Tariff Retaliation versus Financial Compensation in the Enforcement of International Trade Agreements*

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Abstract

We analyze whether financial compensation is preferable to the current system of dispute settlement in the World Trade Organization that permits member countries to impose retaliatory tariffs in response to trade violations committed by other members. We show that monetary fines are more efficient than tariffs in terms of granting compensation to injured parties when violations occur. However, fines suffer from an enforcement problem since they must be paid by the violating country. If the payment of fines must ultimately be supported by the threat of retaliatory tariffs, then they do not yield a more cooperative outcome than the current system. We also consider the exchange of bonds as an enforcement mechanism. These instruments can improve enforcement relative to a system based on retaliatory tariffs but only if bonds are exchanged between countries of asymmetric size. In some cases, small countries, which have raised the issue of financial compensation, do not have to post any bond or pay any fines along the equilibrium path.

Keywords: Dispute Settlement, WTO, Tariffs, Monetary Fines, Bonds, Concessions, Reciprocity, Policy Coordination.

JEL Classifications: F13, F42, K33, H77.

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1 Introduction

One of the major goals of the World Trade Organization (WTO) is to reduce policy barriers to international trade. Yet, its dispute settlement system allows members to raise tariffs in response to trade violations committed by other members. Although retaliation is permitted only as a last resort the fact that the WTO even permits tariff escalation appears to be a direct contradiction of the ideal of freer trade. This contradiction as well as the fact that many small countries cannot effectively retaliate via tariffs have lead to calls for alternative trade dispute remedies.[1]

There are at least two possible reasons why the WTO's Dispute Settlement Understanding (DSU) permits tariff retaliation. First, the threat of retaliation might encourage members to comply with WTO rules: in the absence of any fear of foreign retaliation, members would be tempted to raise their trade barriers whenever so urged by their import lobbies since domestic exporters would suffer no retaliation and thus would have little incentive to counter-lobby to keep the local market open. Second, tariff retaliation may allow an injured country to obtain partial compensation by either improving its terms-of-trade (which happens if it is large enough to affect world prices) or by benefiting those import competing sectors that are favored due to political economy considerations. Of course, even if tariff retaliation helps enforce cooperation and/or enable compensation in trade agreements, it may not necessarily be the optimal instrument for achieving these objectives. In principle, monetary fines payable by a country that violates WTO rules could have both a deterrent effect and a compensatory one while simultaneously avoiding the well-known inefficiencies of tariffs. Our goal in this paper is to evaluate whether the use of fines and bonds can improve upon the WTO's current dispute settlement system based on retaliatory tariffs.

The idea that trade disputes be settled via financial compensation has gained substantial attention in recent years with several new proposals to reform the DSU in the Doha Round, which is still under way.[2] Such proposals have tended to originate in countries that do not have sufficient market power to influence world prices and are therefore incapable of either inflicting significant harm on

[1] See Hoekman and Kostecki (2001) for a good overview of the WTO's dispute settlement procedures. Lawrence (2003) notes that WTO rules are designed to preserve the existing balance of concessions (i.e. to maintain *reciprocity*). Ethier (2003) argues that the role of the WTO's dispute settlement procedure is "not to facilitate punishment: It is to constrain it."

[2] For example, in an article in the *Financial Times* of 24th June, 2004, Bronckers and Van Den Broek have argued strongly in favor of financial compensation as a means of settling trade disputes. See Bronckers and Van Den Broek (2005) for an in-depth discussion of the legal and economic arguments in favor of financial compensation.

large countries or achieving compensation through tariff retaliation. Similar proposals were made in the early 1960s by Uruguay and Brazil who wanted less developed countries to be provided with financial compensation for GATT violations committed by developed countries. As Dam (1970) notes, such proposals are attractive for several reasons. First, the principle of financial liability to injured parties underlies domestic laws across the world and its use in international law seems natural. Second, tariff retaliation is often not in the interest of an injured party. For example, optimal tariffs for countries that are too small to influence world prices would typically be near zero. As a result, any tariff retaliation would only *further* reduce their welfare.[3]

Desirable as it may seem, the implementation of financial compensation faces important hurdles. We address what we think is the major hurdle: *enforcing such a system*. How does one ensure that the required fine, whatever it is ruled to be, is actually paid by a violating country? While an injured country can implement retaliatory tariffs without requiring any cooperation from a violating country, such is not the case for fines. Ultimately, a violating country has to agree to pay the fine and it will only do so when it is in its best interest since there exists no supra-national authority that can enforce the payment of the fine.[4] This enforcement problem with financial compensation is clearly reflected in the current DSU – it allows for compensation but does not specify the form it must take. Article 22.2 of the DSU states that the compensation must be mutually agreed upon and if it is not, an injured country can apply for retaliation. The only case that we know of where a dispute resulted in monetary compensation was when the US was found guilty of non-payment of royalties by US *firms* to the EU. This shows that while financial compensation is possible under the DSU, it simply has not been agreed to in most trade disputes that have come before the WTO.[5]

[3] One alternative is for such countries to retaliate in other parts of the WTO agreement. In the recent bananas dispute involving the European Union (EU) and several banana exporters, Ecuador was authorized to do so and it threatened the EU that it would not respect the intellectual property provisions in the TRIPS for EU products unless the EU carried out the DSU ruling (WTO document WT/DS27/ARB/ECU, 2000). Limão (2005) provides a formal analysis of the enforcement effects of this type of linkage of cooperation across issues with international spillovers in the context of trade agreements. Although this is legally possible, Ecuador must no longer think this recourse is sufficiently satisfactory since it is one of the countries that recently proposed monetary fines to address trade disputes (WTO document TN/DS/W/9, 2002). A different proposal was put forward by Mexico who argued that injured countries be allowed to trade their retaliation rights, i.e. to "sell" them to countries that have sufficient market power to credibly threaten tariff retaliation. Bagwell, Mavroidis, and Staiger (2004a) analyze this proposal and formally show how a properly designed auction for retaliation rights would be efficiency improving.

[4] Another hurdle might be an informational one: determining the financial loss incurred by an exporter. However, a similar issue occurs under the current tariff retaliation system. For more recent discussions by legal scholars on improvements of the WTO's DSU and use of monetary compensation see Shaffer (2003) and Hudec (2002).

[5] However, recently monetary fines have been introduced by the US in its preferential trade agreements with Singapore, Chile, the central American countries, and Australia. More specifically, in these agreements, monetary

An important objective of this paper is to analyze the effectiveness of alternative dispute remedies in maintaining relatively low trade barriers. We also analyze the effectiveness of the different systems from the perspective of compensating injured countries. In so doing, we argue that one needs to account not only for how a remedy is able to enforce cooperation but also *how the remedy itself can be enforced*. For fines to succeed in enforcing low tariffs and providing compensation, it is crucial that they be backed by a *supporting* instrument that is not controlled by a violating country. Retaliatory tariffs are the obvious choice for such a supporting instrument. However, we show that a system where retaliatory tariffs are used to support the payment of fines yields no more cooperation than one that uses tariffs alone to retaliate against violations.

The equivalence of fines and tariff retaliation in terms of enforcement suggests that both mechanisms yield the same payoffs. However, we show that this is only true if there are no deviations from cooperation in equilibrium. When such deviations occur, and they clearly do in practice, we show that fines supported by tariffs have an advantage over tariff retaliation as a primary remedy. Namely, the payoff to an injured country is higher under fines even though the cost of the penalty for a violating country is unchanged. Thus we show that switching to fines generates a Pareto improvement in the presence of shocks that result in disputes along the equilibrium path. The underlying motive for this result is that tariffs are an inefficient form of compensation because the welfare gain they generate for an injured country (if it has market power) is always less than the welfare cost imposed on the country that committed the original violation.[6]

Given that tariff retaliation is usually not a credible threat for small countries, it is important to know whether such countries can benefit from enforcement mechanisms that do not rely solely on tariff retaliation. To this end, we ask whether international cooperation can be sustained by a system where countries exchange bonds of a given amount prior to trading, with the understanding that its bond will be forfeited in case it commits a trade violation. We find that bonds can only improve enforcement relative to a system based on retaliatory tariffs if they are exchanged between

fines are typically a preferred form of compensation when there is a violation related to the trade or intellectual property right provisions.

[6] In a different context, Hoekman and Saggi (2006) argue that since most developing countries lack the institutional capacity for fighting foreign export cartels via antitrust enforcement, developed countries ought to ban such cartels in return for tariff concessions or some monetary compensation. Cartelization creates an inefficiency much like the use of a tariff by a large country in that the loss suffered by the injured party exceeds the gain of the other party. They show that if tariff retaliation is a credible option for an importing low income country, the transfer it has to pay to its high income trade partner in order to secure a ban on export cartels is lower.

countries of asymmetric size. If bonds are simply exchanged by two symmetric countries then a deviating country would have no incentive to return the other country's bond and this extra benefit of deviation exactly offsets the cost of losing its own bond.

Exchanging bonds improves cooperation between countries of asymmetric size because they help to solve a collective action problem by small countries. This point needs elaboration. One problem facing small countries in reciprocal trade negotiations is that their individually optimal tariffs are low—even though they may be able to jointly exert enough market power to hurt large countries. Therefore, if a large country violates its commitments and increases its tariff on a product exported by several small countries, none of them has an individual incentive to sufficiently punish the large country via tariff retaliation. The reason for this is that each small country does not internalize the terms-of-trade benefit that its tariff has on the remaining ones. Put differently they free ride on each other's retaliation. Anticipating this free riding, a large country has no motive to offer tariff reductions in products primarily exported by small countries. When large countries exchange a bond of higher value than the sum of the ones posted by the smaller ones its incentive to deviate from the agreement is decreased. Thus more cooperation is achieved since small countries can simply retain the large country's bond in case it deviates, rather than having to try to coordinate their tariff retaliation. Moreover, in some cases, the small countries would not have to post any bond or pay any fines along the equilibrium path.

This paper is related to the literature on the enforcement of trade agreements and in particular with the following studies. Park (2000) studies cooperation between a large country and a small one (which has no market power) and shows a number of interesting results. The most relevant to our analysis is that trade agreements where the small country can make direct transfers can enforce lower tariffs. This is because the threat of terminating the transfer payment gives the small country more leverage than a tariff retaliation. The "purchase" of market access by a small country is an interesting and relevant result when this transfer is understood as a concession in a non-trade issue, as invoked by Park and analyzed by others (e.g. Limão, 2007). In contrast, when we consider asymmetric countries, we focus on a large country and a group of small ones so we focus on the problem of coordination between the latter and show, among other things, that cooperation in tariffs can be achieved even if small countries do not purchase market access.

