Limiting Cross-Retaliation when Punishment is Limited: How DSU Article 22.3 Complements GATT Article XXVIII

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Abstract

This paper analyzes two prominent institutional rules in the international trading system: a limited cross-retaliation rule characterized by the Understanding on Rules and Procedures Governing the Settlement of Disputes (DSU) Article 22.3 and a limited punishment rule characterized by the General Agreement on Tariffs and Trade (GATT) Article XXVIII. In general, both rules are designed to limit the countermeasures upon a violation; however, the former rule specifies the limits of composition in retaliation, whereas the latter one designates the limits of retaliation magnitude. We show that, albeit seemingly unrelated, the limited cross-retaliation rule complements the limited punishment rule in permitting greater trade liberalization. Specifically, we show how the limited cross-retaliation rule also helps limit the incentives to violate the trade agreement when the limited punishment rule prevails.

1 Introduction

This paper analyzes two prominent institutional rules of the international trading system: a limited cross-retaliation rule characterized by the Understanding on Rules and Procedures Governing the Settlement of Disputes (DSU) Article 22.3 and a limited punishment rule characterized by General Agreement on Tariffs and Trade (GATT) Article XXVIII. In general, both rules are designed to limit the countermeasures upon a violation; however, the former rule specifies the limits of composition in retaliation, whereas the latter one designates the limits of retaliation magnitude. We show that, albeit seemingly unrelated, the limited

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cross-retaliation rule complements the limited punishment rule in permitting greater trade liberalization. Specifically, we show how the limited cross-retaliation rule also helps limit the incentives to violate the trade agreement when the limited punishment rule prevails.

The DSU Article 22.3 emphasizes that the suspension of concessions or other obligations should be implemented with respect to the same sector in which the initial violation or other nullification or impairment has occurred. Governments can seek to suspend concessions across sectors, or agreements, if within-sector punishment cannot be implemented in a practicable and effective manner.[1] However, the basic rationale for this *Limited Cross Retaliation* rule (LCR from now on) is to ensure that retaliation across sectors and agreements remains an exception. There have been only three cases (out of nine requests) where the complainant government was authorized for cross-agreement retaliation in the entire GATT-WTO system history: the US-Internet Gambling Case (Antigua and Barbuda were authorized to retaliate in TRIPs), the EC-Banana III Case (Ecuador was authorized to retaliate by $191 million annually in GATS and TRIPs) and the US-Cotton Case (Brazil was authorized to retaliate by $147 million in GATS and TRIPs).

The GATT Article XXVIII, on the other hand, determines an upper bound for countermeasures that is equivalent to the level of nullification or impairment resulting from the breach of agreement obligations.[2]In principle, this *Withdrawal of Equivalent Concessions* (WEC from now on) rule dismisses the punitive character of countermeasures and, instead, defines them as procedures for inducing compliance with WTO obligations. Suspension of concessions or other obligations are, therefore, typically advised to be temporary and to be applied until the measures inconsistent with the WTO obligations are removed by the violating member or until a mutually agreeable solution is obtained. In practice, this implies that both the violator and complainant governments apply measures and countermeasures until a mutually satisfactory agreement is reached.[3]

In order to analyze the impact of these rules, we employ a two-country two-sector tariff-setting framework, where each country is an exporter and an importer in each sector. Goods in a given sector are substitutes in

[1]Cross retaliation in sectors other than the one where the dispute originated is allowed for in the DSU article 22, paragraph 3, however, it specifically subordinates more distant cross-retaliations to those that are in the same sector or at least the same agreement. In particular, paragraph 3(b) allows cross retaliation in other sectors (of the same agreement) only if same sector retaliation, as described in paragraph 3(a), "is not practical or effective" (WTO, 2008). Paragraph 3(c) allows for cross retaliation in other covered agreements (such as GATS or TRIPS) only if cross retaliation as allowed for in 3(b) "is not practical or effective".

[2]For a detailed analysis of permissible retaliation in international trading system from a legal perspective see Sadiqhodjaev (2009), for economic interpretations see Bown and Ruta (2008) and Bagwell (2008).

