, e^c)\} > 0$. As we show in lemma 1 strict supermodularity in domestic policies ensures that $s_x < 0$, moreover $W_x(\tau^N, e^c) - W_x(\tau^r, e^c) < 0$ since τ^r is the best-response to e^c.

$\omega^{\tau}(\tau^c, e^c) < \omega^{\tau}(\tau^c, e^N)$ also holds for some W strictly supermodular in both domestic and foreign policies. By expanding and rearranging we have $\omega^{\tau}(\tau^c, e^c) - \omega^{\tau}(\tau^c, e^N) = s + W^{I\tau} - W^{N\tau} < 0$, where s is defined in eq.(A1.3). From the proof of lemma 2a $s < 0$. Moreover, as we show for case 1 above, if $W_{y\tau^* e^*} > 0$ and $W_{x\tau e} = 0$ then $W^{I\tau} < W^{N\tau}$, therefore we must have that $\lim_{W_{x\tau e} \to 0^+} (W^{I\tau} - W^{N\tau}) \leq 0$.

Thus under case 2 IC^{τ} does not bind at I^e for $W_{y\tau^* e^*} > 0$ and $W_{x\tau e} \in (0, \bar{\varepsilon}]$. Therefore $W^{Ie} < W^{Ne}$, since at N^e the countries have chosen the optimal cooperative tariff given $e = e^N$. A similar proof applies to show that IC^e does not bind at I^{τ} and therefore $W^{I\tau} < W^{N\tau}$.¤

Proposition 4

$\partial W_{\tau e}/\partial \lambda^p = (p_e^w - 1)(1 + p_{\tau}^w) S\,'$as long as $\Psi''' = 0$, thus, using the results in eq.(2), $\partial W_{\tau e}/\partial \lambda^p < 0$ for all λ^p. From the definition of powerful import lobbies if $\lambda^p = \bar{\lambda}^p$ then $W_{\tau e} = 0$ thus if such a $\bar{\lambda}^p > 1$ exists then we have $W_{\tau e} > 0$ for $\bar{\lambda}^p > \lambda^p \geq 1$. As we describe above, $W_{\tau e}(\lambda^p = 1) > 0$ which implies that a $\bar{\lambda}^p > 1$ exists and is unique, for given values of the other exogenous parameters, because $\partial W_{\tau e}/\partial \lambda^p$ is linear in λ^p.¤

Proposition 5

$\partial W_{\tau^* e^*}/\partial \lambda^{\Psi} = -(p_{e^*}^w - 1)(\alpha S^{*\prime})^2 (1 + p_{\tau^*}^w)\Psi''$ as long as $\Psi''' = 0$. Thus, since we assume $\Psi'' > 0$, if $\alpha > 0$ then $\partial W_{\tau^* e^*}/\partial \lambda^{\Psi} > 0$ for all λ^{Ψ}, by using the results in eq.(2). By definition $W_{\tau^* e^*}(\bar{\lambda}^{\Psi}) = 0$, thus if such a $\bar{\lambda}^{\Psi}$ exists then we have $W_{\tau^* e^*}(\lambda^{\Psi} > \bar{\lambda}^{\Psi}) > 0$. As we describe above, $W_{\tau^* e^*}(\lambda^{\Psi} = 0) < 0$ which implies that a $\bar{\lambda}^{\Psi} > 0$ exists and is unique, for given values of the other exogenous parameters, since $\partial W_{\tau^* e^*}/\partial \lambda^{\Psi}$ is linear in λ^{Ψ}.¤

A.2 Analytical details

Necessary conditions for Nash and global optimal policies

The expressions below represent the FOC for the Nash policies in the general version of the model. That is for $\tilde{\tau}_x^N$ and $\tilde{e}_x^N$ in eq.(21). All variables refer to home's import sector. For $\tilde{e}_y^N$ we again use $W_e = 0$, but now the variables refer to home's export sector, so we set $\lambda^p = 1$ and $\tau = 0$. For eq.(5) we assume, $\alpha_x = 0$, $e_x^* = 0$ and $\bar{\Psi}_x(S_x)$.

