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Stable Multilateral Trade Agreements

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We analyse multilateral tariff negotiations as a game in coalition form. In a model with three identical countries that produce and trade an homogeneous commodity, and where countries' aggregated welfare can weight differently their different components, we analyse how changes in the countries' objective affects the stability of coalitions. In other words, we characterize what tariff-agreements, if any, are stable (i.e. lie in the core).

Introduction

'When the world's largest trading blocks sign a deal reducing trade barriers, everyone is a winner.'[1]

The advantages of cooperative agreements for trade are significant and generally recognized. However, as the history of trade agreements shows, such cooperation is very difficult indeed to achieve. In this paper we deal with the analysis of some of the difficulties that multilateral trade agreements may experience.

When governments set trade policies unilaterally, they usually protect their domestic markets too much. Cooperative agreements for freer trade may well benefit all countries. The General Agreement on Tariffs and Trade (GATT) has been a forum for cooperative trade policies since 1945. Between the end of the Tokyo Round (in 1979) and the beginning of the Uruguay Round (in 1986), however, unilateralism was the rule rather than the exception in world trade affairs. Thus, it is no surprise that the conclusion of the Uruguay Round (in December 1993) was hailed as a major breakthrough. Negotiated over a period of more than seven years, the agreement concerns the reduction of tariffs, the dismantlement of non-tariff barriers and the liberalization of trade in services.

The recent decade of increasing protectionism, as well as the duration and complexity of the Uruguay Round, highlight the fact that, even if countries recognize a great potential for cooperation, this may easily fail. Multilateral agreements may not be enforceable. Cooperation may fail either because of enforcement problems, or because the coalition arrangements that are possible in a multilateral negotiation undermine the stability of general agreements.

The problem of enforcing a cooperative agreement for freer trade is certainly important. As in the Prisoners' Dilemma, although cooperation yields higher payoffs, self-interested parties have incentives to deviate from cooperative agreements, once they have been signed. The problem is severe, as it is usually very difficult to impose sanctions against a country. The creation of the World Trade Organization (WTO), a new body with greater authority and more powerful dispute settlement procedures than previous GATT arrangements, is the result of enforceability receiving greater attention in the Uruguay Round.

However, before attempting to enforce any multilateral agreement, the following questions must be answered: First, is there a multilateral agreement from which no country will have an incentive to defect? And second, if there is one, what is it? Assume that a country that decides not to participate in the general agreement expects that the remaining countries will reach an agreement anyway. Assume that this gives the uncooperative country a better payoff than the general agreement. Then the answer to our first question is no, even if all countries agree that a multilateral agreement is better than unilaterally setting their trade policies. Moreover, even if we answer our first question positively, the answer to our second may well not be the free trade regime.

In this paper we present a model of tariff reduction negotiations and focus our attention on the *stability* of multilateral agreements. We consider a model with three identical countries whose firms produce and trade a single homogeneous commodity. In setting their commercial policy, the governments maximize a social welfare function that depends on domestic welfare (consumer surplus plus domestic profits in domestic markets), exporting firms' profits (currencies) and tariffs revenues. Since setting commercial policies unilaterally is usually inefficient, governments negotiate cooperative agreements to achieve multilateral tariff reductions. We model the cooperative and non-cooperative aspects of this multilateral negotiation. The game in coalitional form that one should use to model such negotiation is not straightforward, because payoffs feasible to a country leaving the multilateral agreement depend on what the remaining countries do. Nevertheless, based on the underlying non-cooperative game that countries play if tariffs are set unilaterally, we claim that it is most reasonable to assume that defection of one country from the grand coalition leads the others to an efficient and symmetric agreement on their feasible set. Thus, we propose a game in coalitional form to model the multilateral negotiations for tariff reduction and characterize the set of agreements that are in the core of the game, that is, such that no country or coalition of countries expects a better outcome for itself if it does not participate in the agreement.[2] We say that an agreement is stable if it lies in the core. We show that the set of agreements that are in the core, if any, depends on the relative importance of each of the factors that are weighted in the social welfare function.

International trade is usually a high conflictive issue in domestic politics because the costs and benefits of different policies are never distributed evenly over the population. It has long been recognized that (internal) disputes over tariff rates usually reflect the atomistic self-interest of the producers, consumers and the government, who have a vital stake in the tariff: 'The history of [American] tariff records the triumph of special interest over the general welfare' (Taussig 1931). Beyond lobbying and special interest groups, balance of payments constraints may provide a motive for increasing export revenues, or public budget constraints may heighten the importance of tariff revenues if collecting money through tariffs is easier than collecting other taxes. We do not model this internal conflict and its resolution explicitly. However, taking the objective function of the government as its reduced form, we analyse how different outcomes affect the possibilities of multilateral cooperation. We can interpret the social welfare function as the result of 'aggregating' internal pressures, domestic policy attitudes, rent-seeking and lobbying practices. More formally, we can also interpret it as the outcome of some median voter mechanism. In the later case the weights of the different components of the government objective function depend on the median preferences for each of these components.

In our model the tariff agreement depends on the different weights that internal surplus, export revenues and tariff revenues have in the aggregate welfare. We show that, for some parameter values, the cooperative game that models the multilateral negotiation to reduce tariffs has an empty core. The instability of a tariff agreement depends on the incentives that a country has to deviate. When a country defects from the multilateral agreement, the two other countries may decide to free-trade among themselves, but to fix a positive tariff against the uncooperative country. That typically reduces the incentives to deviate from the grand coalition. However, a side-effect of the two-country cooperative agreement is to lower tariffs to the uncooperative country. That makes the two-country coalitions more profitable, but in some cases it also makes the third country better off. Even if it suffers higher tariffs than the coalition members, these tariffs are low. Consequently, it can be the case that deviating is a profitable strategy.

The importance of stability in multilateral trade agreements has been stressed previously by Riezman (1985) and Kowalczyk and Sjostrom (1994). While ours is a symmetric model of multilateral trade as a cooperative game without side-payments, Riezman focuses on the role of asymmetries and Kowalczyk and Sjostrom focus on the effects of introducing side-payments. Riezman considers a three-country, three-good pure-exchange model with identical preferences and analyses whether the free trade or customs unions are in the core. In his framework the free trade agreement is the optimal tariff arrangement for any country coalition. He studies whether the grand coalition is in the core as a function of the initial endowments of the different countries, and he finds distributions of initial endowments for which the multilateral free trade agreement is not in the core, while a customs union is in the core. That is, for some asymmetric distributions, while multilateral free trade is not in the core, the latter includes an agreement in which two countries free-trade among themselves and act together against the third country that sets tariffs unilaterally.