[3]In the EC-Banana I case, the US was authorized to retaliate by $191.4 million annually, effective April 1999, after the EC failed to comply with WTO arbitration. The EC measures that favored bananas from former colonial states as well as the US countermeasures, in the form of a withdrawal of tariff concessions, lasted until July 2001, at which point the parties reached a bilateral agreement. A similar interaction is also observable in pre-WTO trade wars. In November 1985, the US increased the tariff on EC egg-pasta exports from 0.25% to 25% (as a response to the EC's failure to comply in its regulations against US citrus exports). The EC counter-retaliated by increasing the tariffs on US lemon exports to 20%. This retaliation and counter-retaliation lasted until August 1986 (Lawrence, 2003), at which point an agreement was reached.

consumption, and goods across the sectors are independent. Our representation of preferences captures these demand substitutabilities and, in turn, generates welfare functions whereby tariffs in each sector are strategic substitutes. Tariffs across the sectors are independent. In the absence of a trade agreement, governments apply unilaterally optimal tariffs in each sector, which are globally inefficient. We then characterize alternative cooperation paths by formally introducing the LCR and WEC punishment rules. We first analyze the structure of cooperation under the benchmark Nash-reversion strategies. We then introduce both the LCR and the WEC Rules. In this case, any deviation from the cooperative path in a given sector is punished by an equivalent deviation within the same sector (unlinked agreements). Formally, we characterize the punishment stage with simultaneous applications of the deviation tariff, which, we believe, is a good approximation to the "inducing compliance" interpretation of countermeasures.[4] Finally, we remove the LCR rule to allow cross-retaliation, where an initial violation in a given sector might be punished by an equivalent deviation in the other sector (linkage case).

Our first main result shows that, given symmetric issues and identical cooperative tariffs, the magnitude of initial violations are greater under the linkage case. Hence, removing the LCR rule and linking the agreements reduces the self-enforcing level of cooperation. The idea here is that when tariffs are strategic substitutes an equivalent punishment within the same sector hurts the deviating country more than does cross-retaliation across independent sectors. In order to reduce retaliation, governments, therefore, reduce the violation magnitude when both LCR and WEC rules prevail. The maximum level of cooperation in our model (the lowest self-enforcing-tariff) decreases in the magnitude of the deviation tariffs. Limiting cross-retaliation, therefore, enhances cooperation between governments.

Our second main result actually shows that whenever it is possible governments will always choose cross-retaliation over within-sector retaliation. After a violation occurs, the punishing government prefers avoiding within-sector punishment. The relative gain from increasing their own tariff in a sector where the trading partner has already raised its tariff is lower when tariffs are strategic substitutes, therefore, the punisher suspends its concessions in the other sector. The initial violator does not oppose this choice. This result is interesting in the sense that it points to a time inconsistency problem: once a deviation occurs, both countries prefer the punishment path with less enforcement power. Therefore, our third main result shows that, for sufficiently patient governments, limiting the punishment by LCR and WEC rules together at the outset generates the preferred subgame perfect outcome.

[4] See footnote 3.

1.1 A Simple Example with Discrete Actions

In this section we briefly introduce a reduced form example of our model. There are two players interacting indefinitely in two separate issues (Sector A and Sector B). Issues and payoffs are assumed to be symmetric as shown in Figure 1. Players choose among a low action (L), a medium action (M), and a high action (H) in each period, where the lower actions are assumed to be more cooperative than the higher ones. In the absence of WEC and LCR rules, governments apply Nash-reversion strategies, where any deviation in either policy triggers the play $(H_aH_b, H_a^*H_b^*)$, where the subscripts show the sector. Hence, cooperation is enforceable, i.e, $(L_aL_b, L_a^*L_b^*)$ is played forever, when the following incentive constraint holds:

$$(1-\delta)\cdot(19+19)+\delta\cdot(0)\leq(10+10)$$

where δ denotes the discount factor. Cooperation requires a sufficiently patient government, $\delta \geq \delta^N = \frac{9}{19}$.

Now, we introduce both the WEC and the LCR rules simultaneously. Any deviation in a given sector is punished within the same sector by the same amount. After either party plays M in sector a, the action profile $(M_aL_b, M_a^*L_b^*)$ is played forever . Cooperation is, therefore, sustained under Unlinked-WEC strategies if the following constraint is satisfied:

$$(1-\delta)\cdot(16+10)+\delta\cdot(4+10)\leq(10+10)$$

or if $\delta \geq \delta^U = \frac{1}{2}$. The limited punishment, however, needs to be credible for an agreement under Unlinked-WEC strategies to be self-enforcing. Our idea is that a deviation from the punishment path is *egregious* and is punished by Nash reversion. Hence, a rational player prefers deviating in both issues when it deviates from its punishment. For neither player to have a profitable deviation from the punishment path requires that:

$$(1-\delta)\cdot(6+19)+\delta\cdot(0)\leq(4+10)$$

The minimum discount factor that supports credibility of the Unlinked-WEC punishment regime, then, is given by $\delta \geq \delta^{spU} = \frac{11}{25} < \delta^U$.