$$W_{\tau} = 0 : (1 + p_{\tau}^w)(\tau M' + (e - \bar{\Psi}' + (\lambda^p - 1)S/S\,')S\,') - \alpha_x \bar{\Psi}' p_{\tau}^w S^{*\prime} - p_{\tau}^w M = 0 \quad \text{(A2.1)}$$
$$W_e = 0 : (p_e^w - 1)(e - \bar{\Psi}' + (\lambda^p - 1)S/S\,')S' + \tau S' + p_e^w(\tau M' - M - \alpha_x S^{*\prime}\bar{\Psi}') = 0 \quad \text{(A2.2)}$$

The expressions below represent the FOC for the global optimal policies in the general version of the model. That is for $\tilde{\tau}_x^g$ and $\tilde{e}_x^g$ in eq.(22). For $\tilde{e}_y^g$ we again use $W_e^c = 0$, but now the variables refer to sector y and home and foreign variables are interchanged (e.g. $\lambda^p = \lambda^{*p}, S^{*\prime} = S_y'$, etc.).

For eq.(6) we assume $\alpha_x = 0$. Moreover, in the simple model $e_x^* = 0$ and $\bar{\Psi}_x(S_x)$, thus the terms in brackets are not present.

$$W^c_\tau = 0 : (1 + p^w_\tau)(\tau M' + (e - (\bar{\Psi}' + \alpha^* \bar{\Psi}^{*\prime}) + (\lambda^p - 1)\frac{S}{S'})S') + \{p^w_\tau(e^* - (\bar{\Psi}^{*\prime} + \alpha_x \bar{\Psi}'))S^{*\prime}\} = 0 \quad \text{(A2.3)}$$

$$W^c_e = 0 : (p^w_e - 1)((e - (\bar{\Psi}' + \alpha^* \bar{\Psi}^{*\prime}) + (\lambda^p - 1)\frac{S}{S'})S') + \tau S' + p^w_e \tau M' + \{p^w_e(e^* - (\alpha_x \bar{\Psi}' + \bar{\Psi}^{*\prime}))S^{*\prime}\} = 0 \quad \text{(A2.4)}$$

Figure 1

If $\partial^2 W/\partial\tau_x\partial e_x > 0$ and $\partial^2 W/\partial\tau^*_y\partial e^*_y > 0$ then the cooperative iso-welfare lines are ellipses with origin at C and with a positively sloped long axis, W^{c1} depicts the bottom half of such an ellipse. This complementarity between τ^c and e^c implies that welfare falls more slowly when the variables move in the same rather than in opposite directions.

The slopes of e^r and τ^r are given by $\frac{\partial e}{\partial \tau}|_{e^r} = -\frac{\partial^2 W/\partial\tau_x\partial e_x}{\partial^2 W/\partial e_x\partial e_x}$ and $\frac{\partial e}{\partial \tau}|_{\tau^r} = -\frac{\partial^2 W/\partial\tau_x\partial\tau_x}{\partial^2 W/\partial\tau_x\partial e_x}$. The second order conditions for the Nash equilibrium ensure that τ^r is steeper than e^r at N. By differentiating eq.(A2.1) and eq.(A2.2) it is simple to show that $\partial^2 W/\partial e_x\partial e_x$ and $\partial^2 W/\partial\tau_x\partial\tau_x$ are always negative so that e^r and τ^r are also positively sloped away from N.