Following most of the literature, we model trade agreements as the sub-game perfect equilibria of repeated games. But rather than focusing on infinite Nash reversion in tariffs as a form to punish violations we focus on renegotiation proof agreements, which better captures the WTO as argued by Ludema (2001). He notes that most trade disputes in the WTO have been settled through negotiations and whenever sanctions have been used, their level has been in accordance with the principle of reciprocity. He then shows that this important feature of disputes in the WTO implies that only those trade agreements that are renegotiation proof are sustained in equilibrium.

A broader question is why a third party such as the WTO is needed at all if trade agreements are self-enforcing. Maggi (1999) argues that the role of the WTO is to disseminate information about violations. Klimenko, Ramey, and Watson (2006) argue that the WTO can facilitate cooperation by helping countries to condition their negotiations on the history of cooperation. This role is important when there are ongoing negotiations with outcomes that can differ depending on whether the history is one of cooperation or disputes.

The structure of the paper is as follows. In section 2 we introduce the model and derive the Nash and cooperative tariffs in the absence of enforcement problems. In section 3 we introduce the alternative enforcement mechanisms and contrast their outcomes in terms of the liberalization they can enforce. In section 4 we discuss enforcement under tariff retaliation, fines and bonds with asymmetric countries. We also show the ex-post efficiency of fines relative to tariff retaliation as a form of compensation when trade disputes occur in equilibrium. In section 5 we summarize the results and discuss possible extensions.

2 Model

Given that the issue of alternative enforcement mechanisms is not yet well understood we start with the simpler case of two symmetric countries (home and foreign). In section 4 we consider the case where countries are asymmetric in size. Each country produces two homogeneous goods, $i = x, y$ as well as a numeraire good, n. Individual utility over the three goods is given by

$$u \equiv c_n + \sum_i u_i(c_i)$$

Since utility is quasi-linear, the demand function for good i depends only on its own price and is similar for all individuals so we denote aggregate demand at home by $D_i(p_i)$. Each unit of the numeraire good c_n is produced with a constant returns to scale technology using only labor, which is available in fixed supply L. We also assume that good i is produced with a constant returns technology that uses both labor and a specific factor, each of which is also available in fixed supply. So we denote the supply function for good i by $S_i(p_i)$.

Let x denote home's import. Under trade, domestic import prices are given by $p_x = p_x^w + \tau$ where p^w is the "world" price and τ is a specific import tariff on x. Home's excess demand is then $M_i \equiv D_i(p_i) - S_i(p_i)$. Denoting foreign variables with an asterisk (*) the world price for home's import is determined by the market clearing condition

$$M_x(p_x^w + \tau) + M_x^*(p_x^w) = 0 \tag{1}$$

A similar condition applies to foreign's import good, y. We assume that no export policies are used so that trade policy is simply described by the level of the import tariff in each country, τ and τ^*. Moreover, we assume that countries have market power in trade so that their optimal tariffs are positive. It is then simple to verify that, in this setup, increasing the tariff on good x lowers the world price, $p_x^w(\tau)$, and raises the domestic one, similarly for y and τ^*.[7]

We focus directly on a reduced form objective function for the government that may allow extra weight (measured by $\lambda_i \geq 1$) to be placed on specific factor owners.

$$W(\tau, \tau^*) \equiv \sum\nolimits_i [\int_{p_i}^{\infty} D_i(p_i)dp_i + \lambda_i \int_0^{p_i} S_i(p_i)dp_i + \tau_i M_i(p_i)] + wL \tag{2}$$

where we recall that τ affects W both directly through tariff revenue, the term $\tau_x M_x$, and through its effect on home prices; whereas the effect of τ^* is indirect and occurs only through the world price, $p_y^w(\tau^*)$. The first term in parenthesis is consumer surplus. The second one captures producer surplus, or alternatively it can be interpreted as the quasi-rents accruing to the fixed factor owners. The last term, wL, is the total wage income. We assume that L is large enough to ensure a positive supply of the numeraire and so the wage rate in the economy is fixed by the marginal productivity of labor in the numeraire good, which in the absence of labor taxes we normalize to unity. Therefore, W can be interpreted as a reduced form of a political contributions model such as Grossman-Helpman

[7] Broda, Limão and Weinstein (2006) estimate that several countries have considerable market power in trade and use it to set higher tariffs prior to their WTO accession.

(1994).[8]

The Nash tariff is obtained by maximizing (2) while taking the other country's tariff as given. Since we do not model export policies the good subscript, i, can be dropped. Let

$$\tau^N \equiv \arg_\tau \max W(\tau, \tau^*) \tag{3}$$

Recalling that the equilibrium prices are a function of the tariff, the first order condition for τ is

$$-Dp_\tau + \lambda S p_\tau + M + \tau M_p p_\tau = 0 \tag{4}$$

where subscripts denote partial derivatives. Using $M = D - S$, $p_\tau = p^w_\tau + 1$ and re-arranging the above we obtain

$$(p^w_\tau + 1)[\tau M_p + (\lambda - 1)S] - M p^w_\tau = 0 \ , \tag{5}$$

which implies that the Nash tariff in ad-valorem terms, $\tau^N / p^w(\tau)$, is implicitly defined by:

$$\frac{\tau^N}{p^w(\tau)} = \frac{1}{\varepsilon(\tau)} + (\lambda - 1)\frac{S(\tau)/M(\tau)}{\xi(\tau)} \tag{6}$$

We explicitly show the potential dependence of the various terms, with the exception of λ, on the tariff. We do so for clarity in the formula but will omit them below for notational simplicity. The first term, $1/\varepsilon \equiv \frac{M^*}{p^w M^*_p}$, is the inverse of the foreign export supply elasticity and it reflects the terms-of-trade motive for the use of tariffs. The second term reflects a political economy motive that is increasing in the extra weight placed on specific factor owners (λ) and decreasing in home's import demand elasticity ξ where $\xi \equiv -\frac{\partial M}{\partial p^w}\frac{p^w}{M} = -M_p p^w / M$. Given symmetry, the foreign country's import tariff is the same, i.e. $\tau^N = \tau^{*N}$.

At the other extreme, if cooperation was not subject to any enforcement problems, countries would choose tariffs that maximize their joint objective $W + W^*$. This is equivalent to maximizing the objective of either one once we employ symmetry and note that $\tau = \tau^*$. Thus we obtain

$$\tau^G \equiv \arg_{\tau^c} \max W(\tau^c, \tau^* = \tau^c) \tag{7}$$

[8] In Grossman-Helpman (1994) the government's objective is $W^{GH} = a\bar{W} + c$, where $\bar{W}$ is social welfare, c is political contributions and a is the marginal rate of substitution between the two. In W the term $\lambda - 1$ can be directly interpreted as the inverse of a when factor ownership is extremely concentrated.

which implies that the globally optimal ad-valorem tariff $\tau^G/p^w(\tau^G)$ is given by

$$\frac{\tau^G}{p^w(\tau)} = (\lambda - 1)\frac{S(\tau)/M(\tau)}{\xi(\tau)} \tag{8}$$

It is simple to see that the globally optimal cooperative tariff is lower than the non-cooperative tariff (i.e. $\tau^G/p^w < \tau^N/p^w$). The difference between the Nash and globally cooperative policies confirms that market power in trade leads to international externalities that can potentially be resolved by trade agreements.[9] Moreover, it points out that even in the presence of an international agreement, countries may choose to have positive tariffs due to internal political economy distortions. Since the globally optimum tariff is below the level that is optimal for each *individual* country, each country has an incentive to deviate from it and would do so if it faced no punishment. We now address how countries can enforce cooperation.

3 Enforcement of trade agreements

The absence of a supra-national authority to punish violators implies that international agreements must be self-enforcing. Cooperative self-enforcing agreements are well characterized by certain repeated games.[10] We begin with the standard approach in the literature of using the threat of tariff retaliation to enforce cooperation and then contrast its outcome with alternative enforcement mechanisms.

3.1 Supporting cooperation via tariff retaliation

Consider an indefinitely repeated game where the stage game delivers the Nash tariff described in the previous section. Assume that governments observe each other's actions at the end of each period. The strategy employed by countries is to start by cooperating until one deviates by raising its tariff. Any deviation is followed by a punishment phase of n periods after which cooperation is resumed. The motive for modelling temporary punishments is that they are clearly more realistic than infinite Nash reversion. Although the latter is a possibility, we view it as the ultimate

[9] This role for the WTO is argued in Bagwell and Staiger (1999). Bagwell and Staiger (2006) provide evidence for their theory by showing that WTO accession leads to greater tariff reductions in products with higher initial import volumes.

[10] See Dixit (1987) and Bagwell and Staiger (1990) for example.

punishment corresponding to an unravelling of the GATT/WTO system that results from member countries not following its rules. The more common occurrence are trade disputes that are met with temporary punishments, which is more similar to what we now model.[11]

To find the lowest cooperative tariff that is renegotiation proof we must first define the payoffs to each government under the alternative situations that can arise.