In contrast with Riezman's, ours is a symmetric model. This symmetry allows us to concentrate on the stability of multilateral trade agreements as a function of the different weights that different lobbying and special interest groups can have. Our claim is not that the pure characteristics of trade policy agreements with asymmetries between countries (size, objectives, wealth, etc.) or markets (heterogeneous goods) are not relevant for the analysis of the multilateral agreements' stability. However, in order to stress the role of the internal pressures on the stability of tariff agreements, we have chosen to present a symmetric framework.

Kowalczyk and Sjostrom formalize the multilateral trade negotiation as a game with side-payments: their model supports the claim that GATT should be reformed by explicitly allowing side-payments in exchange for commercial policy concessions.

The remainder of the paper is organized as follows. Section I presents the model and characterizes the relevant cooperative game. Section II characterizes the equilibrium of the non-cooperative game and the core of the cooperative game. Section III concludes. The formal proofs of our results are presented in the Appendix.

I. The Model

We consider the international trade of a homogeneous product among three countries, denoted by 1, 2 and 3. The willingness to pay of consumers in country i is expressed by an aggregate linear demand

$$p_i = 1 - Q_i, \qquad i = 1, 2, 3,$$

where p_i denotes the domestic price and Q_i is the total amount sold in country i. Each country has a domestic firm that produces the good, sells it to the domestic market and exports it to the foreign markets.[3] In each country, domestic and importing firms choose quantities in a non-cooperative fashion; that is, the price of the good and the quantities sold by each firm are the result of a Cournot equilibrium.

We are interested in the cooperative and non-cooperative games that the governments of the three countries play when they fix tariffs on the product imported into their domestic market.[4] The tariff that country i imposes on the firm from country j will be denoted by t_{ij} $(i, j = 1, 2, 3, i \neq j)$. A tariff in our framework can be read as an increase in the marginal production cost. In other words, the average production cost of firm from country j in country i is increased by t_{ij}, country i making a profit of t_{ij} on each unit of good that firm j sells in market i.

The objective function of the government of country 1 (which we will identify with country 1) responds to the internal pressures of interest groups referred to in the Introduction. It is a weighted average (with positive weights α, δ, and μ) of the 'internal welfare' (that is the domestic consumer's surplus, C_1, plus the profits of the domestic firm in the domestic market, Π_{11}), the profits of the domestic firm exporting to markets 2 and 3, Π_{12} and Π_{13}, and the revenue raised by tariffs imposed on firms from countries 2 and 3, T_{12} and T_{13}. We have chosen to weight the aggregated welfare in this way, in particular giving a different weight to the firm's profit in the internal market and in the other countries, since that allows us to consider special interest in export revenues (foreign currencies) related to balance of payments constraints, and public budget constraints may stress the importance of tariff revenues if collecting money through tariffs is easier than collecting other taxes.

In other words, country 1 (similarly 2 and 3) chooses tariffs in order to maximize the social welfare function,[5]

$$W_1 = \alpha(C_1 + \Pi_{11}) + \delta(\Pi_{12} + \Pi_{13}) + \mu(T_{12} + T_{13}).$$

We normalize $\alpha = 1$. A configuration of tariffs is denoted by $\mathbf{t} = (t_{12}, t_{13}, t_{21}, t_{23}, t_{31}, t_{32})$; $\mathbf{t}_i$ denotes the pair of tariffs imposed by i on its partners, and $\mathbf{t}_{-i}$, the vector $\mathbf{t}$ without $\mathbf{t}_i$; $W_i(\mathbf{t})$ makes explicit the dependence of W_i on all the tariffs. We require tariffs to be non-negative.

For simplicity, we assume that the production technology has constant returns to scale with marginal (and average) cost normalized to 0. In this framework, simple computations yield the Cournot equilibrium prices and quantities in each country, and evaluating each component of the welfare function yields:

$$C_1 = \frac{(3 - t_{12} - t_{13})^2}{32}, \qquad \Pi_{11} = \frac{(1 + t_{12} + t_{13})^2}{16},$$

$$\Pi_{12} = \frac{(1 - 3t_{21} + t_{23})^2}{16}, \qquad \Pi_{13} = \frac{(1 - 3t_{31} + t_{32})^2}{16},$$

$$T_{12} = t_{12}\frac{(1 - 3t_{12} + t_{13})}{4}, \qquad T_{13} = t_{13}\frac{(1 + t_{12} - 3t_{13})}{4}.$$

Note that the preceding expressions are correct when the quantities exported by the firm from 2 or 3 (which will be referred to as firm 2 or 3) into country 1 are non-negative, that is when $t_{12} \leq (1 + t_{13})/3$, and $t_{13} \leq (1 + t_{12})/3$; and similarly when the expression for the quantity firm 1 sells in countries 2 and 3 is not negative, that is, $t_{21} \leq (1 + t_{23})/3$, and $t_{31} \leq (1 + t_{32})/3$. Otherwise, the preceding expressions should take into account that one, or both, quantities are zero (i.e. that the Cournot quantity is not an interior solution).

Before discussing the possibility of cooperation among countries in setting their tariffs, it is important to characterize the non-cooperative game that countries play if they choose to act non-cooperatively, unilaterally choosing tariffs to maximize their welfare. A *unilateral tariff equilibrium* (UTE) is a vector of tariffs $\mathbf{t}^u$ such that, for each i,

$$W_i(\mathbf{t}^u) \geq W_i(\mathbf{t}_i, \mathbf{t}^u_{-i}) \qquad \text{for all } \mathbf{t}_i \text{ in } R^2_+.$$

Note that C_i, Π_{ii}, T_{ij} and T_{ih} (for j, $h \neq i$) depend only on $\mathbf{t}_i$, while Π_{ij} and Π_{ih} depend only on $\mathbf{t}_{-i}$. Therefore, $\mathbf{t}_\mu$ is a UTE if and only if, for $i = 1, 2, 3$,

$$\mathbf{t}^u_i = \underset{\mathbf{t}_i \in R^2_+}{\operatorname{argmax}} \{C_i(\mathbf{t}_i) + \Pi_{ii}(\mathbf{t}_i) + \mu[T_{ij}(\mathbf{t}_i) + T_{ih}(\mathbf{t}_i)]\}.$$

This implies that $\mathbf{t}^u_i$ is independent of the tariff schedule of the other countries. This simple fact is of important consequences in the analysis of what is possible when countries attempt cooperation.

The tariff configuration of a UTE in general is not efficient, as diminishing all tariffs could increase the welfare of all countries. Recognizing this potential for cooperation, countries may attempt a multilateral negotiation looking for an agreement to decrease tariffs. An agreement among all countries selects a whole tariff scheme. Although two-country coalitions could in principle jointly set tariffs against the third country, we assume that this is not the case. Agreements fix only the tariff that countries charge to the firms of their counterpart in the negotiation, and tariffs to the third country are set non-cooperatively.[6]

The analysis of cooperation is carried out under the Most Favoured Nation (MFN) clause. Under the MFN principle, countries impose the same tariff on all foreign firms that sell in their domestic market and belong to countries that have ratified the agreement. In our model this clause only implies a constraint on the decision of the grand coalition. Formally, MFN implies that $t_{ij} = t_{ih}$, for all $i, j, h = 1, 2, 3$. $i \neq j$, h whenever i, j, and h reach an agreement. In our model with three countries, the MFN clause does not imply any constraints on the two-country negotiations, since, by assumption, agreements fix only the tariff that countries charge each other.