Figure 3a (independent policies):

Consider the simple case given in section 4.1.2 ($W = W_x(\tau_x, e_x) + W_y(\tau^*_y, e^*_y)$) and assume that tariffs and e-taxes are independent ($W_{\tau e} = W_{\tau^* e^*} = 0$). The slopes of the incentive frontiers in e^c, τ^c space ($\frac{\partial e^c}{\partial \tau^c}|_{\overline{IC}^k} = -\frac{\partial IC^k}{\partial \tau^c}/\frac{\partial IC^k}{\partial e^c}, k = \tau, e, \tau e$) are:

$$\frac{\partial e^c}{\partial \tau^c}|_{\overline{IC}^\tau} = \infty \quad ; \quad \frac{\partial e^c}{\partial \tau^c}|_{\overline{IC}^e} = 0 \quad ; \quad \frac{\partial e^c}{\partial \tau^c}|_{\overline{IC}^{\tau e}} = -\frac{(W_\tau + \delta W_{\tau *})}{(W_e + \delta W_{e*})}$$

The slope of $\overline{IC}^{\tau e}$ is positive at NL as we explain in the text. To understand the shape of $\overline{IC}^{\tau e}$ we must "anchor" four points. Since policies are independent when $\overline{IC}^\tau$ and $\overline{IC}^e$ intersect so must $\overline{IC}^{\tau e}$. In addition to the drawn individual incentive frontiers there exist two other parallel to the original ones but through N. Thus $\overline{IC}^{\tau e}$ must go through NL, N and the points directly above as well as to the left of N. Moreover, $\exists\ \bar{\tau} \in (\tau^{NL}, \tau^N)$ such that $\frac{\partial e^c}{\partial \tau^c}|_{\overline{IC}^{\tau e}} = 0$ since: (i) for $\tau \in (\tau^c, \tau^r]$ $W_\tau \geq 0$ and $W_{\tau *} < 0$; (ii) at C, $W_\tau + W_{\tau *} = 0$ by the FOC for τ^g at C; (iii) $\delta < 1$ along with (i) and (ii) imply that, at C, $W_\tau + \delta W_{\tau *} > 0$; (iv) at $\tau = \tau^N$, $W_\tau = 0$, thus $W_\tau + \delta W_{\tau *} = \delta W_{\tau *} < 0$. Thus, by continuity of the payoff functions, $W_\tau(\bar{\tau}) + \delta W_{\tau *}(\bar{\tau}) = 0$ and $\bar{\tau} > \tau^{NL}$ since, as we show above, at τ^{NL} we have $\frac{\partial e^c}{\partial \tau^c}|_{\overline{IC}^{\tau e}} > 0$. A similar argument shows $\exists\ \bar{e} \in (e^r, e^{NL})$ such that $\frac{\partial e^c}{\partial \tau^c}|_{\overline{IC}^{\tau e}} = \infty$.

Figure 3b (interdependent policies):

After simplification the slopes of the incentive frontiers in e^c, τ^c space are:

$$\frac{\partial e^c}{\partial \tau^c}|_{\overline{IC}^\tau} = -\frac{W_\tau(\tau^c, e^c) + \delta W_{\tau *}(\tau^c, e^c)}{\eta^\tau} ; \ \frac{\partial e^c}{\partial \tau^c}|_{\overline{IC}^e} = -\frac{\eta^e}{W_e(\tau^c, e^c) + \delta W_{e*}(\tau^c, e^c)}$$

$$\frac{\partial e^c}{\partial \tau^c}|_{\overline{IC}^{\tau e}} = -\frac{W_\tau(\tau^c, e^c) + \delta W_{\tau *}(\tau^c, e^c)}{W_e(\tau^c, e^c) + \delta W_{e*}(\tau^c, e^c)}$$

where $\eta^\tau = W_e(\tau^c, e^c) + \delta W_{e*}(\tau^c, e^c) - (1 - \delta)W_e(\tau^r, e^c)$ and $\eta^e = W_\tau(\tau^c, e^c) + \delta W_{\tau *}(\tau^c, e^c) - (1 - \delta)W_\tau(\tau^c, e^r)$. The points at which the functions are evaluated are described in figure 2.