In the absence of cooperation, the payoff to each country equals the government's objective evaluated at the non-cooperative tariffs:

$$W^N \equiv W(\tau^N, \tau^{*N}) \tag{9}$$

Similarly, when countries cooperate, i.e. set their tariffs at τ^c and τ^{*c} (determined below), the payoff to each is given by:

$$W^C \equiv W(\tau^c, \tau^{*c}) \tag{10}$$

If a country deviates, it does so by imposing its optimal Nash tariff τ^N on its trading partner who, in that period, still utilizes the cooperative tariff, τ^{*c}. The payoff to a country in the period it deviates is therefore given by

$$W^D \equiv W(\tau^N, \tau^{*c}) \tag{11}$$

In the symmetric case we consider in this section we have that in equilibrium $\tau^c = \tau^{*c}$ and $\tau^N = \tau^{*N}$, where τ^N is defined by (6). Since we allow for renegotiation after a deviation we must model the punishment phase before cooperation is resumed. We assume that countries agree that a deviation will be followed by n periods of punishment where the country that deviated faces τ^{*N} on its exports and must show its willingness to restart cooperation by setting its own import tariff at the cooperative level $\tau^c < \tau^N$. The per-period payoff for the deviating country during the punishment phase is therefore

$$W^P \equiv W(\tau^c, \tau^{*N})$$

Given these payoffs, the incentive compatibility (IC) constraint needed to sustain cooperation is

$$W^D + V^\tau \leq \frac{W^C}{1-\delta} \tag{12}$$

[11] Here we focus on a case with no deviations along the equilibrium path. In section 4 we examine the compensation aspect of different remedies when shocks cause a deviation to occur.

which is identical for the symmetric countries. That is, the sum of the payoff of a deviation, W^D, and the continuation payoff, V^τ, should not exceed the payoff of cooperation, which is discounted by $\delta < 1$. We define V^τ as:

$$V^\tau \equiv \Sigma_{t=1}^{n} \delta^t W^P + \Sigma_{t=n+1}^{\infty} \delta^t W^C \tag{13}$$

Since $W^P < W^N$ the punishment phase is subgame perfect only if it is not profitable for the country that is being punished to simply abandon the agreement and revert to Nash forever. So we require that V^τ exceed the Nash payoff in order to be *weakly renegotiation proof* (WRP):[12]

$$V^\tau \geq \frac{\delta}{1-\delta} W^N \tag{14}$$

Because $W^C > W^P$, the longer the punishment phase, the lower is V^τ. Therefore the maximum punishment that is WRP is found by increasing n to lower the continuation payoff until it is equal to the RHS of (14). We define this value as $n^{\max}$, which is implicitly given by

$$V^{\tau \min} \equiv \delta \frac{1-\delta^{n^{\max}}}{1-\delta} W^P + \frac{\delta^{n^{\max}+1}}{1-\delta} W^C = \frac{\delta}{1-\delta} W^N \tag{15}$$

To confirm that the lowest cooperative tariff that is WRP is identical to the one under infinite Nash reversion we can replace (15) in (12) to obtain

$$W^D + \frac{\delta}{1-\delta} W^N \leq \frac{1}{1-\delta} W^C \tag{16}$$

The lowest self-enforcing tariff under infinite Nash reversion or WRP is implicitly defined when (16) holds with equality. This serves as a convenient benchmark against which alternative enforcement mechanisms can be compared. Since we are interested in cases where the threat of tariff retaliation is insufficient to enforce the global optimum, we consider discount factors δ low enough that tariff retaliation alone cannot sustain τ^G. In the symmetric case above this requires $\delta < \delta_g$, where δ_g is defined when (16) holds with equality at τ^G.

[12] Farrell and Maskin (1989) and Van Damme (1989) show that using the following punishment as part of the strategy is WRP: the party that deviates accepts to be punished and during that period it plays cooperatively. In this case clearly $W^P < W^N$. The WRP concept requires the strategy not to be Pareto dominated (i.e. $W^{*P} > W^{*C}$) so that cooperation does not Pareto dominate the punishment phase for the injured party. When this is the case, the foreign country is better off when home is punished than under cooperation but home is worse off.

3.2 Fines and tariff retaliation

We now consider the effect of switching from tariff retaliation to a monetary fine to punish deviations from a trade agreement. One key difference between these options is that the fine must be voluntarily paid by the deviating country whereas retaliatory tariffs are imposed by the other country. This means that if the country that deviates decides *not* to pay the fine, the only thing the other country can ultimately do is to revert to non-cooperation in tariffs, which in our model is equivalent to leaving the agreement altogether. Given this, the most cooperative tariff that can be achieved with fines is determined as follows.

After a deviation, a country must pay a fine equal to f units of the numeraire, which the government collects via a lump-sum tax. Cooperation in tariffs resumes the same period the fine is paid. It is reasonable to suppose that if the fine is paid, the transfer occurs in a single period. Thus we set $n = 1$ without loss of generality since we can always alter the value of the fine, f, to mimic the effects of changes in n. The incentive constraint is then similar to the one we had previously, with the possible exception of the continuation payoff that is now V^f:

$$W^D + V^f \leq \frac{W^C}{1-\delta} \tag{17}$$

The continuation payoff V^f is now the cost of the fine, $-\delta f$, plus the stream of cooperative payoffs

$$V^f \equiv -\delta f + \frac{\delta}{1-\delta} W^C \tag{18}$$

If we ignore the renegotiation constraint, there exists a sufficiently large f that delivers the global optimum, τ^G. However, we must ensure that the punishment payoff is WRP. Also, since in the absence of tariff retaliation a deviating country has no incentive to pay the fine, there ultimately must be a punishment for not doing so. In the context of our model, the only punishment that the other country can impose thus far is to increase its tariff. Therefore the WRP constraint is defined with respect to the payoff under infinite Nash reversion and it requires that

$$V^f \geq W^N \delta/(1-\delta) \tag{19}$$

Thus WRP requires the maximum fine, $f^{\max}$, and resulting minimum payoff that the deviating country can be held to, $V^{f\,\min}$, to be

$$V^{f\,\min} \equiv -\delta f^{\max} + \frac{\delta}{1-\delta}W^C = \frac{\delta}{1-\delta}W^N \tag{20}$$

which implies that the maximum fine that is WRP is the present discounted value of cooperation in the trade agreement, i.e.

$$f^{\max} = (W^C - W^N)/(1-\delta) \tag{21}$$

By substituting $V^f = V^{f\,\min}$ in (17) we can obtain the lowest cooperative tariff that is WRP when fines are used and enforced by the threat of abandoning the agreement altogether. This gives

$$W^D + \frac{\delta}{1-\delta}W^N \leq \frac{W^C}{1-\delta} \tag{22}$$

which is *identical* to the constraint under tariff retaliation in (16). We summarize this result in the following proposition.

Proposition 1 *(Enforcement equivalence of tariffs and fines):*
In a trade agreement between two symmetric countries, the most cooperative tariff that can be enforced by tariff retaliation is equal to the tariff that can be enforced with WRP fines.

The basic intuition behind this result becomes clear after we note two points. First, since the fine must be paid by the violating country it must find it in its best interest to do so. Therefore, the fine itself needs to be enforced. In the absence of additional instruments this enforcement must rely on the threat of infinite tariff retaliation, i.e. the breakdown of the trade agreement. Second, the maximum punishment that is WRP is the payoff that the deviating country would get if it abandoned the agreement. This is true of the value of the fine paid and the cost imposed by temporary tariff retaliation. Thus both alternatives yield the same cooperative tariff.

There is one important corollary of proposition 1. Since the most cooperative tariff is identical under these two mechanisms, the payoffs are also exactly the same. This is because thus far we have not introduced any deviations in equilibrium and, along the equilibrium path, countries always obtain the cooperative payoff W^C (that depends only on the level of the cooperative tariff). In section 4.2 we show that if deviations do occur along the equilibrium path, the payoffs under the two mechanisms are different. Before doing so, we analyze whether an alternative enforcement mechanism can improve cooperation relative to the ones analyzed above.

3.3 Exchanging bonds

Suppose that at the beginning of every period each country posts a bond of value b (measured in terms of the numeraire good) that it forfeits in case it commits a violation. Assume also that countries observe this and cooperate only if such a bond is posted by both of them. Naturally, once bonds are posted, countries are free to decide whether to cooperate on tariffs or not. If either country does not post a bond, both play Nash in tariffs forever (we later discuss the case where the punishment phase is finite). We assume there is no third party that can hold the bonds so that governments must post them with each other. If at the end of a period both countries have cooperated then they "return" their bonds to each other, otherwise the country that deviated loses its bond.[13]

Under infinite Nash reversion, if a country deviates in tariffs it will be optimal for it not to return the other country's bond. In this case, the equilibrium tariff remains unchanged relative to the case of no bonds. To see this, note that the incentive constraint is given by:

$$(W^D + b^* - b) + \frac{\delta}{1-\delta} W^N \leq \frac{W^C}{1-\delta} \tag{23}$$

where the payoff under Nash reversion is the same as before since under no cooperation both countries simply set their tariffs at τ^N and bonds are irrelevant. The functional form of the cooperation payoff is also unchanged because we assume that if countries cooperate they receive their bond and consume it at the end of the period (and we assume no discounting within the period). The key difference is the deviation payoff, which is now given by the original value, W^D, net of the value of the bond that is lost, $-b$ and the one not returned, b^*. However, if, as we expect due to symmetry and stationarity, the optimal bond is the same for both countries (i.e. $b^* = b$), the constraint in (23) is identical to the one in (16) and thus the resulting cooperative tariff is equal to that under infinite Nash reversion.

Now consider the case where the punishment phase is finite. Countries start cooperating by initially posting a bond b with each other. If a country deviates from the cooperative tariff, it loses

[13] A third party may be "available" but too costly to use due to transaction costs and/or non-verifiability. In our working paper we relax this assumption

its bond. For cooperation to resume, the deviating country must return the present discounted value of the bond of the injured country, b^*/δ. If it does so in the period after the deviation occurs, tariffs return to the cooperative level. The incentive constraint for cooperation can be written as:

$$W^D + b^* - b + V^b \leq \frac{W^C}{1-\delta} \tag{24}$$

We can again write the minimum continuation payoff that is WRP:

$$V^{b\min} \equiv -\frac{\delta b^{*\max}}{\delta} + \frac{\delta W^C}{1-\delta} = \frac{\delta}{1-\delta} W^N$$

which implies a maximum bond of

$$b^{*\max} = b^{\max} = \delta \frac{W^C - W^N}{1-\delta} \tag{25}$$

Replacing this in (24) we obtain an IC for the lowest cooperative tariff under bonds that is exactly the same as in (23), which we already noted yields the same tariff as infinite Nash reversion. Therefore we have the following proposition.

Proposition 2 *(Enforcement under tariffs versus exchanged bonds):*
In a trade agreement between two symmetric countries, the most cooperative tariff that can be enforced by tariff retaliation is equal to the tariff enforced by WRP bonds exchanged between them.

4 Extensions

4.1 Asymmetries in country size

We now analyze the case where countries are asymmetric in size. This is important because small countries may lack the ability to use tariff retaliation and apparently stand to gain the most from an alternative enforcement mechanism. In fact, Bagwell, Mavroidis, and Staiger (2004b) note that there has been *no* trade dispute in which a developing country (defined as a non-OECD member) has imposed retaliatory measures to induce compliance when faced with a trade violation.[14]

[14] Further empirical evidence on this issue is available in Bown (2004a, 2004b).