Can we model the multilateral negotiations to set tariffs as a cooperative game with non-transferable utility (bearing in mind that direct payments from one country to another are not possible)? Formally, a non-transferable utility cooperative game is described by a finite set of players N and a characteristic function that assigns to each coalition (a subset of N) the set of utilities that are feasible for players in the coalition. It is clear what the set of players and possible coalitions are for any cooperative game attempting to represent our problem: players are $N=\{1,2,3\}$, and the possible coalitions are N, $\{1,2\}$, $\{1,3\}$, $\{2,3\}$, $\{1\}$, $\{2\}$, $\{3\}$. What utilities are feasible for each coalition is not as easily stated, since benefits for a coalition depend on what tariffs are set by countries outside the coalition. In our model, however, assuming a specific scenario after the defection of one country from the grand coalition allows one to fully characterize the multilateral negotiation as a non-transferable utility cooperative game.

Imagine a single country trying to evaluate the consequences of withdrawing from multilateral cooperation. These consequences very much depend on whether or not the other two continue to cooperate, and on what agreement prevails if cooperation continues among them. If the other two countries decide to cooperate in punishing defection as much as possible, defectors cannot expect very much. Prospects will look brighter to defectors (and thus multilateral agreement will be more difficult) if defection is followed by a cooperative agreement of the other two not specially targeted at punishment. We will argue that, among the many scenarios that may follow after one defection, the latter is the most plausible.

Let us now describe our problem as a non-transferable utility cooperative game. We must consider two distinct possibilities: either the three countries cooperate, or a subset of two cooperate while the third sets tariffs unilaterally. What payoffs are feasible?

1. What is feasible to the grand coalition is unequivocal: it is simply the set of utilities $W=\{W_1(\mathbf{t}), W_2(\mathbf{t}), W_3(\mathbf{t}) \,|\, \mathbf{t}\geq 0 \text{ and } t_{ij}=t_{ih}\}$.
2. The set of utilities that are feasible to any coalition $\{j,h\}$, W_{jh}, is also well defined. Country i not participating in a cooperative agreement with the other countries will set $\mathbf{t}_i=\mathbf{t}_i^u$ since $\mathbf{t}_i^u$ is independent of the tariffs of other countries and thus this policy is optimal for i regardless of whether the other countries cooperate. Therefore, each decision that countries $\{j,h\}$ take concerning their mutual tariffs, taking into account (a) that i acts unilaterally $\mathbf{t}_i=\mathbf{t}_i^u$ and (b) that tariffs against i, t_{ji} and t_{hi}, are set unilaterally, yields a pair of utilities $(W_j(\mathbf{t}), W_h(\mathbf{t}))$.
3. Finally, the utility of country i setting tariffs unilaterally is the more complicated matter. It depends on what agreement (if any) on mutual tariff reduction is reached by $\{j,h\}$. Since the behaviour of the defector is by no means affected by what the other two countries do, and since cooperation among them offers gains above the non-cooperative outcome, it is most likely that cooperative countries facing the defection of a partner will continue to cooperate and reach an efficient outcome.[7] Hence we will assume that, when country i acts unilaterally, it expects that its opponents $\{j,h\}$, facing the two-person bargaining problem with feasible utilities in W_{jh} and status quo $(W_j(\mathbf{t}^u), W_h(\mathbf{t}^u))$, reach agreement according to an efficient and symmetric bargaining solution.[8]

Formally, we propose to represent our problem as the cooperative game in which payoffs to singleton coalitions are computed as follows. For each potential agreement on a pair of mutual tariffs (t_{jh}, t_{hj}), since t_{ji} and t_{hi} are fixed unilaterally by j and h respectively, i gets tariffs $\tau(t_{jh}, t_{hj}) = (\tau_j(t_{jh}, t_{hj}), \tau_h(t_{jh}, t_{hj}))$ such that:

$$\tau_j(t_{jh}, t_{hj}) = \underset{t_{ji} \in R_+}{\operatorname{argmax}} W_j(t_{jh}, t_{ji}, t_{hj}, \tau_h(t_{jh}, t_{hj}), \mathbf{t}_i^u)$$

and similarly for $\tau_h(t_{jh}, t_{hj})$. The resulting tariffs $\underline{\mathbf{t}}^{jh} = (\underline{t}_{ji}, \underline{t}_{jh}, \underline{t}_{hi}, \underline{t}_{hj})$, are then determined by the choice of $(\underline{t}_{jh}, \underline{t}_{hj})$:

$$(\underline{t}_{jh}, \underline{t}_{hj}) = \underset{(t_{jh}, t_{hj}) \in R_+^2}{\operatorname{argmax}} [W_j(t_{jh}, t_{hj}, \tau(t_{jh}, t_{hj}), \mathbf{t}_i^u) - W_j(\mathbf{t}^u)]$$
$$+ [W_h(t_{jh}, t_{hj}, \tau(t_{jh}, t_{hj}), \mathbf{t}_i^u) - W_h(\mathbf{t}^u)].$$

Thus, the utility of coalition $\{i\}$ is $W_i(\mathbf{t}_i^u, \underline{\mathbf{t}}^{jh})$.

Note that $\tau(\underline{t}_{jh}, \underline{t}_{hj})$ may be very different from the UTE tariff because, when countries set their tariffs for the non-cooperating country i, part of their external policy is already fixed by the two-country agreement. The cooperative step has strategic consequences on the subsequent tariffs policy, a feature that would not arise if two-country coalitions could reach agreements on their whole tariff scheme.

We are now ready to discuss multilateral tariff agreements. Given a configuration of tariffs $\mathbf{t}$, we say that it is objected to by a coalition if there is an alternative tariff configuration that the coalition can impose that leaves all its members better off. The grand coalition, $\{1, 2, 3\}$, objects to $\mathbf{t}$ if there is an alternative $\mathbf{t}'$ that leaves all countries better off. Tariffs $\mathbf{t}$ will be objected by a coalition $\{j, h\}$ if it can find tariffs such that both j and h are better off, taking into account that i will set tariffs unilaterally. Finally, $\{i\}$ will object to tariffs $\mathbf{t}$ if it gets a higher payoff by setting the unilateral tariff and expecting that $\{j, h\}$ will set tariffs to obtain a *symmetric efficient solution* of their bargaining problem.