In figure 3b, $\overline{IC}^{\tau e}$ is as in figure 3a but rotated counter-clockwise. To see why start at NL in figure 3 where $W_{\tau e} = 0$ and increase $W_{\tau e}$. At NL $\overline{IC}^{\tau e}$ still has a positive slope, but the turning points $\bar{\tau}$ and $\bar{e}$, defined above for figure 3a, have now shifted right and down respectively. The tariff at which $\frac{\partial e^c}{\partial \tau^c}|_{\overline{IC}^{\tau e}} = 0$ shifts right because $W_\tau(\tau^r(e^{n\tau}), e^{n\tau}) > 0$ whereas before it was zero (this is clear from τ^r in figure 1). Simultaneously the negative impact of an increase in τ^* has fallen because of the positive cross-effect ($W_{\tau^* e^*} > 0$).Thus $W_\tau(\tau^c > \bar{\tau}, e^c) + \delta W_{\tau*}(\tau^c > \bar{\tau}, e^c) = 0$, i.e. the turning point shifts right of the original one, $\bar{\tau}$, for the top part of $\overline{IC}^{\tau e}$ and left for the bottom part (since the latter is evaluated at a lower e.) A similar argument holds for the downward shift of $\bar{e}$ on the left side of $\overline{IC}^{\tau e}$ and upwards shift on the right side. So, the effect of the complementarity on $\overline{IC}^{\tau e}$ is to rotate it counter-clockwise relative to the case where the policies are independent. The slopes of $\overline{IC}^{\tau}$ and $\overline{IC}^{e}$ are positive in the relevant range, as argued in the text.

Supermodularity conditions

Impact of domestic e-taxes on domestic imports (sector x):

$$M_e = (D' - S\,')p_e^w + S\,' = M'p_e^w + S\,' = \frac{S\,'M^{*\prime}}{(M' + M^{*\prime})} > 0 \qquad \text{(A2.5)}$$

Where $p_e^w = -S'/(M'+M^{*\prime})$ from applying the implicit function theorem to the world market equilibrium eq.(1).

Impact of foreign e-taxes on domestic exports (sector y):

$$M_{e^*} = p_{e^*}^w M' \qquad \text{(A2.6)}$$

A.3 Analysis of the general model

Linkage IC

Due to the symmetry we can rewrite everything in terms of domestic variables. The gains from cooperation and deviation are respectively $\tilde{\omega}^{\tau_x e_x e_y}(\tau_x^c, e_x^c, e_y^c) \equiv \tilde{W}^{C\tau e} - \tilde{W}^{N\tau e}$ and $\tilde{\Omega}^{\tau_x e_x e_y}(\tau_x^c, e_x^c, e_y^c) \equiv \tilde{W}^{D\tau e} - \tilde{W}^{C\tau e}$. The linkage IC is $\tilde{\Omega}^{\tau_x e_x e_y}(\tau_x^c, e_x^c, e_y^c) \leq \frac{\delta}{1-\delta}\tilde{\omega}^{\tau_x e_x e_y}(\tau_x^c, e_x^c, e_y^c)$, where:

$$\begin{aligned} \tilde{W}^{C\tau e}(\tau_x^c, e_x^c, e_y^c) &\equiv \tilde{W}_x(\tau_x^c, e_x^c, e_x^{*c} = e_y^c) + \tilde{W}_y(\tau_y^{*c} = \tau_x^c, e_y^{*c} = e_x^c, e_y^c) \\ \tilde{W}^{D\tau e}(\tau_x^c, e_x^c, e_y^c) &\equiv \tilde{W}_x(\tau_x^r, e_x^r, e_x^{*c} = e_y^c) + \tilde{W}_y(\tau_y^{*c} = \tau_x^c, e_y^{*c} = e_x^c, e_y^r) \\ \tilde{W}^{N\tau e} &\equiv \tilde{W}_x(\tau_x^N, e_x^N, e_x^{*N} = e_y^N) + \tilde{W}_y(\tau_y^{*N} = \tau_x^N, e_y^{*N} = e_x^N, e_y^N) \end{aligned} \qquad \text{(A3.1)}$$