The first problem in modelling asymmetry is that if a country is truly small from a trade perspective then, under the current trading system, it will not obtain multilateral tariff reductions in products that it *alone* exports. This is simply due to the reciprocal nature of tariff concessions. If a small country's tariff reduction has little or no effect on the price received by an exporter then the exporter has little or no incentive to offer a reciprocal tariff concession to the small country.[15] Therefore we consider a case where each country trading with a large country is small individually but large collectively. We then ask if there is a problem in the current enforcement system that may be ameliorated with an alternative mechanism.

Suppose that there is a set of small countries, that are jointly large in importing a particular good, and that they all export a common good (that no other set of countries export) to a single large country. If small countries can *threaten joint retaliation* they can achieve tariff concessions from the large country. However, such a threat may not be credible because no small country has an *individual incentive* to punish a deviation by the large country (since the terms-of-trade gain for an individual small country from raising its tariff is close to zero). We can think of the optimal joint tariff punishment for compliance purposes as a public good subject to a free rider problem. Therefore, ex-ante the small countries may fail to extract significant tariff concessions from the large country. *We now show this free rider problem continues to exist even if fines (supported by tariffs) are used to enforce cooperation but that it can be overcome by the exchange of bonds.*

To focus on the coordination problem, the only change in the setup is to assume that instead of a single foreign country there is a collection of κ independent and identical small countries. Each small country will therefore have a fraction κ of the population and fixed factors of the originally defined foreign country. So the demand and supply functions for each of the κ countries are equal to D_i^*/κ and S_i^*/κ respectively and the welfare function is simply $W^{*\kappa} = W^*/\kappa$, where we recall that W^* is defined symmetrically to W in (2). If the small countries could coordinate their efforts and maximize their joint objective, our analysis of cooperation between two symmetric countries enforced via the threat of tariff retaliation would remain relevant since the joint objective of the small countries, defined by $\Sigma_\kappa W^{*\kappa}$, equals W^*. Thus, the *jointly* optimal Nash tariff for small countries would still be τ^N.

However, a problem arises if there is no instrument via which small countries can successfully co-

[15] One alternative is that small countries "offer" non-trade related concessions, as was done with TRIPS in the Uruguay Round. However, here we want to focus strictly on the exchange of trade concessions.

ordinate their choices. In this case if *individual* small countries consider punishments (or deviations) the Nash tariff $\tau^{*N\kappa}$ each imposes in its import sector, y, is given by

$$\frac{\tau^{*N\kappa}}{p^w} = \frac{1}{\kappa}\frac{1}{\varepsilon^*} + (\lambda - 1)\frac{S^*/M^*}{\xi^*} \tag{26}$$

where all the variables are defined similarly to τ^N in (6). The key difference is that the terms-of-trade effect is now reduced to a fraction $1/\kappa$ of its previous value. Thus at the original prices implied by (6), the Nash tariff for the large country is unchanged but each small country sets a lower tariff than the large one since $\kappa > 1$.[16]

From (26) we can see that if the number of small countries κ is sufficiently high and $\lambda = 1$, the Nash tariff of each is zero. Under such circumstances, there is nothing a small country can individually offer to or credibly threaten the large country with. Thus, in the case of the standard enforcement mechanism that uses only tariffs, explored in section 3.1, the only self-enforcing tariff for the large country is the Nash value, τ^N. So relative to the case where small countries act jointly, they are now clearly worse off—on their exports they face $\tau^N > \tau^{C\tau}$ (the equilibrium cooperative tariff under symmetry) and impose $\tau^{*N\kappa} < \tau^{*N}$ on their imports—and the large country is better off. The use of fines backed by tariff retaliation, as we explored in section 3.2, fails to improve upon this outcome for the small countries because, as we showed before, the maximum WRP fine is tied to the payoff under infinite Nash reversion in tariffs, which is $\tau^{*N\kappa}$ in the absence of coordination.

Naturally if κ is so high that the value of $\tau^{*N\kappa}$ is close to the global optimum value then the large country would always prefer not to cooperate. But for smaller values of κ the large country prefers cooperation. When the countries are not sufficiently patient for tariff retaliation to enforce the global optimum the cooperative tariffs with $\lambda \geq 1$ and a finite number of small countries are *asymmetric.* That is, the large country sets a cooperative tariff that is higher than the one it faces from the small countries (as we prove in Proposition 3). The basic motive is simply the inability of the latter to retaliate jointly. However, we now show that the exchange of bonds can improve cooperation and enforce the global optimum (i.e. the symmetric tariff in (8)) even when this outcome is not enforceable under tariff retaliation.

To understand why an exchange of bonds between asymmetric countries improves cooperation we

[16] The variables in (26) refer to foreign's import sector, y. At the original prices we have $z_y^* = z_x$ for all the variables $z = S, M, \varepsilon, \xi$ because of symmetry.

must first consider their incentive constraints under tariff retaliation alone. Recall that each of the κ countries is exactly identical, so the cooperative tariff for each in the vector $\boldsymbol{\tau}^{*c}$ will, in equilibrium, be identical to the same value, $\tau^{C\kappa}$. We assume that if the large country deviates against any of the small countries then it deviates against all. This assumption allows us to focus on the coordination of small countries in tariff retaliation as the only difference relative to the previous setup; it may also be justified by the fact that all of the small countries are identical so that if the large country has an incentive to deviate against one it has a similar incentive to deviate against all others. The IC under tariff retaliation for the large country is

$$W(\tau^N, \boldsymbol{\tau}^{*c}) + \frac{\delta}{1-\delta} W(\tau^N, \boldsymbol{\tau}^{*N}) \leq \frac{W(\tau^c, \boldsymbol{\tau}^{*c})}{1-\delta} \tag{27}$$

where we recall that since it deviated against all the worst punishment that the uncoordinated small countries can inflict is to revert to their individual Nash tariffs, so all elements of the vector $\boldsymbol{\tau}^{*N}$ equal $\tau^{*N\kappa}$. Thus (27) represents both the constraint under WRP and infinite reversion. Since $\tau^N > \tau^{*N\kappa}$ when $\kappa > 1$ we can immediately see that, for any given cooperative tariff, the total payoff upon deviating, given by the RHS of (27), is greater than in the symmetric case (when $\kappa = 1$). So the lack of coordination between small countries leads to less cooperation by the large country. However, it simultaneously reduces the payoff and thus the incentive of each individual small country to deviate. This proves crucial for understanding the benefit of bonds.

Consider an initial situation where $\delta = \delta_\kappa$ where δ_κ is the discount factor required for (27) to hold with equality at the global optimum $\tau^c = \tau^{*c\kappa} = \tau^G$ for some value of κ. In other words, at $\delta = \delta_\kappa$, the IC of the large country is satisfied. The constraint for each of the individual small countries is similar to (27), except their exporters face a higher tariff, $\tau^N > \tau^{*N\kappa}$, and their payoffs are divided by κ (but κ cancels out because it enters similarly on both sides of the IC). Thus at τ^G the cooperative payoff for the small countries as a group is equal to the one for the large one (due to symmetry) and the payoffs for small countries upon deviating are smaller since $\tau^N > \tau^{*N\kappa}$. This means that at δ_κ, where (27) holds with equality, there is slack in the corresponding IC for each small country. If we lower δ below δ_κ then (27) no longer holds at τ^G. So under tariff retaliation the global optimum is not feasible for $\delta < \delta_\kappa$. But the corresponding constraint for the small countries still holds and has slack, at least for some $\delta < \delta_\kappa$.

We now allow for the exchange of bonds as described in section 3.3. If the large country posted a bond larger than the one posted by small countries this could reduce its incentive to deviate, as we can clearly see from (23) when $b > b^*$. It would also increase the incentive for each small country to deviate but this would not affect the outcome initially because we have just seen their constraints have slack at the initial symmetric tariffs for some $\delta < \delta_\kappa$. Thus an exchange of bonds between asymmetric countries can serve to "transfer enforcement" and thus improve cooperation relative to the tariff retaliation case. The following proposition shows that the required exchange, with higher bonds for the large country, is feasible and WRP.

Proposition 3 *(Enforcement under tariffs versus exchanged bonds with asymmetric countries): In a trade agreement between a large country and a group of $\kappa>1$ uncoordinated small countries, the most cooperative tariff set by the large country, $\tau^{C\kappa}$, is*
(a) higher than the global optimum, τ^G, and the tariff set by each of the small countries, $\tau^{*C\kappa}$, if the agreement is enforced only by tariffs for all $\delta<\delta_\kappa$.
(b) equal to $\tau^{*C\kappa}$ and both are equal to τ^G if the agreement is enforced by an exchange of WRP bonds for some $\delta<\delta_\kappa$.
Moreover, the bond posted by the large country to sustain the global optimum is b^g (given by (28)) and it exceeds the total value of the bonds posted by the small countries, $\kappa b^{*\kappa g}$ (in (29)).

The first part of the proposition is clear from the explanation above. By definition, when $\delta < \delta_\kappa$ the constraint in (27) fails at τ^G so the equilibrium value for large's cooperative tariff is $\tau^{C\kappa} > \tau^G$. We also explained why at a symmetric cooperative tariff the constraint for the small countries has slack if (27) holds with equality and so $\tau^{C\kappa} > \tau^{*C\kappa}$.

To understand the last part of the proposition we compare the value of the bonds required to sustain the global optimum. We denote these values as b^g for the large country and $b^{*\kappa g}$ for each of the small, which we show in the appendix are given by

$$b^g = W(\tau^N, \boldsymbol{\tau}^{*G}) - W(\tau^G, \boldsymbol{\tau}^{*G}) \tag{28}$$

$$\kappa b^{*\kappa g} = W^*(\tau^G, \boldsymbol{\tau}^{*N\kappa}) - W^*(\tau^G, \boldsymbol{\tau}^{*G}) \tag{29}$$

The required bonds to achieve the global optimum are equal to the terms-of-trade gain from deviating for each country. Since the large country deviates to an optimal tariff, τ^N, that is larger than the one the small countries deviate to whenever $\kappa > 1$, its terms-of-trade gain from deviating is larger than the total gain by the uncoordinated small ones. Therefore the large country must post a larger bond, i.e. $b^g > \kappa b^{*\kappa g}$, which reduces its incentive to deviate relative to the tariff retaliation case and so opens up the possibility of increased cooperation in part (b) of the proposition.