A configuration of tariffs that is not objected to by any coalition is said to be in the *core* of the cooperative game. In our game, any outcome that results in the competition of a set of countries or coalitions of countries can also be implemented by an agreement within the grand coalition. Consequently, if the core is nonempty it must contain some agreement of the grand coalition. We say that the grand coalition is stable if countries in the grand coalition can reach a tariff agreement that lies in the core. In what follows we address the question of what agreements, if any, lie in the core.

II. The Core of the Cooperative Game

The UTE tariff

First of all, we compute the non-cooperative equilibrium, that is the UTE tariffs. This analysis is useful in itself, as it gives the tariffs that will appear in a non-cooperative situation. Moreover, it constitues the threat point of the cooperative agreements.

To fix the UTE tariffs, country 1 (and similarly 2 and 3) solves

$$\underset{(t_{12},t_{13})}{\text{Max}}\ W_1(\mathbf{t}) = \underset{(t_{12},t_{13})}{\text{Max}} \left\{ \frac{(3-t_{12}-t_{13})^2}{32} + \frac{(1+t_{12}+t_{13})^2}{16} + \mu \left[t_{12}\frac{(1-3t_{12}+t_{13})}{4} + t_{13}\frac{(1+t_{12}-3t_{13})}{4} \right] \right\}$$

$$\text{s.t.}\quad 0 \le t_{12} \le (1+t_{13})/3, \qquad 0 \le t_{13} \le (1+t_{12})/3.$$[9]

Solving the first-order conditions of this programme we obtain each country's best response function which is independent of its neighbour's behaviour. (That does not mean that country 1's welfare is independent of the other country behaviour.) The unilateral tariffs' Nash equilibrium $\mathbf{t}^u$ is then:

$$t^u_{ij} = \begin{cases} \dfrac{4\mu-1}{16\mu-6} & \text{if } \mu \ge \frac{1}{2} \\ \frac{1}{2} & \text{if } \mu < \frac{1}{2}. \end{cases}$$

Given the symmetry of the model, if we impose the constraint that $t^u_{ij} = t^u_{ih}$ in the programme, the resulting optimal tariffs would be the same. (We denote the tariff by t^u.) It is also easy to verify that the optimal unilateral tariff is independent of δ, the weight of the domestic firm's profit on foreign markets, since the decision of a country has no effect on this welfare component and the external effects on other countries are not taken into account.

The unilateral tariff is always strictly positive. It is decreasing on μ and tends to $\frac{1}{4}$ (the tariff that maximizes the revenue raised by tariffs) when μ goes to infinity. When μ decreases, the optimal unilateral tariff increases until it reaches the corner solution $t^u = \frac{1}{2}$. At this point no foreign country will sell its product in the domestic market. Tariff increases beyond this point are meaningless. To understand the influence of μ on the unilateral tariff, remember that μ is the weight of the tariff revenue on the domestic country's welfare. If this weight is low enough, the main components of the country welfare over which the country has some control are the domestic consumers' surplus and the profit of the domestic firm in the domestic market.

Why is a prohibitive tariff optimal in this case?[10] Decreasing tariffs from its prohibitive level increases consumers' surplus and decreases the domestic firm's profit (while increasing profits of foreign firms), yet the loss in domestic profit is greater than the gain in consumer surplus, so the domestic welfare will be maximized when the profit of the domestic firm is highest, that is when foreign firms are not allowed to enter the domestic market.[11] The same argument explains the tariff decreases as tariff revenues become important.

The symmetric cooperative agreement of the grand coalition

We now compute the unique efficient and symmetric tariff configuration $\mathbf{t}^*$. Under the MFN principle, the efficient tariffs $\mathbf{t}^*$ solve:

$$\underset{t}{\text{Max}}\ \{W_1(\mathbf{t}) + W_2(\mathbf{t}) + W_3(\mathbf{t})\}$$

$$\text{s.t.}\quad 0 \le t_i \le \tfrac{1}{2}.$$

As before, we can restrict attention to symmetric tariffs, so that the constraints can be written in an easier way. Solving this optimization problem, we find that the symmetric optimal tariff t^* is:

$$t^* = \begin{cases} 0 & \text{if } \mu \le \frac{1}{4} + \delta \text{ and } \delta > \frac{1}{4}, \\ \dfrac{4\mu - 4\delta - 1}{16\mu - 8\delta - 6} & \text{if } \mu > \max\{\frac{1}{2}, \frac{1}{4} + \delta\}, \\ \frac{1}{2} & \text{if } \mu \le \frac{1}{2} \text{ and } \delta \le \frac{1}{4}. \end{cases}$$

The optimal tariff agreement for the grand coalition is decreasing in δ and decreasing (increasing) in μ if δ is lower (greater) than $\frac{1}{2}$. The reasons are similar to the one discussed in the previous section. Note that the free trade agreement is not always the optimal decision for the grand coalition. First, in the extreme case in which exports and tariff revenue have little weight on each country's welfare, autarchy is the optimal situation. To understand the intuition for this result, remember that very low δ and μ means that each country is interested only in the consumer surplus and the domestic firm's profit in the internal market. In particular, for $\delta = 0$ the discussion is the same as for the unilateral tariff, since the only gain associated with countries' cooperation is precisely to internalize firms' profits in foreign countries. Not being interested in either the firm's profit abroad or the tariff revenue, the government's trade-off between consumer surplus and firm profit in this case leads it to support the best strategy for firms. Second, when the weight of the revenue raised by tariffs is important, countries have an interest in fixing positive tariffs in order to get positive revenue from foreign firms.

The cooperative agreements of two-country coalitions

We must first compute $\tau(\cdot)$, that is the function that yields the tariffs that each country in a two-country coalition $\{j, h\}$ unilaterally charges to the third country, i, for each possible agreement (t_{jh}, t_{hj}). Given $\tau(\cdot)$, we can compute the optimal tariffs $(\underline{t}_{jh}, \underline{t}_{hj})$. Given the symmetry of the model, $\tau_j(\cdot) = \tau_h(\cdot) = \tau(\cdot)$, and we can consider $\underline{t}_{jh} = \underline{t}_{hj}$. For notational convenience we will denote $\underline{t}_M = \underline{t}_{jh}$ (M stands for 'member' of the coalition) and $\underline{t}_N = \tau(\underline{t}_M, \underline{t}_M)$ (N stands for 'non member').

Lemma 1 states the efficient and symmetric tariffs a two-country coalition sets, using the following notation:

$$\beta(\mu) = \frac{4\mu - 1}{3(8\mu - 1)},$$

$$\sigma(\mu, \delta) = \frac{3\mu(4\mu - 1)(8\mu - 1) - \delta(16\mu - 3)(7\mu - 1)}{6\mu(8\mu - 1)(8\mu - 3) - \delta(16\mu - 3)^2}$$

$$\rho(\mu, \delta) = \frac{3\mu(4\mu - 1)(8\mu - 1) - 5\delta\mu(16\mu - 3)}{6\mu(8\mu - 1)(8\mu - 3) - \delta(16\mu - 3)^2}.$$

Lemma 1. Assume that two countries jointly set their cross-tariff, selecting an efficient and symmetric cooperative solution, and then decide unilaterally the tariff they will apply to the third country, which in turn sets tariffs against the coalition unilaterally. Then, the resulting tariffs are:

For $\mu \leq \frac{1}{4}$: $\underline{t}_M = 0$ and $\underline{t}_N = 0$ iff $\delta \geq \frac{1}{2}$

$\underline{t}_M = \frac{1}{2}$ and $\underline{t}_N = \frac{1}{2}$ otherwise.