No-linkage IC

The IC under no linkage reflect the possibility of deviation in either the trade policy: $\tilde{\Omega}^{\tau_x} \leq \frac{\delta}{1-\delta}\tilde{\omega}^{\tau_x}$, in both e-policies: $\tilde{\Omega}^{e_x e_y} \leq \frac{\delta}{1-\delta}\tilde{\omega}^{e_x e_y}$, or in all: $\tilde{\Omega}^{\tau_x e_x e_y} \leq \frac{\delta}{1-\delta}\tilde{\omega}^{\tau_x e_x e_y}$. Where $\tilde{\Omega}^{\tau_x} \equiv \tilde{W}^{D\tau} - \tilde{W}^{C\tau e}$, $\tilde{\omega}^{\tau_x} \equiv \tilde{W}^{C\tau e} - \tilde{W}^{N\tau}$, $\tilde{\Omega}^{e_x e_y} \equiv \tilde{W}^{De} - \tilde{W}^{C\tau e}$, $\tilde{\omega}^{e_x e_y} \equiv \tilde{W}^{C\tau e} - \tilde{W}^{Ne}$.

$$\begin{aligned} \tilde{W}^{D\tau}(\tau_x^c, e_x^c, e_y^c) &\equiv \tilde{W}_x(\tau_x^r, e_x^c, e_y^c) + \tilde{W}_y(\tau_x^c, e_x^c, e_y^c) \\ \tilde{W}^{De}(\tau_x^c, e_x^c, e_y^c) &\equiv \tilde{W}_x(\tau_x^c, e_x^r, e_y^c) + \tilde{W}_y(\tau_x^c, e_x^c, e_y^r) \\ \tilde{W}^{N\tau} &\equiv \tilde{W}_x(\tau_x^r(e_x^{n\tau}, e_y^{n\tau}), e_x^{n\tau}, e_y^{n\tau}) + \tilde{W}_y(\tau_x^r(e_x^{n\tau}, e_y^{n\tau}), e_x^{n\tau}, e_y^{n\tau}) \\ \tilde{W}^{Ne} &\equiv \tilde{W}_x(\tau_x^{ne}, e_x^r(\tau_x^{ne}, e_x^*), e_x^* = e_y^r(\tau_x^{ne}, e_y^*)) \\ &+\tilde{W}_y(\tau_x^{ne}, e_y^* = e_x^r(\tau_x^{ne}, e_x^*), e_y^r(\tau_x^{ne}, e_y^*)) \end{aligned} \qquad \text{(A3.2)}$$

The functions are evaluated at the following points. At (τ_x^c, e_x^r, e_y^c) home has deviated in e_x and sets $e_x = e_x^r$, the non-cooperative value given τ_x^c and $e_x^{*c} = e_y^c$. At $(\tau_x^r(e_x^{n\tau}, e_y^{n\tau}), e_x^{n\tau}, e_y^{n\tau})$ countries choose (e_x^c, e_x^{*c}) to maximize cooperative welfare given $\tau = \tau^r$. At $(\tau_x^{ne}, e_x^r(\tau_x^{ne}, e_x^*), e_x^* = e_y^r(\tau_x^{ne}, e_y^*))$ countries choose τ to maximize cooperative welfare given $e_x = e_x^r$ and $e_y = e_y^r$.

Creation of enforcement

The conditions for the creation of enforcement are identical to eqs.(13,14), but now apply to $\tilde{W}$.

$$\tilde{\Omega}^{\tau_x e_x e_y} \leq \tilde{\Omega}^{\tau_x} + \tilde{\Omega}^{e_x e_y} \tag{A3.3}$$

$$\tilde{W}_x(\tau_x^c, e_x^c, e_y^c) + \tilde{W}_x(\tau_x^r, e_x^r, e_y^c) \leq \tilde{W}_x(\tau_x^r, e_x^c, e_y^c) + \tilde{W}_x(\tau_x^c, e_x^r, e_y^c) \tag{A3.4}$$

$$\tilde{\omega}^{\tau_x e_x e_y} \geq \tilde{\omega}^{\tau_x} + \tilde{\omega}^{e_x e_y} \tag{A3.5}$$

$$\tilde{W}^{C\tau e} + \tilde{W}^{N\tau e} \leq \tilde{W}^{N\tau} + \tilde{W}^{Ne} \tag{A3.6}$$

Lemma 1 (general model)

Using the definitions in eqs.(A3.1,A3.2) we rewrite $\tilde{\Omega}^{\tau_x e_x e_y} \leq \tilde{\Omega}^{\tau_x} + \tilde{\Omega}^{e_x e_y}$ in terms of payoffs we obtain eq.(A3.4). Comparing eq.(A3.4) to eq.(16) it is clear that lemma 1 applies directly to the general model.