The final step is to ensure that these bonds satisfy the WRP constraint. To do so, b^g and $b^{*\kappa g}$ must be respectively lower than $b^{g\max}$ and $b^{*\kappa g\max}$, the values that imply a minimum continuation payoff equal to abandoning the agreement. As we show in the appendix both conditions are individually satisfied for some $\delta < \delta_\kappa$. Here we provide some intuition. A necessary condition for these bonds to be WRP is that

$$b^g + \kappa b^{*\kappa g} \leq b^{g\max} + \kappa b^{*\kappa g\max} \tag{30}$$

Now recall from section 3.3 that the maximum bond value that home is willing to return to resume cooperation, $\kappa b^{*\kappa g\max}$, is given by (25), now evaluated at $\delta(W(\tau^G, \boldsymbol{\tau}^{*G}) - W^N(\tau^N, \boldsymbol{\tau}^{*N}))/(1-\delta)$. An analogous condition holds for each of the small countries. When we replace those values and those for b^g and $\kappa b^{*\kappa g}$ into (30) we obtain

$$\begin{aligned}&[W(\tau^N, \boldsymbol{\tau}^{*G}) - W(\tau^G, \boldsymbol{\tau}^{*G})] + [W^*(\tau^G, \boldsymbol{\tau}^{*N\kappa}) - W^*(\tau^G, \boldsymbol{\tau}^{*G})] \\ &\leq \frac{\delta[W^*(\tau^G, \boldsymbol{\tau}^{*G}) - W^*(\tau^N, \boldsymbol{\tau}^{*N})]}{1-\delta} + \frac{\delta[W(\tau^G, \boldsymbol{\tau}^{*G}) - W(\tau^N, \boldsymbol{\tau}^{*N})]}{1-\delta}\end{aligned} \tag{31}$$

This requires that the sum of the terms-of-trade gain obtained from deviating in the large country and all of the small (the LHS) does not exceed the discounted gain from tariff cooperation relative to abandoning the agreement. In other words, this is simply the sum of the IC for all the countries under tariff retaliation. As we noted above, when $\delta = \delta_\kappa$ this condition always holds with strict inequality at τ^G. So it also holds for some $\delta < \delta_\kappa$. Therefore, when bonds are exchanged the individual constraints under *tariff retaliation* no longer need to hold, only their sum does. In this way bonds effectively allow an "aggregation of enforcement" and an improvement in cooperation relative to tariff retaliation. Note that when $\kappa = 1$ this necessary condition holds with equality only if each IC holds individually (since countries are symmetric in that case) and so it only holds when $\delta = \delta_g$, i.e. when tariff retaliation can also sustain maximum cooperation. This is another way to understand why in proposition 2 we found no enforcement benefits of bonds with symmetric countries.[17]

In the simple setup considered thus far there are no equilibrium deviations and no opportunity cost of exchanging bonds when they receive them back at the end of each cooperation period and consume them. Moreover, the bond value may be fairly insignificant for the small countries given their low incentive to deviate. Nonetheless, it is interesting to ask if the outcome in proposition 3 can be achieved without requiring the small countries to post any bond at all. This is indeed possible provided that small countries pay a fine if (when off the equilibrium path) they ever deviate and want to resume cooperation. These fines are WRP as they can be supported by the large country's threat of tariff retaliation (which would be another way to ensure the small countries cooperate in the absence of a fine). The large country would still need to post a bond that it would loose if it ever deviated. Moreover the value of this bond is lower than b^g in (28) if a WRP fine was charged in order to resume cooperation if the large country ever deviated.

In sum, *in a trade agreement between a large country and a group of $\kappa > 1$ uncoordinated small countries, the global optimum can also be enforced by WRP fines and an exchange of bonds for some $\delta < \delta_\kappa$. Moreover, this exchange requires only the large country to post a positive bond, which is lower than b^g.*[18] Because this alternative mechanism requires smaller bonds (none for the small countries) and no fines along the equilibrium path, it may increase the attractiveness of bonds, particularly if we allowed for an opportunity cost of posting bonds and for equilibrium deviations.

4.2 Compensation under alternative mechanisms

As we note in the Introduction, WTO dispute settlement remedies have both an enforcement and a compensation role. Thus far we have focused only on the enforcement aspect and shown that enforcement cannot be improved by replacing the current system with fines alone. When the most cooperative tariff under that alternative mechanism is identical so is the payoff to governments. The reason is that our model assumes perfect foresight and no shocks, so that no violations occur in equilibrium. Clearly the assumption of no shocks is not realistic and consequently neither is the

[17] The gains from trade are maximized when the global optimum is implemented. But one may wonder why in the complete absence of coordination between small countries the large country would not try to use its bargaining power. By solving the enforcement problem, the existence of bonds may also allow the small countries to coordinate at the time of the negotiation, making the symmetric solution plausible. If such coordination fails to occur then the outcome predicted by the model is still the global optimum as long as transfers are available. But the distribution of surplus between the large and small countries would then depend on the specifics of the bargaining model.

[18] We prove this claim in the appendix.

result that no deviations occur along the equilibrium path. We observe plenty of WTO disputes and violations are found to have occurred in many of the cases. This is important because once we allow for deviations to occur in equilibrium, the payoffs to countries depend not only on the cooperative tariff but also on the exact mechanism used to deal with violations. We now show that fines can generate *higher compensation* for the injured country at the same cost to the violator even if the cooperative tariff enforced is identical. For ease of exposition we illustrate this result for the punishments considered thus far but prove the result also holds for the less severe punishments often contemplated by the DSU.[19]

We illustrate our point in the simplest possible way. We assume governments base their policies on the set of parameters currently observed and expect them to hold in the future. We then consider the impact of an unexpected shock, e.g. a shock to the political economy parameter λ in (2) so that in a given period a country desires a higher tariff than the cooperative level previously set. In the following period λ returns to the original level. Such a shock and the resulting tariff increase would likely trigger a dispute and a ruling against the country because tariffs are bound at a numerical value in the WTO and not on a contingent set of parameters.[20]

The question we ask is the following: Given that a country deviates from the agreement due to an unexpected shock, under which mechanisms are the continuation payoffs higher? We focus on fines supported by tariffs so as to yield the same enforcement outcome as temporary tariff retaliation. Since we focus on the most cooperative tariff, the minimum payoff that the deviating country can be held to is the discounted Nash payoff, $W^N\delta/(1-\delta)$. The question then is whether this alternative yields a higher compensation for the injured country. The continuation payoff for the injured country under temporary tariff retaliation when the most cooperative WRP is implemented is

$$V^{*\tau} \equiv \delta W^{*P}\frac{1-\delta^{n^{\max}}}{1-\delta} + \frac{\delta^{n^{\max}+1}}{1-\delta}W^{*C} \tag{32}$$

where we recall that the payoff for the injured country under the punishment phase W^{*P} exceeds W^{*C} because the punishment involves the injured setting its optimal tariff $\tau^* = \tau^N$ and the other

[19]We show the result for symmetric countries but the basic insight should apply to the asymmetric case.

[20]The reason for this is probably the difficulty of writing an agreement that is conditional on political economy parameters that may be hard to observe by other countries An alternative way to model this is to assume that the governments anticipate that shocks will occur and have a well defined distribution of all possible shocks. Bagwell and Staiger (2005) analyze this issue when governments have private information about future political shocks. One of their findings is that a transfer can help in the implementation of efficient tariffs.

country setting its cooperative tariff, τ^c.

Under a fine supported by infinite Nash tariff reversion the payoff analogous to (32) is

$$V^{*f} \equiv \delta f^{\max} + \frac{\delta}{1-\delta} W^{*C} \tag{33}$$

This payoff reflects the received fine and the immediate resumption of cooperation with a payoff W^{*C} per period, identical to the one in (32) since we derived that both sustain the same cooperative tariff. Therefore the compensation under fines is higher than under tariff retaliation if and only if the expression in (33) exceeds (32). This yields the following condition for the fine:

$$f^{\max} > \frac{1-\delta^{n^{\max}}}{1-\delta}(W^{*P} - W^{*C}) \tag{34}$$

With this condition we are ready to compare the compensation properties of each mechanism and rank them. Since we consider unanticipated shocks we think that a reasonable ranking of the two can be established by comparing their payoffs under cooperation and their continuation payoffs if a shock does occur. Denoting the equilibrium WRP cooperative levels of tariffs under fines and tariff retaliation by τ^{Cf} and $\tau^{C\tau}$ we use the following definition. *A trade agreement enforced by fines generates a Pareto improvement relative to one using tariffs if the following inequalities hold: (i) $W^C(\tau^{Cf}) \geq W^C(\tau^{C\tau})$; (ii) $W^{*C}(\tau^{Cf}) \geq W^{*C}(\tau^{C\tau})$; (iii) $V^f \geq V^\tau$; and (iv) $V^{*f} \geq V^{*\tau}$ with at least one holding strictly.* We can now state the following.

Proposition 4 *(Compensation properties and ranking of tariffs versus fines):*
(a) In the presence of unanticipated shocks, e.g. to the political economy parameter λ, a trade agreement between two symmetric countries that is enforced by WRP fines supported by tariffs yields higher compensation for the injured country ($V^{*f} > V^{*\tau}$) and generates a Pareto improvement relative to a similar agreement enforced by tariff retaliation alone.
(b) The results in (a) are independent of restrictions on the severity of the punishment (i.e. they hold for $n < n^{\max}$ or $f < f^{\max}$) whenever the tariff retaliation and fine mechanisms enforce the same cooperative tariff.

The first part of the proposition says that the continuation payoff for the injured country after a shock is higher under fines, i.e. the inequality in (34) always holds. We show this in the appendix, below we provide the intuition. The Pareto improvement is then a corollary of the higher continuation payoff and of proposition 1. In proposition 1 we show that fines and tariffs enforce the same cooperative tariff so $W^C(\tau^{Cf}) = W^C(\tau^{C\tau})$ for home and similarly for foreign due to symmetry. Moreover, we also showed that the WRP continuation payoff that a country is held to in equilibrium is the same under the two alternatives, $V^f = V^\tau$. So fines generate a Pareto improvement. The last part of the proposition shows the same result holds even if punishments are less severe provided we consider punishments that enforce similar tariffs.