For $\frac{1}{4} < \mu \leq \frac{1}{2}$: $\underline{t}_M = 0$ and $\underline{t}_N = \beta(\mu)$ iff $\delta > \dfrac{3(-4\mu^2 + 8\mu - 1)(8\mu - 1)}{8(7\mu - 1)^2}$

$\underline{t}_M = \frac{1}{2}$ and $\underline{t}_N = \frac{1}{2}$ otherwise.

For $\mu \geq \frac{1}{2}$: $\underline{t}_M = \sigma(\mu, \delta)$ and $\underline{t}_N = \rho(\mu, \delta)$ iff $\delta < \dfrac{3\mu(4\mu - 1)(8\mu - 1)}{(16\mu - 3)(7\mu - 1)}$

$\underline{t}_M = 0$ and $\underline{t}_N = \beta(\mu)$ otherwise.

First, note that the functional forms we are using imply that the two-country coalition's best response (but not the countries' payoff) is independent of non-member's decision. This absence of strategic interactions at this level is related to the linearity of the cost function, but it does not depend on the particular demand function we are using. Second, we have different regions depending on the parameters of the welfare function. Note that $\underline{t}_N$ is decreasing in $\underline{t}_M$. Note also that $\underline{t}_M \leq \underline{t}_N$ (with equality only when both are either 0 or $\frac{1}{2}$).

Combining the tariff structure defined in Lemma 1 with the unilateral tariff scheme and the grand coalition agreement (analysed in the previous section), we have different regions depending on the value of the welfare function parameters. The different cases are represented in Figure 1 in the (δ, μ) space. It can be shown that $t^* \leq \underline{t}_M \leq t_N \leq \underline{t}^u$. (The equalities are reached in the corner solutions.)

Necessary and sufficient conditions for existence of the core

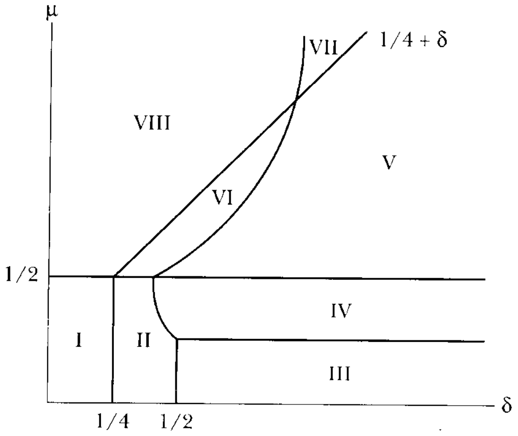
In a symmetric cooperative game such as the one we are examining, if the core is not empty, it must contain the symmetric efficient agreement. If the symmetric efficient agreement is not in the core, then the core is empty. Therefore, the core is not empty if and only if no coalition objects to the symmetric efficient agreement of the grand coalition **t***. (Of course, if the core is non-empty, it usually contains other tariffs besides the symmetric efficient agreement.)

The symmetric efficient agreement of the grand coalition **t*** is in the core if and only if a country does not win by leaving the grand coalition, that is, if $W_i(\mathbf{t}^*) \geq W_i(\mathbf{t}_i^u, \underline{\mathbf{t}}^{jh})$. Proposition 1 states the necessary and sufficient conditions for the core to be non-empty.

Proposition 1. The core is empty if and only if one of the following conditions holds:

(1) $\mu \leq \frac{1}{4}$ and $\delta > \frac{1}{2}$;
(2) $\frac{1}{4} < \mu \leq \frac{1}{2}$ and

$$\frac{(8\mu - 1)^2}{4(4\mu - 1)(12\mu - 1)} > \delta > \frac{3(-4\mu^2 + 8\mu - 1)(8\mu - 1)}{8(7\mu - 1)^2};$$



where in

I	$t^u = \frac{1}{2}$	$\underline{t}_M = \frac{1}{2}$	$\underline{t}_N = \frac{1}{2}$	$t^* = \frac{1}{2}$
II	$t^u = \frac{1}{2}$	$\underline{t}_M = \frac{1}{2}$	$\underline{t}_N = \frac{1}{2}$	$t^* = 0$
III	$t^u = \frac{1}{2}$	$\underline{t}_M = 0$	$\underline{t}_N = 0$	$t^* = 0$
IV	$t^u = \frac{1}{2}$	$\underline{t}_M = 0$	$\underline{t}_N = \beta(\mu)$	$t^* = 0$
V	$t^u = \dfrac{4\mu - 1}{16\mu - 6}$	$\underline{t}_M = 0$	$\underline{t}_N = \beta(\mu)$	$t^* = 0$
VI	$t^u = \dfrac{4\mu - 1}{16\mu - 6}$	$\underline{t}_M = \sigma(\mu, \delta)$	$\underline{t}_N = \rho(\mu, \delta)$	$t^* = 0$
VII	$t^u = \dfrac{4\mu - 1}{16\mu - 6}$	$\underline{t}_M = 0$	$\underline{t}_N = \beta(\mu)$	$t^* = \dfrac{4\mu - 1 - 4\delta}{16\mu - 6 - 8\delta}$
VIII	$t^u = \dfrac{4\mu - 1}{16\mu - 6}$	$\underline{t}_M = \sigma(\mu, \delta)$	$\underline{t}_N = \rho(\mu, \delta)$	$t^* = \dfrac{4\mu - 1 - 4\delta}{16\mu - 6 - 8\delta}$

FIGURE 1

(3) $\mu > \frac{1}{2}$ and

$$\frac{(4\mu - 1)(8\mu - 1)^2}{4(8\mu - 3)(12\mu - 1)} > \delta > \max\left\{\frac{3(-4\mu^2 + 8\mu - 1)(8\mu - 1)}{8(7\mu - 1)^2}, \mu - \frac{1}{4}\right\};$$

(4) $\mu > \frac{1}{2}$ and $F(\mu) \leq \delta \leq [3\mu(4\mu - 1)(8\mu - 1)]/[(16\mu - 3)(7\mu - 1)]$, where $F(\mu)$ is a function lying under $[3\mu(4\mu - 1)(8\mu - 1)]/[(16\mu - 3)(7\mu - 1)]$ in a nonempty interval $[\frac{1}{2}, \mu']$.