Lemma 2b (general model)

Using the definitions in eqs.(A3.1,A3.2) we rewrite $\tilde{\omega}^{\tau_x e_x e_y} \geq \tilde{\omega}^{\tau_x} + \tilde{\omega}^{e_x e_y}$ to obtain eq.(A3.6). Comparing eq.(A3.6) to eq.(17) we note that the supermodularity requirement must now apply to the new instruments. Moreover, to use supermodularity, the deviations in e_y must occur in the same direction as those in e_x. The proof is then identical to that for the simple model.

After redefining creation of enforcement to reflect the modified objective function and IC we use lemmas 1 and 2b to obtain the creation of enforcement proposition for the general model.

Supermodularity conditions

The new supermodularity conditions are:

$$\tilde{W}_{x\ \tau e^*} = (\underset{-}{-p_\tau^w} M_{x\ e^*}) + (\underset{+/-}{-\bar{\Psi}_{x\ \tau e^*}}) + \underset{+}{\Pi_{\tau e^*}} \tag{A3.7}$$

$$\tilde{W}_{y\ \tau^* e} = \underset{-}{\{\underset{-}{p_{\tau^*}^w} S_x' + (\underset{+}{-p_{\tau^*}^w} M_{y\ e})\}} + (\underset{+/-}{-\bar{\Psi}_{y\ \tau^* e}}) \tag{A3.8}$$

Where $\Pi_{\tau e^*} \equiv (\lambda^p - 1)(1 + p_\tau^w) S_x{}' p_{e*}^w$. The only difference in the conditions which were present in the simple model, is that now the strategic externality effects in $\tilde{W}_{x\ \tau e}$ and $\tilde{W}_{y\ \tau^* e^*}$ reflect both the domestic and foreign production externality. This is also the case for $\tilde{W}_{x\ \tau e^*}$ and $\tilde{W}_{y\ \tau^* e}$ and it implies that α_i becomes the determinant of whether the strategic externality effect is positive. Thus, for example:

$$\bar{\Psi}_{x\tau e} = \{(p_e^w - 1) S_x{}' + \alpha_x p_e^w S_x^*{}'\} \lambda_x^\Psi \Psi_x'' \{(1 + p_\tau^w) S_x{}' + \alpha_x p_\tau^w S_x^*{}'\} \tag{A3.9}$$

The exact conditions for α_i under which the strategic externality effects are positive are analyzed in Limão (2001a). Instead of analyzing the general conditions we provide an example where the supermodularity requirements are met.

Parametrized example

The following parametrized example illustrates the existence of parameters such that the general model satisfies the supermodularity conditions, $\tilde{W}_{x\tau e}$, $\tilde{W}_{x\tau e^*}$, $W_{y\tau^* e} \geq 0$ and $W_{y\tau^* e^*} > 0$, as well as the export tax requirement, which are sufficient for the creation of enforcement, as described in sections 6.1 and 6.2.

$$D_x = 1 - q_x \ ; \quad D_x^* = 1 - q_x^* \ ; \quad S_x = p_x \ ; \quad S_x^* = 10p_x^* \ ; \quad \bar{\Psi}_i = \lambda_i^{\Psi}(S_i + \alpha_i S_i^*)^2$$

Symmetric demand and supply functions hold for home's export good, y. Market clearing delivers a world price of $p_x^w = (2 - 2\tau_x + e_x + 10e_x^*)/13$ with a symmetric expression for good y.