To see why inequality (34) always holds, note that when the WRP constraint under fines binds then $f^{\max}$ is given by (21), which due to symmetry is also equal $(W^{*C} - W^{*N})/(1-\delta)$. Using this and the definition of the payoffs we can rewrite (34) as

$$\frac{W^{*C} - W^{*N}}{1-\delta} > \frac{1-\delta^{n^{\max}}}{1-\delta}(W^*(\tau^c, \tau^{*N}) - W^*(\tau^c, \tau^{*c})) \tag{35}$$

The value of the fine received by the injured country (i.e. the left hand side) is equal to the present discounted value of cooperation in the trade agreement relative to infinite Nash reversion. This value needs to exceed any temporary gains that the injured country can obtain by raising its tariff during the punishment phase of $n^{\max}$ periods. The latter gain is simply the terms-of-trade benefit that it obtains from using its Nash tariff relative to the cooperative one. By using the definition for $n^{\max}$ in (15) and simplifying we can show this condition always holds. The underlying reason is that while tariffs can also transfer income by changing the terms-of-trade, they lead to a deadweight loss whereas fines do not.

The objective in this section is to determine if fines have an advantage over tariff retaliation when both enforce the same degree of tariff cooperation. In this context, considering the punishment that leads to the most cooperative tariffs seems a natural benchmark since proposition 1 shows that under this type of punishment both tariff retaliation and fines deliver identical enforcement. However, since the WTO's DSU can restrict punishment to be less severe, it is worth asking how such a restriction affects our results regarding compensation. The last part of proposition 4 shows that our results hold for all punishments that yield the same cooperative tariffs under fines and tariff retaliation.

Consider, for example, the case when the tariff punishment period is $n^p \in [1, n^{\max}]$ so that it may be less severe than before and can be chosen to match a range of alternative payoffs for either the violating country or the injured one (e.g. n^p can be chosen to allow the injured country to impose higher tariffs for a sufficient period as to "withdraw substantially equivalent concessions"). To hold constant the degree of enforcement across the two mechanisms and to focus on compensation, consider a fine equal to f^p, which delivers the same cooperative tariff as tariff retaliation when $n = n^p$. This fine is easily found by requiring the continuation payoffs for a country that deviates to be identical under the alternative mechanisms, i.e. $V^\tau(n^p) = V^f(f^p)$. It is then simple to show that compensation for the injured country is higher under fines relative to tariff retaliation if and only if a condition exactly analogous to (34) holds. The only difference being that it is now evaluated at n^p (and f^p), which can be restricted to fall below the maximum value $n^{\max}$ (and $f^{\max}$). Such a condition holds for exactly the same reasons as those described above.

5 Conclusion

The opinion that the WTO's dispute settlement system needs improvement is widespread. In particular, there is much concern about the use of tariff retaliation as the sole mechanism for dealing with member countries that fail to comply with a WTO ruling against them. In this paper, we analyze alternative mechanisms based on financial compensation and argue that one of the major problems in their implementation is enforcement.

Ultimately, the enforcement of monetary fines may require the use of some type of retaliatory instrument and if that is the case, fines fail to yield any more cooperation than tariffs. Thus, despite their problems, a desirable aspect of retaliatory tariffs is that they are controlled by injured parties and can be used in the event a violating country fails to comply with the ruling of a WTO panel. We also analyze whether bonds (posted prior to trading and revoked in case of a violation) can substitute for tariff retaliation. We show they can indeed do so when exchanged between countries of asymmetric size but not between symmetric countries. Moreover, in some cases small countries, which have raised the issue of financial compensation, would not have to post any bond or pay any fines along the equilibrium path (provided they do not deviate).[21]

[21] Posting bonds with a third party may improve cooperation between symmetric countries. As we discuss in our working paper if bonds are deposited in an escrow fund (i.e. with a third party), tariff retaliation is no longer necessary since the bond posted by the violating country can be used to compensate the injured country. Such an escrow scheme was in fact proposed by Chile in its bilateral trade agreement with the US. "Chile Looks for Monetary Sanctions as Enforcement Mechanism", INSIDE U.S. TRADE 13, 11/11/2002. It would be interesting to extend our results and

A major problem with tariff retaliation as a means of settling disputes is that tariffs can only be used by countries that have sufficient market power in world markets. As a result, the WTO's current dispute settlement system does not provide its smaller and/or developing country members with any real ability to retaliate against violations by other countries. As Bagwell, Mavroidis, and Staiger (2004a) have shown, making the right to retaliate tradable via an auction can help remedy this defect. A similar argument applies to the use of fines. If fines are indeed adopted, they would need to be tradable for small countries to benefit from their introduction since large countries would then be willing to bid for the right to collect a fine. Alternatively, we showed that a combination of fines to be paid by violators and bonds posted by large countries would also improve cooperation.

We also showed that fines have an advantage over tariff retaliation as a primary remedy: if a violation does occur, the payoff to an injured country is higher under fines even though the cost of the penalty for a violating country is unchanged. The intuition is simple: tariffs are an inefficient form of compensation because the welfare gain they generate for an injured country (if it has market power) is always less than the welfare cost on the country facing the tariff punishment. This establishes the ex-post efficiency of fines.

Future research should build on these insights to determine whether the WTO's dispute system should move to financial compensation as the primary remedy. In our view, several aspects related to the ex-ante efficiency of tariffs as an enforcement mechanism deserve to be modelled carefully in the future. First, the level of compensation under fines deserves attention. If fines were required to deliver the exact same level of compensation to the injured country as it would obtain under tariff retaliation, then equilibrium tariffs would actually be higher under fines. The logic is similar to proposition 4 but now it applies to the violating country: a given amount of compensation *received* is less costly to the violating country if it can pay it with a fine instead of having to face higher tariffs on its exports during the punishment period. Second, the enforcement advantage of tariff retaliation would be even stronger if injured countries can select the goods on which they retaliate, as observed in recent cases where retaliating parties chose products concentrated in swing states. By targeting states with greater political influence, tariffs may be more effective in generating pressure through exporters for the violating government to comply with the WTO's ruling. As Lawrence (2003) notes, parties often retaliate in a fashion that maximizes incentives for compliance. Third,

model more precisely what such an agreement would entail.

this advantage of tariffs relative to fines can be further reinforced when fines are raised via general taxation because then the punishment for violating the trade agreement is dispersed and can go unnoticed. Future research on the optimal design of enforcement mechanisms should extend our analysis to incorporate these ex-ante efficiency arguments of tariffs relative to fines.

6 Appendix

6.1 Analytical expressions

The global optimum tariffs in (8) are obtained by solving the following first-order condition for τ^c

$$W_\tau(\tau^c) + W_{\tau^*}(\tau^* = \tau^c) = 0 : (1 + p^w_\tau)[\tau^c M_p + (\lambda - 1)S] = 0$$

The Nash tariff for each small country in (26) is obtained by solving the following first-order condition for $\tau^{*\kappa}$, where all variables correspond to their import good, y.

$$\begin{aligned} W^\kappa_{\tau^{*\kappa}} &= 0 : (1 + p^w_{\tau^{*\kappa}})[\tau^{*\kappa} M^{*\kappa}_p + (\lambda - 1)S^{*\kappa}] - p^w_{\tau^{*\kappa}} M^{*\kappa} = 0 \\ \tau^\kappa &= \frac{p^w_{\tau^{*\kappa}}}{1 + p^w_{\tau^{*\kappa}}} \frac{M^*}{M^*_p} - (\lambda - 1)\frac{S^*}{M^*_p} \end{aligned}$$

where in the second line we use the property that the demand and supply for each κ are identical to the original value divided by κ s.t. $z^\kappa = z/\kappa$ for $z = S^*, M^*, M^*_p$. We then implicitly differentiate the market clearing condition for y to obtain $p^w_{\tau^{*\kappa}}$

$$M(p^w) + (\kappa - 1)M^{*\kappa}(p^w + \tau^{j\neq\kappa}) + M^{*\kappa}(p^w + \tau^\kappa) = 0$$

We obtain $p^w_{\tau^{*\kappa}}/(1+p^w_{\tau^{*\kappa}}) = \frac{1}{\kappa}(-M^*_p/M'(p^w))$. Employing the same definitions as before, $1/\varepsilon^* \equiv \frac{M}{p^w M_p}$ and $\xi^* \equiv -\frac{\partial M^*}{\partial p^w}\frac{p^w}{M^*} = -M^*_p p^w/M^*$, we have (26).

6.2 Additional Proofs

Proposition 3: Enforcement under tariffs versus exchanged bonds with asymmetric countries

(a) $\tau^{C\kappa} > \tau^G$, $\tau^{C\kappa} > \tau^{*C\kappa}$ for all $\delta < \delta_\kappa$ under tariff retaliation.

Since the large country has at least κ identical ICs (more if it decides to deviate against any subgroup of countries), we assume that if it deviates in one of them, it deviates in all. The payoffs are defined as in section 3.1 but now the foreign tariffs are not symmetric, $\tau^{*c\kappa}$ is to be determined and $\tau^{*N\kappa}$ is given in (26). Thus the relevant IC for the large country when it deviates against all is

$$W(\tau^N, \boldsymbol{\tau}^{*c}) + \frac{\delta}{1-\delta} W(\tau^N, \boldsymbol{\tau}^{*N}) \leq \frac{W(\tau^c, \boldsymbol{\tau}^{*c})}{1-\delta} \tag{36}$$

Since the large country deviates against all the small ones, the worst (SPNE) punishment that each uncoordinated small country can inflict is to revert to their individual Nash tariffs, $\tau^{*N\kappa}$, and they all do so since they all faced a deviation so all the elements of the vector $\boldsymbol{\tau}^{*N}$ are equal to $\tau^{*N\kappa}$.

For each of the small countries $W^{*\kappa} = W^*/\kappa$ and the κ ICs are identical so we can multiply both sides of each by κ to rewrite them as follows:

$$W^*(\tau^c, \boldsymbol{\tau}^{*N\kappa}) + \frac{\delta}{1-\delta} W^*(\tau^N, \boldsymbol{\tau}^{*N}) \leq \frac{W^*(\tau^c, \boldsymbol{\tau}^{*c})}{1-\delta} \tag{37}$$

where we recall that each constraint is identical under infinite reversion and WRP when the latter uses the minimum possible continuation payoff. The worst punishment that the large country can inflict on any deviating small country is to set τ^N on all countries exporting the good so as to lower the world price as much as possible. Therefore the minimum continuation payoff corresponds to all countries abandoning the agreement. Note that if we assume that all small countries happened to deviate at the same time then $\boldsymbol{\tau}^{*N\kappa} = \boldsymbol{\tau}^{*N}$. Alternatively, if only $\kappa = j$ deviates then $\boldsymbol{\tau}^{*N\kappa}$ is equal to $\boldsymbol{\tau}^{*c}$ for all $\kappa \neq j$ which leads to a higher world price than under $\boldsymbol{\tau}^{*N}$ and so we must evaluate $\tau^{*N\kappa=j}$ at those prices. It is simple to show that the results below are independent of which of these two assumptions we use since in either case the aggregate payoff of small countries from deviating is lower than for the large one, i.e. $W^*(\tau^c, \boldsymbol{\tau}^{*N\kappa}) < W(\tau^N, \boldsymbol{\tau}^{*c})$, which is the key to several results.