Figure 2 shows the region in which the core is empty. When μ is very low, i.e. $\mu \leq \frac{1}{4}$, the core is empty when δ is large enough (with respect to μ), that is when countries are eager to export. The reason is that δ measures the claims of each coalition member for the damages that the tariffs of other countries impose on it. Consequently, countries participating in any multilateral agreement will have an incentive to set very low tariffs in order to promote exports. Obviously, the grand coalition can set the lowest tariffs. But if the reduction of tariffs is important enough in the two-country coalition (in regions III and IV they agree on the free trade), the non-member countries can benefit from a significant exports profit without renouncing the revenues raised by their domestic tariffs. That is why the incentive to free-ride in multilateral trade agreements is strong when the weight of exports on the welfare function is high relatively to the importance of the revenue raised by tariffs.

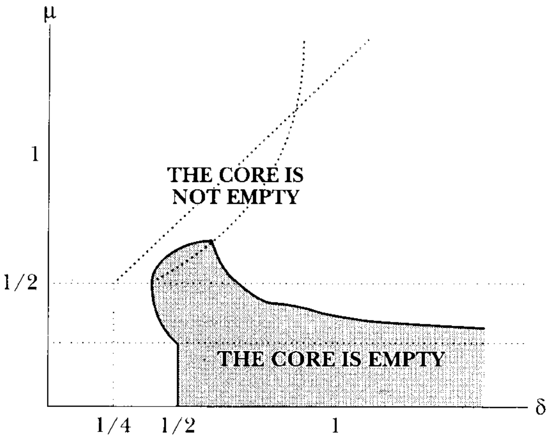


FIGURE 2

However, for $\mu > \frac{1}{4}$, one can expect emptiness of the core for 'intermediate' values of δ, and no longer for very high δs. To understand the reason for this, let us focus on regions IV and V in Figure 1. In these regions, $\underline{t}_M = 0$ and $\underline{t}_N = \beta(\mu)$. On the one hand, the interest of the countries in raising their export revenues is high enough so that two countries have incentives to free-trade among themselves as they decide to form a coalition, so $\underline{t}_M = 0$. On the other hand, the tariff that each of these cooperating countries will impose on the third country depends on their interest in raising money through tariffs, $\underline{t}_N = \beta(\mu)$, because this tariff does not influence the profits of their exporting activity. If we look now at the non-cooperating country's welfare, the more interested it is in export revenues (the higher δ), the more damage $\beta(\mu)$ imposes on its welfare compared with the tariff set by the coalition of the whole, $t^* = 0$. Therefore, for high δ, no country is interested in deviating from the free trade agreement of the grand coalition, while there is interest in deviating for δ low enough in regions IV and V (that is, for intermediate δs). Similar reasoning applies to region VI, but now $\underline{t}_N$ depends on both μ and (indirectly) δ. Note finally that, for μ high enough, $\beta(\mu)$ or $\sigma(\mu, \delta)$ are so high that every individual country prefers to cooperate rather than suffer $\underline{t}_N$.

Moreover, there are regions of parameters where the core is not empty but does not include the free trade. In the extreme region I (see Figure 1), autarky is the only symmetric agreement in the core, while in regions VII and VIII, the core includes symmetric agreements only with strictly positive (but not prohibitive) tariffs.

Finally, let us remark that the conclusions of our analysis are robust to the way in which we have pooled the different arguments of the social welfare function. If the government's objective function is the weighted average of consumers' surplus, domestic firm profits (both in the domestic market and in the foreign markets), and tariffs revenues, then, as in the case analysed above, there is a region of parameters where the core is empty. This assertion is easy to confirm. If we set $\delta = 1$ in our model, we are in a particular case of the previous situation, and for low variations of tariff revenues the core is empty.

III. Conclusion

Our analysis suggests that, even if multilateral trade negotiations may yield gains to all participants, agreements can be unstable. There may be no cooperative agreement to which all countries will subscribe. Moreover, this does not depend on the usual arguments about incompatible claims and immature positions of some of the (developing) countries. The problem may arise in completely symmetric trade talks when negotiators must follow an objective function which weights domestic producers, consumers and government interests that are not coincident.

The 'internal welfare' of a country depends only on the tariffs it fixes, and this is not influenced by the behaviour of the other countries. However, what the exporting firm gets in the foreign markets strongly depends on the foreign tariffs. When a coalition of cooperative countries reaches a partial agreement, they usually set tariffs lower than if they were playing in a non-cooperative way. The outsider country takes advantage of this, getting more profits. This free rider problem may be severe enough to yield an empty core, so that no multilateral agreement to reduce tariffs can be reached.

APPENDIX

Proof of Lemma 1

At the second stage, the welfare of country 1 is concave in $\underline{t}_{13}$ (similarly, the welfare of country 2 is concave in $\underline{t}_{23}$) if and only if $\mu > \frac{1}{8}$. Consequently we have the following.

(a) If $\mu \leq \frac{1}{8}$, the optimal tariff is a corner solution (and the same for both countries), so $\underline{t}_N = \underline{t}_{13} = \underline{t}_{23}$; that is,

$$\underline{t}_N = 0 \qquad \text{if } \underline{t}_M \leq 1/(8\mu + 7) \qquad \text{or}$$
$$\underline{t}_N = (1 + \underline{t}_M)/3 \qquad \text{if } \underline{t}_M \geq 1/(8\mu + 7).$$

(In the second case country 3 does not export to countries 1 and 2.)

In the first stage, when $\underline{t}_M$ is decided, the optimal strategy for the coalition is to set $\underline{t}_M = 0$ (and consequently they will unilaterally choose $\underline{t}_N = 0$ afterwards) if and only if $\delta \geq \frac{1}{2}$; and $\underline{t}_M = \frac{1}{2}$ (and in the second stage they will choose $\underline{t}_N = \frac{1}{2}$) if and only if $\delta \leq \frac{1}{2}$.

(b) If $\mu \geq \frac{1}{8}$, the optimal tariff can be an interior solution or a corner solution. More precisely, the optimal decision in the second stage is

$$\underline{t}_N = 0 \qquad \text{if } \underline{t}_M \leq \frac{1 - 4\mu}{8\mu + 3}$$
$$\underline{t}_N = \frac{(4\mu - 1) + \underline{t}_M(8\mu + 3)}{3(8\mu - 1)} \qquad \text{if } \mu \geq \underline{t}_M \geq \frac{1 - 4\mu}{8\mu + 3}$$
$$\underline{t}_N = (1 + \underline{t}_M)/3 \qquad \text{if } \underline{t}_M \geq \mu.$$

The first stage of the problem is somewhat more complicated.