Differentiating $\tilde{W}$ (obtained by not restricting the use of e-taxes in the export sector in the original expression in eq.(3)) and using the expression above for p_x^w we have:

$$\tilde{W}_{x\tau e} = \{309 + 4\lambda_x^{\Psi}(20\alpha_x - 11)(5\alpha_x - 6) - 144\lambda^p\}/169 \quad \text{(A3.10)}$$

$$\tilde{W}_{x\tau e^*} = \{-160 - 20\lambda_x^{\Psi}(20\alpha_x - 11)(3\alpha_x - 1) + 120\lambda\}/169 \quad \text{(A3.11)}$$

Solving $\tilde{W}_{x\tau e} = \tilde{W}_{x\tau e^*} = 0$ under the constraints that $\alpha_x \geq 0$, $\lambda_x^{\Psi} \geq 0$ and $\lambda^p \geq 1$ we obtain:

$\alpha_x > 11/20$, $\lambda_x^{\Psi}(\alpha_x) = 9/\{4\alpha_x(-11 + 20\alpha_x)\}$ (> 0) and $\lambda^p(\alpha_x) = (59\alpha_x - 9)/24\alpha_x$ (> 1).

For any given $\alpha_x > 11/20$, $\tilde{W}_{x\tau e} = \tilde{W}_{x\tau e^*} = 0$ intersect at most once in $\lambda^p, \lambda_x^{\Psi}$ space since they are linear in $\lambda^p, \lambda_x^{\Psi}$. This and the continuity of $\tilde{W}_{x\tau e}$ and $\tilde{W}_{x\tau e^*}$ in $\lambda^p, \lambda_x^{\Psi}$ ensures the existence of $\lambda^p, \lambda_x^{\Psi}$ that converge to $\lambda_x^{\Psi}(\alpha_x)$, $\lambda^p(\alpha_x)$. Therefore there exist parameters such that $\tilde{W}_{x\tau e} \geq 0$ and $\tilde{W}_{x\tau e^*} \geq 0$.

In the export sector we have:

$$\tilde{W}_{y\tau^* e} = \{-40 - 20\lambda_y^{\Psi}(11\alpha_y - 20)(\alpha_y - 3)\}/169 \quad \text{(A3.12)}$$

$$\tilde{W}_{y\tau^* e^*} = \{-4 - 2(-20 + 11\alpha_y)(10 - 12\alpha_y)\lambda_y^{\Psi}\}/169 \quad \text{(A3.13)}$$

Solving $W_{y\tau^* e^*} > 0 = W_{y\tau^* e}$ under the constraints that $\alpha_y > 0$ and $\lambda_y^{\Psi} > 0$ we obtain:

$\alpha_y \in (20/11, 3)$ and $\lambda_y^{\Psi} = -2/(11\alpha - 20)(\alpha - 3)$.

The dark curve in figure A1 depicts the combinations of λ_y^{Ψ} and α_y such that $\tilde{W}_{y\tau^* e} = 0$, points north of the curve yield $\tilde{W}_{y\tau^* e} > 0$. The lighter curve depicts $\tilde{W}_{y\tau^* e^*} = 0$. The points east of the segment of $\tilde{W}_{y\tau^* e^*} = 0$ closest to $\tilde{W}_{y\tau^* e} = 0$ yield $\tilde{W}_{y\tau^* e^*} > 0$. Finally note that the export tax requirement, which ensures that the deviation in e_y is in the same direction as e_x, is also satisfied. The requirement we discuss in pages 35 and 36 is for the externality to be sufficiently costly, i.e. for the product $\alpha_y \lambda_y^{\Psi}$ to be sufficiently large. To achieve this start at a point on $\tilde{W}_{y\tau^* e} = 0$ and increase both α_y and λ_y^{Ψ} along the right side of that curve until the requirement is satisfied. At that point any further increases in λ_y^{Ψ}, at given α_y, will yield strictly positive $\tilde{W}_{y\tau^* e}$ and $\tilde{W}_{y\tau^* e^*}$.

Figure A1

Weight, λ_y^{Ψ}, vs. scope of externality, α_y, s.t. $W_{y\tau^* e} = W_{y\tau^* e^*} = 0$