First, since we define δ_κ in the text as the minimum discount factor at which (36) holds with equality at the global optimum, $\tau^{C\kappa} = \tau^{*C\kappa} = \tau^G$, we know that for any $\delta < \delta_\kappa$ tariff retaliation cannot sustain τ^G. Thus we need only show that the lowest self-enforcing cooperative tariffs when $\delta < \delta_\kappa$ satisfy $\tau^{C\kappa} > \tau^{*C\kappa}$. We prove this by contradiction. Assume that the lowest self-enforcing cooperative tariff is $\tau^{C\kappa} = \tau^{*C\kappa} \geq \tau^G$ and that it is such that the IC in (36) binds. We then show that when $\tau^{C\kappa} = \tau^{*C\kappa}$ the IC in (37) has slack. Since the RHS of (36) and (37) are equal at $\tau^{C\kappa} = \tau^{*C\kappa}$ (due to symmetry) we need only show that the LHS of (36) exceeds that of (37). This holds because (i) the deviation and (ii) the Nash payoff is higher for the large country than the corresponding values for the $\kappa > 1$ uncoordinated small countries as a whole. We now show (i) and (ii).

(i) $W(\tau^N, \boldsymbol{\tau}^{*c}) > W^*(\tau^c, \boldsymbol{\tau}^{*N\kappa})$ at $\tau^{C\kappa} = \tau^{*C\kappa}$:

To see this, recall that the symmetry in W and W^* implies that if $\tau^{C\kappa} = \tau^{*C\kappa}$ and all small countries set their tariffs equal to τ^N we would have the following equality

$$W(\tau^N, \boldsymbol{\tau}^{*c} = \tau^{*C\kappa}) = W^*(\tau^c = \tau^{C\kappa}, \boldsymbol{\tau}^* = \tau^N) > W^*(\tau^c, \boldsymbol{\tau}^{*N\kappa})$$

The inequality follows from the fact that τ^N is the value that maximizes W^* for a given τ^c and the elements of $\boldsymbol{\tau}^{*N\kappa}$ are not equal to τ^N (from (26) when $\kappa > 1$).

(ii) $W(\tau^N, \boldsymbol{\tau}^{*N}) > W^*(\tau^N, \boldsymbol{\tau}^{*N})$

Symmetry also implies that $W(\tau^N, \boldsymbol{\tau}^{*N} = \tau^N) = W^*(\tau^N, \boldsymbol{\tau}^* = \tau^N)$, which we use to derive

$$\begin{aligned} W(\tau^N, \boldsymbol{\tau}^{*N}) &> W(\tau^N, \boldsymbol{\tau}^{*N} = \tau^N) = W^*(\tau^N, \boldsymbol{\tau}^* = \tau^N) \\ &> W^*(\tau^N, \boldsymbol{\tau}^{*N}) \end{aligned}$$

where the first inequality is due to the fact that $\boldsymbol{\tau}^{*N} = \tau^{*N\kappa}$ for all κ and it is smaller than τ^N (from (26)) and so the export price obtained by the large country is higher than if it faced τ^N in all κ. The last inequality is because $\boldsymbol{\tau}^* = \tau^N$ for all κ is the value that maximizes W^* for any given tariff in the large country, not $\boldsymbol{\tau}^{*N}$.

Given that at a symmetric cooperative tariff the LHS of the IC for each small country is lower than for large (and the RHS is equal) there is some $\tau^{*c\kappa} < \tau^{C\kappa}$ that is self-enforcing since the reduction in τ^{*c} reduces the slack in (37) without violating (36).

(b) $\tau^{C\kappa} = \tau^{*C\kappa} = \tau^G$ *for some* $\delta < \delta_\kappa$ *under a bond exchange and* $b^g > \kappa b^{*\kappa g}$

When the large country posts a bond b and receives $\kappa b^{*\kappa}$ in total bonds from the small ones, the WRP constraint for it and *each* of the small countries are respectively

$$W(\tau^N, \boldsymbol{\tau}^{*c}) - b + \kappa b^{*\kappa} + V^b \leq \frac{W(\tau^c, \boldsymbol{\tau}^{*c})}{1-\delta} \tag{38}$$

$$W^*(\tau^c, \boldsymbol{\tau}^{*N\kappa})/\kappa - b^{*\kappa} + b/\kappa + V^{*b} \leq \frac{W^*(\tau^c, \boldsymbol{\tau}^{*c})/\kappa}{1-\delta} \tag{39}$$

Their respective continuation payoffs are defined as

$$V^b \equiv -\frac{\delta \kappa b^{*\kappa}}{\delta} + \frac{\delta W(\tau^c, \boldsymbol{\tau}^{*c})}{1-\delta} \tag{40}$$

$$V^{*b} \equiv -\frac{\delta b}{\delta \kappa} + \frac{\delta W^*(\tau^c, \boldsymbol{\tau}^{*c})/\kappa}{1-\delta} \tag{41}$$

Substituting these payoff expressions into (38) and (39) respectively and solving for the minimum bonds that enforce the global optimum we obtain b^g and $\kappa b^{*\kappa g}$ as defined in (28) and (29) in the text. We can immediately prove the last part of the proposition, $b^g > \kappa b^{*\kappa g}$, since it requires

$$W(\tau^N, \boldsymbol{\tau}^{*G}) - W(\tau^G, \boldsymbol{\tau}^{*G}) > W^*(\tau^G, \boldsymbol{\tau}^{*N\kappa}) - W^*(\tau^G, \boldsymbol{\tau}^{*G})$$

and $W(\tau^G, \boldsymbol{\tau}^{*G}) = W^*(\tau^G, \boldsymbol{\tau}^{*G})$ (symmetry) and $W(\tau^N, \boldsymbol{\tau}^{*G}) > W^*(\tau^G, \boldsymbol{\tau}^{*N\kappa})$ (as proved in part (a) (i) of this proposition for $\kappa > 1$).

The final step is to show that there exists some $\delta < \delta_\kappa$ such that tariff retaliation does *not* enforce the global optimum but that these bonds do *and* also satisfy the WRP constraint. This requires that $b^g \leq b^{\max}$ and $\kappa b^{*\kappa g} \leq \kappa b^{*\kappa \max}$, where $b^{\max}$ and $b^{*\kappa \max}$ are the values that equate V^{*b} and V^b in (41) and (40) respectively to $W^*(\tau^N, \boldsymbol{\tau}^{*N})\delta/(1-\delta)$ and $W(\tau^N, \boldsymbol{\tau}^{*N})\delta/(1-\delta)$, the payoff from abandoning the agreement. These yield

$$b^{\max} = \frac{\delta[W^*(\tau^c, \boldsymbol{\tau}^{*c}) - W^*(\tau^N, \boldsymbol{\tau}^{*N})]}{1-\delta} \tag{42}$$

$$\kappa b^{*\kappa \max} = \frac{\delta[W(\tau^c, \boldsymbol{\tau}^{*c}) - W(\tau^N, \boldsymbol{\tau}^{*N})]}{1-\delta} \tag{43}$$

As we note in the text a necessary condition for each bond to be WRP at the global optimum is that their sum does not exceed the maximum WRP sum at that tariff

$$\begin{aligned} b^g + \kappa b^{*\kappa g} &\leq b^{\max} + \kappa b^{*\kappa \max} \\ [W(\tau^N, \boldsymbol{\tau}^{*G}) + \frac{\delta W(\tau^N, \boldsymbol{\tau}^{*N})}{1-\delta}] + [W^*(\tau^G, \boldsymbol{\tau}^{*N\kappa}) + \frac{\delta W^*(\tau^N, \boldsymbol{\tau}^{*N})}{1-\delta}] &\leq \frac{W(\tau^G, \boldsymbol{\tau}^{*G}) + W^*(\tau^G, \boldsymbol{\tau}^{*G})}{1-\delta} \end{aligned} \tag{44}$$

We obtain (31) in the text by using the values for the bonds in (28), (29), (42) and (43). The second line in the expression above uses these values and re-arranges to show that the condition is simply the sum of the enforcement constraints for the large and all the small countries under tariff retaliation (i.e. (36) and (37)). We know that (44) holds with slack for $\delta = \delta_\kappa$ since by the definition of δ_κ the constraint for the large country in (36) holds with equality and we have proved in the first part of the proposition that in this case the one for each small country, (37), has slack. Therefore there exists some $\delta < \delta_\kappa$ such that this condition holds. We now show that there also exists some $\delta < \delta_\kappa$ such that $b^g \leq b^{\max}$ and $\kappa b^{*\kappa g} \leq \kappa b^{*\kappa \max}$ individually hold.

We first consider $b^g \leq b^{\max}(\tau^G)$ Using the value for b^g (28) on the LHS and starting at $\delta = \delta_\kappa$ we have

$$\begin{aligned} W(\tau^N, \boldsymbol{\tau}^{*G}) - W^C(\tau^G, \boldsymbol{\tau}^{*G}) &= \frac{\delta_\kappa [W(\tau^G, \boldsymbol{\tau}^{*G}) - W(\tau^N, \boldsymbol{\tau}^{*N})]}{1-\delta_\kappa} \\ &= \frac{\delta_\kappa [W^*(\tau^G, \boldsymbol{\tau}^{*G}) - W(\tau^N, \boldsymbol{\tau}^{*N})]}{1-\delta_\kappa} \\ &< \frac{\delta_\kappa [W^*(\tau^G, \boldsymbol{\tau}^{*G}) - W^*(\tau^N, \boldsymbol{\tau}^{*N})]}{1-\delta_\kappa} \end{aligned}$$

where the first equality follows from the definition of δ_κ in the proof of the first part of this proposition. The second from the symmetry of W and W^* and the symmetric global optimum. The last inequality is due to $W(\tau^N, \boldsymbol{\tau}^{*N}) > W^*(\tau^N, \boldsymbol{\tau}^{*N})$ for $\kappa > 1$, as proved in part (a) (ii). Since the RHS in the last line is equal to $b^{\max}$ and is continuously decreasing in δ_κ even holding the cooperative tariff fixed, we have that when $\kappa > 1$ there exists a $\delta < \delta_\kappa$ s.t. $b^g \leq b^{\max}(\tau^G)$. Note also that if $\kappa = 1$ then we are back to the symmetric case and would have an equality. So $b^g = b^{\max}(\tau^G)$ iff $\delta = \delta_\kappa$, i.e. only if the discount factor was high enough to also support the global optimum under tariffs, which confirms the result for the symmetric case in proposition 2.