(i) If $\mu \geq \frac{1}{2}$, in the second stage an interior tariff will be set for sure. Given this continuation of the game, we can write the first-stage welfare function of a member country. This function is convex in $\underline{t}_M$ if and only if:

$$\delta \geq \frac{6\mu(8\mu - 1)(8\mu - 3)}{(16\mu - 3)^2} = \delta^*(\mu).$$

Consequently, a corner solution will be optimal for $\underline{t}_M$ if $\delta \geq \delta^*(\mu)$. More precisely, countries 1 and 2 will choose $\underline{t}_M = 0$, since for these values of δ this gives a higher welfare than the other corner solution, $(7\mu-1)/(16\mu-3)$. In this case, countries 1 and 2 will choose the tariff $\underline{t}_N=\beta(\mu)$.

For $\delta<\delta^*(\mu)$, the interior solution is optimal whenever it lies in the interval $(0,\frac{1}{2})$. The eventual interior solution is defined by $\underline{t}_M=\sigma(\mu,\delta)$. This function is always lower than $\frac{1}{2}$ for $\mu>\frac{1}{2}$ and will be positive if and only if

$$\delta<\frac{3\mu(4\mu-1)(8\mu-1)}{(16\mu-3)(7\mu-1)}=\delta^{**}(\mu).$$

It can be proved that $\delta^{**}(\mu)<\delta^*(\mu)$ for $\mu>\frac{1}{2}$. Therefore, there are two regions for $\mu>\frac{1}{2}$: $\underline{t}_M=\sigma(\mu,\delta)$ if $\delta<\delta^{**}(\mu)$, with $\underline{t}_N=\rho(\mu,\delta)$ in the continuation of the game; and $\underline{t}_M=0$ if $\delta\geq\delta^{**}(\mu)$, with $\underline{t}_N=\beta(\mu)$ in the following stage.

(ii) For $\frac{1}{4}<\mu\leq\frac{1}{2}$, note that at the second stage we have

$$\underline{t}_N=\frac{(4\mu-1)+\underline{t}_M(8\mu+3)}{3(8\mu-1)} \qquad \text{if } \mu\geq\underline{t}_M$$

$$\underline{t}_N=(1+\underline{t}_M)/3 \qquad \text{otherwise.}$$

First of all, we could have two regions: $\frac{1}{4}<\mu<\frac{3}{8}$ and $\frac{3}{8}\leq\mu\leq\frac{1}{2}$. In the second one, the welfare of a coalition member at the first stage is concave in $\underline{t}_M$ when the decision $\underline{t}_N$ is interior. But the interior solution $\underline{t}_M$ takes values greater than $\frac{1}{2}$. Second, for $\underline{t}_N=(1+\underline{t}_M)/3$, the welfare function at stage 1 is convex if and only if $3\mu<1+2\delta$. The candidate for an interior solution in this region is

$$\underline{t}_M=\frac{-4\delta+3\mu}{-3-8\delta+12\mu},$$

but for $\mu<\frac{1}{2}$ this gives a tariff $\underline{t}_M>\frac{1}{2}$. Consequently, for $\frac{1}{4}<\mu\leq\frac{1}{2}$ we must take care of the three corner solutions: $\underline{t}_M=0$ and $\underline{t}_N=\beta(\mu)$: $\underline{t}_M=\frac{1}{2}$ and $\underline{t}_N=\frac{1}{2}$; $\underline{t}_M=\mu$ and $\underline{t}_N=(1+\mu)/3$. Comparing the welfare of coalition members at these corner solutions, we see that the optimal tariff agreement is

$$\underline{t}_M=0 \qquad \text{iff } \delta>\frac{3(-4\mu^2+8\mu-1)(8\mu-1)}{8(7\mu-1)^2}$$

$$\underline{t}_M=\tfrac{1}{2} \qquad \text{otherwise.}$$

(iii) Finally, we must consider the cases in which $\frac{1}{8}\geq\mu\geq\frac{1}{4}$. At stage 1, again, only the corner solutions can be optimal. We must consider $\underline{t}_M=0$ and then $\underline{t}_N=0$; $\underline{t}_M=(1-4\mu)/(3+8\mu)$ and $\underline{t}_N=0$; $\underline{t}_M=\mu$ and then $\underline{t}_N=(1+\mu)/3$; $\underline{t}_M=\frac{1}{2}$ and $\underline{t}_M=\frac{1}{2}$.

Comparing the welfare reached by country 1 under the four different possibilities, and after tedious calculations, we conclude that the second possibility is always dominated by the first one, as is the third. Moreover, the optimal strategy in the cooperative stage will be $\underline{t}_M=0$ if $\delta\geq\frac{1}{2}$, while $\underline{t}_M=\frac{1}{2}$ for $\delta\leq\frac{1}{2}$. □

Proof of Proposition 1.

We must analyse the different regions in Figure 1.

Region I $\mu\leq\frac{1}{2}$ and $\delta\leq\frac{1}{4}$. In this case, $t^*=\frac{1}{2}$, $\underline{t}_M=\underline{t}_N=\frac{1}{2}$ and $t^u=\frac{1}{2}$. The UTE yields total protectionism, it is efficient, and it lies in the core. It is a degenerate region, as total protectionism is efficient from both a unilateral and a global point of view.

Region II $\mu\leq\frac{1}{2}$ and $\frac{1}{4}<\delta\leq\frac{1}{2}$. In this case, $t^*=0$, $\underline{t}_M=\underline{t}_N=\frac{1}{2}$ and $t^u=\frac{1}{2}$. Both a one-country and a two-country coalition agreement yield total protectionism, but it is inefficient. The efficient symmetric agreement of the grand coalition yields free trade. Since free trade is strictly preferred to total protectionism by all countries, it cannot be objected to by any coalition and therefore it lies in the core.

Region III $\mu \le \frac{1}{2}$ and $\delta > \frac{1}{2}$. In this case $t^* = 0$, $\underline{t}_M = \underline{t}_N = 0$ and $t^u = \frac{1}{2}$. The efficient symmetric agreement of the grand coalition yields free trade, and in addition the symmetric efficient agreement of $\{j, h\}$ yields free trade in countries j and h. The payoff to country i under general free trade is lower than it is if i unilaterally protects its domestic market while retaining free access to j and h. Therefore free trade, the symmetric agreement of the grand coalition, is not in the core and the core is empty.