Consider now $\kappa b^{*\kappa g} \leq b^{*\kappa \max}(\tau^G)$. Using the value for $\kappa b^{*\kappa g}$ in (29) on the LHS we have

$$\begin{aligned} W^*(\tau^G, \boldsymbol{\tau}^{*N\kappa}) - W^*(\tau^G, \boldsymbol{\tau}^{*G}) &< W(\tau^N, \boldsymbol{\tau}^{*G}) - W(\tau^G, \boldsymbol{\tau}^{*G}) \\ &= \frac{\delta_\kappa [W(\tau^G, \boldsymbol{\tau}^{*G}) - W(\tau^N, \boldsymbol{\tau}^{*N})]}{1-\delta_\kappa} \end{aligned}$$

where the first inequality follows from $W(\tau^G, \boldsymbol{\tau}^{*G}) = W^*(\tau^G, \boldsymbol{\tau}^{*G})$ (by symmetry) and $W(\tau^N, \boldsymbol{\tau}^{*G}) > W^*(\tau^G, \boldsymbol{\tau}^{*N\kappa})$ for $\kappa > 1$, as proved in part (a) (i). The equality on the second line follows from the definition of δ_κ. Since the RHS in the last line is equal to $b^{*\kappa \max}(\tau^G)$ in (43), and is continuously decreasing in δ_κ even holding the cooperative tariff fixed, we have that when $\kappa > 1$ there exists a $\delta < \delta_\kappa$ s.t. $\kappa b^{*\kappa g} \leq b^{*\kappa \max}(\tau^G)$.□

Claim: "In a trade agreement between a large country and a group of $\kappa > 1$ uncoordinated small countries, the global optimum can also be enforced by WRP fines and an exchange of bonds for some $\delta < \delta_\kappa$. Moreover, this exchange requires only the large country to post a positive bond equal to $\tilde{b}^g$, which is lower than b^g. "

Here we prove the claim above made at the end of section 4.1. Similarly to before, in the absence of deviations each country must first exchange bonds before cooperation starts. If a country deviates it looses its bond but keeps any foreign bond it holds. But now, if a deviation were to occur then cooperation resumes only after a fine f (or f^*) is paid. Moreover, we consider a positive bond b posted by the large country and divided by the κ small ones and a bond equal to zero posted by the small ones. The incentive constraints for the large and each of the small countries are respectively

$$W(\tau^N, \boldsymbol{\tau}^{*G}) - b + V^b \leq \frac{W(\tau^G, \boldsymbol{\tau}^{*G})}{1-\delta} \tag{45}$$

$$W^*(\tau^G, \boldsymbol{\tau}^{*N\kappa})/\kappa + b/\kappa + V^{*b} \leq \frac{W^*(\tau^G, \boldsymbol{\tau}^{*G})/\kappa}{1-\delta} \tag{46}$$

and the minimum continuation payoffs for each are

$$V^{b\,\min} \equiv -\delta f^{\max} + \frac{\delta W(\tau^G, \boldsymbol{\tau}^{*G})}{1-\delta} = \frac{\delta W(\tau^N, \boldsymbol{\tau}^{*N})}{1-\delta}$$

$$V^{*b\,\min} \equiv -\delta f^{*\max} + \frac{\delta W^*(\tau^G, \boldsymbol{\tau}^{*G})/\kappa}{1-\delta} = \frac{\delta W^*(\tau^N, \boldsymbol{\tau}^{*N})/\kappa}{1-\delta}$$

replacing $V^{b\,\min}$ in (45) and solving for the minimum bond required to sustain τ^G we have

$$\tilde{b}^g = [W(\tau^N, \boldsymbol{\tau}^{*G}) - W(\tau^G, \boldsymbol{\tau}^{*G})] - \frac{\delta}{1-\delta}[W(\tau^G, \boldsymbol{\tau}^{*G}) - W(\tau^N, \boldsymbol{\tau}^{*N})] < b^g$$

The inequality holds because b^g is given by (28) and is equal to the term in the first parenthesis of $\tilde{b}^g$. The second term in parenthesis for $\tilde{b}^g$ is positive whenever $\kappa > 1$ is small enough that the large country wants an agreement rather than a trade war (our assumption throughout). Large can now post a lower bond because the threat of the maximum fine off the equilibrium path reduces the continuation payoff relative to the case without fines.

To show that $\tilde{b}^g$ does not violate the constraint for small countries in (46) we replace $\tilde{b}^g$ and

$V^{*b\min}$ into (46) and rearrange it to obtain

$$[W(\tau^N,\boldsymbol{\tau}^{*G})+\frac{\delta W(\tau^N,\boldsymbol{\tau}^{*N})}{1-\delta}]+[W^*(\tau^G,\boldsymbol{\tau}^{*N\kappa})+\frac{\delta W^*(\tau^N,\boldsymbol{\tau}^{*N})}{1-\delta}]\leq\frac{W(\tau^G,\boldsymbol{\tau}^{*G})}{1-\delta}+\frac{W^*(\tau^G,\boldsymbol{\tau}^{*G})}{1-\delta}$$

This is the same condition for the sum of the constraints derived in (44) and it holds for some $\delta<\delta_\kappa$ as we show in the proof for part (b) of proposition 3.□

Proposition 4

Higher compensation: $V^{*f}(f)>V^{*\tau}(n)$

Proposition 1 shows that we obtain $\tau^{Cf}(f=f^{\max})=\tau^{C\tau}(n=n^{\max})$. Consider now some arbitrary $n^p\in[1,n^{\max}]$ and a corresponding fine f^p defined by $V^f(f^p)=V^\tau(n^p)$, as given in (13) and (18). These punishments also imply the equilibrium cooperative tariff is identical across enforcement mechanisms, i.e. $\tau^{Cf}(f=f^p)=\tau^{C\tau}(n=n^p)$, as is clear from the constraints in (12) and (17). When $n^p=n^{\max}$ we have $f=f^{\max}$ since $V^f(f^{\max})=\frac{\delta}{1-\delta}W^N=V^\tau(n^{\max})$, so $n^p=n^{\max}$ is simply a special case and we prove the general result for n^p. For a given n^p we obtain the following f^p by employing the definitions in (13) and (18) and $\tau^{Cf}(f=f^p)=\tau^{C\tau}(n=n^p)$

$$\begin{aligned}V^\tau(n^p)&=V^f(f^p)\\ f^p&=\frac{1-\delta^{n^p}}{1-\delta}(W^C-W^P)\end{aligned}$$

The payoffs $V^{*\tau}(n)$ and $V^{*f}(f)$ are defined in (32) and (33) when $f=f^{\max}$ and $n=n^{\max}$. The definition is the same at $f=f^p$ and $n=n^p$ and so $V^{*f}(f^p)>V^{*\tau}(n^p)$ iff

$$\delta f^p+\frac{\delta}{1-\delta}W^{*C}(\tau^{Cf})>\delta W^{*P}(\tau^{C\tau},\tau^{*N})\frac{1-\delta^{n^p}}{1-\delta}+\frac{\delta^{n^p+1}}{1-\delta}W^{*C}(\tau^{C\tau})$$

Since $\tau^{Cf}(f=f^p)=\tau^{C\tau}(n=n^p)$ we simplify this to obtain the expression in (34) in the text and now show it must hold for the general case.

$$\begin{aligned}
f^p &> \frac{1-\delta^{n^p}}{1-\delta}(W^{*P} - W^{*C}) \\
&\Leftrightarrow W^C - W^P > W^{*P} - W^{*C} \\
&\Leftrightarrow W(\tau^c, \tau^{*c}) - W(\tau^c, \tau^{*N}) > W^*(\tau^c, \tau^{*N}) - W^*(\tau^c, \tau^{*c}) \\
&\Leftrightarrow W(\tau^c, \tau^{*c}) > W(\tau^c, \tau^{*N}) + W(\tau^N, \tau^{*c}) - W(\tau^c, \tau^{*c}) \\
&\Leftrightarrow W(\tau^c, \tau^{*c}) > W(\tau^N, \tau^{*N})
\end{aligned}$$

where the second line uses the value of f^p found above, the third uses the definition of the punishment and cooperative payoffs, the third uses the symmetry assumption across countries. The fourth simplifies by using the separability of W in domestic and foreign tariffs (e.g. $W(\tau^N, \tau^{*c}) - W(\tau^c, \tau^{*c})$ is simply the difference between $\int_{p_x}^{\infty} D_x(p_x(\tau))dp_x + \lambda_x \int_0^{p_x} S_x(p_x(\tau))dp_x + \tau_x M_x(p_x(\tau))$ evaluated at $\tau = \tau^N$ and $\tau = \tau^c$). The last line is necessarily true because Nash tariffs are inefficient and each country's payoff under own and foreign Nash tariffs is lower than its cooperative payoff.

Pareto improvement. Our definition of Pareto improvement in the text is satisfied if *(i)* $W^C(\tau^{Cf}) = W^C(\tau^{C\tau})$*; (ii)* $W^{*C}(\tau^{Cf}) = W^{*C}(\tau^{C\tau})$; *(iii)* $V^f = V^\tau$*; and (iv)* $V^{*f} > V^{*\tau}$. Since the last inequality was just shown we need only show the first three equalities. From proposition 1 we know that $\tau^{Cf} = \tau^{C\tau}$ for $n^{\max}$ and $f^{\max}$. Therefore $W^C(\tau^{Cf}) = W^C(\tau^{C\tau})$. Given symmetry we also have $W^{*C}(\tau^{Cf}) = W^{*C}(\tau^{C\tau})$. As we show in section 3.1, equation (15), $V^\tau = V^{\tau \min} = \frac{\delta}{1-\delta} W^N$. In section 3.2, equation (20) shows that V^f is also equal to that value. Thus, under the most cooperative tariff we have $V^\tau = V^f$. By definition of n^p and f^p we have $V^\tau(n^p) = V^f(f^p)$ and as shown above this implies $\tau^{Cf}(f = f^p) = \tau^{C\tau}(n = n^p)$ so conditions *(i)*; *(ii)* and *(iii)* also hold for the general case. □

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