Region IV $\frac{1}{4} < \mu \le \frac{1}{2}$ and $\delta > [3(-4\mu^2 + 8\mu - 1)(8\mu - 1)]/[8(7\mu - 1)^2]$. In this case, $t^* = 0$, $\underline{t}_M = 0$, $\underline{t}_N = \beta(\mu)$ and $t^u = \frac{1}{2}$. The core is empty if and only if $W_3[\{1, 2\}, \{3\}] > W_3[\{1, 2, 3\}]$, that is, if:

$$12 + 4\delta\left(1 - \frac{4\mu - 1}{8\mu - 1}\right)^2 > 11 + 4\delta.$$

Simple calculations shows that the preceding equation is equivalent to:

$$\delta < \frac{(8\mu - 1)^2}{4(4\mu - 1)(12\mu - 1)}.$$

Region V $\mu > \frac{1}{2}$ and $\delta > \max\{[3\mu(4\mu - 1)(8\mu - 1)]/[(16\mu - 3)(7\mu - 1)], \mu - \frac{1}{4}\}$. In this region, $t^* = 0$, $\underline{t}_M = 0$, $\underline{t}_N = \beta(\mu)$ and $t^u = \tau(\mu)$. After some calculations, we find that $W_3[\{1, 2\}, \{3\}] > W_3[\{1, 2, 3\}]$ if and only if:

$$16\left[\frac{\mu^2 + 5\mu - 2}{8\mu - 3} + \frac{4\delta\mu^2}{(8\mu - 1)^2}\right] > 11 + 4\delta,$$

that is, if and only if:

$$\delta < \frac{(4\mu - 1)(8\mu - 1)^2}{4(8\mu - 3)(12\mu - 1)}.$$

Region VI $\mu > \frac{1}{2}$ and $\mu - \frac{1}{4} \le \delta \le [3\mu(4\mu - 1)(8\mu - 1)]/[(16\mu - 3)(7\mu - 1)]$. In this region, $t^* = 0$, $\underline{t}_M = \sigma(\mu, \delta)$, $\underline{t}_N = \rho(\mu, \delta)$ and $t^u = \tau(\mu)$. The zones in this region are difficult to identify. For $\delta = \mu - \frac{1}{4}$ the core is not empty, while for $\delta = [3\mu(4\mu - 1)(8\mu - 1)]/[(16\mu - 3)(7\mu - 1)]$ there is a $\mu'(\approx 0{\cdot}6)$ such that the core is non-empty for $\mu' \le \mu \le (25 + \sqrt{433})/32$ and the core is empty for $\frac{1}{2} < \mu < \mu'$. Inside the region, it is possible to find a function $F(\mu)$ such that the core is empty if and only if $F(\mu) \le \delta \le [3\mu(4\mu - 1)(8\mu - 1)]/[(16\mu - 3)(7\mu - 1)]$. (The particular expression of $F(\mu)$ is very long, and we have calculated it using Mathematica. We could also have applied arguments using continuity to demonstrate the existence of a sub-region in which the core is empty.)

Region VII $\mu > \frac{1}{2}$ and $\mu - \frac{1}{4} \ge \delta \ge [3\mu(4\mu - 1)(8\mu - 1)]/[(16\mu - 3)(7\mu - 1)]$. In this region, $t^* = \gamma(\mu, \delta)$, $\underline{t}_M = 0$, $\underline{t}_N = \beta(\mu)$ and $t^u = \tau(\mu)$. After some calculations, we find that the core is not empty if and only if:

$$\Phi(\mu, \delta) \equiv 1 - 20\mu + 96\mu^2 - 48\delta\mu^2 + 128\mu^3(\delta - 1) < 0.$$

$\Phi(\mu, \delta)$ is increasing in δ in this region. Let $\hat{\delta}(\mu)$ be defined by $\Phi(\mu, \delta) = 0$. Then, the core is not empty if $\delta \ge \hat{\delta}$. Proving that the core exists at all points of the region is equivalent to proving that $\hat{\delta}(\mu) < \mu - \frac{1}{4}$ in this region. This is the case since $\hat{\delta}(\mu) < \mu - \frac{1}{4}$ for $\mu \ge \underline{\mu} \equiv (14 + 2\sqrt{33})/32$ and the minimum μ for which region VII is defined is characterized by the crossing of $\delta = \mu - \frac{1}{4}$ and $\delta = [3\mu(4\mu - 1)(8\mu - 1)]/[(16\mu - 3)(7\mu - 1)]$, which occurs at $\bar{\mu} \equiv (25 + \sqrt{433})/32$. It is easy to verify that $\bar{\mu} > \underline{\mu}$.

Region VIII $\mu > \frac{1}{2}$ and $\delta \le \min\{[3\mu(4\mu - 1)(8\mu - 1)]/[(16\mu - 3)(7\mu - 1)], \mu - \frac{1}{4}\}$. In this region, $t^* = \gamma(\mu, \delta)$, $\underline{t}_M = \sigma(\mu, \delta)$, $\underline{t}_N = \beta(\mu)$ and $t^u = \tau(\mu)$. Here the core is not empty if

$$-243\delta - 432\delta^2 + 324\mu + 4320\delta\mu + 5760\delta^2\mu - 5616\mu^2 - 29952\delta\mu^2 - 24576\delta^2\mu^2$$
$$+33408\mu^3 + 92160\delta\mu^3 + 32768\delta^2\mu^3 - 82944\mu^4 - 98304\delta\mu^4 + 73728\mu^5$$

is positive. The function above is convex in δ. Its minimum can be reached either in a corner solution ($\delta = 0$ or $\mu - \frac{1}{4}$) or in an interior solution (satisfying the first-order condition when it lies in the region). After some calculations, it can be verified that the three possibilities imply a positive value for the function. Consequently the core is non-empty. □

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NOTES

1. 'EU and GATT, Drinks All Round'. *The Economist* 18 December 1993, p. 49.
2. Another approach to the problem of tariff-setting is to consider that the countries play a repeated game. In such a framework, Bagwell and Staiger (1993a, b); Dixit (1987); Hungerford (1991) and Riezman (1991) characterize the circumstances under which cooperation can be self-enforcing.
3. The assumption that there is only one firm in each country is made for simplicity.
4. The analysis is similar if countries choose subsidiaries to domestic production or export subsidies.
5. A welfare function with different weights on consumers' surplus and domestic firm's profits (i.e. $\alpha' C_1 + \delta'(\Pi_{11} + \Pi_{12} + \Pi_{13}) + \mu'(T_{12} + T_{13})$) would yield similar qualitative results.
6. It hardly seems possible that countries reach binding trade agreements on the treatment of third parties without its participation.
7. Ray and Vorha (1994), who address problems of this kind in a more general framework, call the coalition structure ($\{i\}$, $\{j, h\}$) an 'Equilibrium Coalition Structure'.
8. Symmetry is assumed for convenience. Note also that, by the symmetry of the bargaining problem, any efficient and symmetric bargaining solution selects the same outcome.
9. Any tariff $t_{13} > (1 + t_{12})/3$ is equivalent to $t_{13} = (1 + t_{12})/3$, as the production of firm 3 in market 1 will be zero.
10. Note that if the three firms were domestic the country's welfare would be maximized when no distortion is introduced ('tariffs' equal to zero). Some firms, however, are foreign, and they obtain profits that do not enter into the country's welfare function.
11. Stronger competition among firms than in our case may yield only interior solutions ruling out prohibitive tariffs. In fact, if firm competition is extreme (i.e. Bertrand with homogeneous product) the optimal tariff is always zero.

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