We now remove the LCR rule; therefore, players are allowed to punish the violator in the other sector, i.e., $(M_aL_b, L_a^*M_b^*)$ is played forever upon a medium deviation in sector a. Any greater deviation or any deviation from the punishment path is considered *egregious* and is punished by infinite Nash play. Cooperation is

	L^*	M^*	H^*
L	$10, 10$	$1, 16$	$-3, 19$
M	$16, 1$	$4, 4$	$-1, 6$
H	$19, -3$	$6, -1$	$0, 0$

Sector A

	L^*	M^*	H^*
L	$10, 10$	$1, 16$	$-3, 19$
M	$16, 1$	$4, 4$	$-1, 6$
H	$19, -3$	$6, -1$	$0, 0$

Sector B

Figure 1: Interaction in Two Sectors

supported by the Linked-WEC regime if:

$$(1-\delta)\cdot(16+10)+\delta\cdot(16+1)\leq(10+10)$$

or if $\delta \geq \delta^L = \frac{2}{3}$. This value is greater than the Unlinked-WEC minimum discount factor, $\delta^L > \delta^U$, therefore allowing cross-retaliation reduces the enforcement power. The Linked-WEC punishment strategy is subgame perfect if:

$$(1-\delta)\cdot(19+6)+\delta\cdot(0)\leq(16+1).$$

This condition is satisfied for $\delta \geq \delta^{spL} = \frac{8}{25}$. Overall, the required minimum discount factors under different strategies are ranked as follows: $0 < \delta^{spL} < \delta^{spU} < \delta^N < \delta^U < \delta^L < 1$. Linked-WEC supports the least cooperation whereas the harshest punishments under Nash Reversion supports the most. Note, however, that there exists discount factors where neither strategy is incentive compatible yet both limited punishment strategies are subgame perfect, i.e., $\delta \in \left[\delta^{spU}, \delta^N\right)$. Now, we present some useful observations regarding the discount factor that resonate with our main findings in this paper:

1. For $\frac{12}{29} \leq \delta < \frac{9}{19}$, cooperation under any punishment regime (Nash Reversion or WEC) is not implementable. However, when WEC is available, a rational player would prefer a limited deviation in only one sector, rather than a large deviation in both.

To see this, we compare the continuation payoffs for a deviation under Linked-WEC and Nash-reversion:

$$(1-\delta)\cdot 26+\delta\cdot 17\geq(1-\delta)\cdot 38+\delta\cdot(0) \quad \Longrightarrow \delta\geq\delta^{L\succ N}=\frac{12}{29}$$

This observation points to an interesting rationale for the WEC rule. Limiting the punishment reduces the magnitude of deviation for impatient players. In particular, if the value of the future unexpectedly drops below that necessary to support cooperation, then without WEC the continuation would be grim. WEC generates a less severe deviation and a less punitive future. This result also holds with Unlinked-WEC punishments whereby a limited deviation in one sector is preferred to an egregious deviation if $(1-\delta)\cdot 26+\delta\cdot 14 \geq (1-\delta)\cdot 38+\delta\cdot(0) \quad \Longrightarrow \delta \geq \delta^{U\succ N}=\frac{6}{13}\in(\frac{12}{29},\frac{9}{19})$.

Given the limited punishment rationale for WEC, we now show how our simple example generates the three main results of our paper. Our second observation is:

2. After a limited deviation occurs under WEC players prefer cross-retaliation over same-sector retaliation.

This observation is because the punishment path under Linked-WEC strategies generates a higher average payoff for both players: $16+1>10+4$. Our third observation reiterates that Unlinked-WEC has more enforcement power than does Linked-WEC.

3. For $\frac{1}{2}\leq\delta<\frac{2}{3}$, players can support cooperation under the Unlinked-WEC strategies, but not under the Linked-WEC strategies because $\delta^{U}=\frac{1}{2}$ and $\delta^{L}=\frac{2}{3}$.

Our fourth observation is that:

4. If $\frac{1}{2}\leq\delta<\frac{2}{3}$, and if the players do not commit to the Unlinked-WEC strategy ex-ante, then cooperation is not implementable ex-post.

This observation follows from the previous two. After any deviation from the cooperative path, both players prefer the punishment path with cross-retaliation. Punishing within the same issue is, therefore, no longer a credible threat when players can renegotiate away the limitation on cross-retaliation. The availability of cross-retaliation provides less cooperation ex-ante. It is through these results, that we develop in the body of the paper, that we show how the limits on cross retaliation given by the LCR complement the limited retaliation of the the WEC.

It is important to note that our observations do not depend too specifically on the selection of payoffs in this simple example. The key to our results in this Prisoners' Dilemma type game (and more generally in the model to follow) is that the payoffs are submodular in the player's actions. A simple example of submodularity is given by the following.[5]

Example. Let $f(t,t^{*}):\mathbb{R}^{2}\rightarrow\mathbb{R}$, and $t\in[0,1]$ and $t^{*}\in[0,1]$. If $f(t,t^{*})$ is submodular then

$$f(1,0)+f(0,1)\geq f(0,0)+f(1,1)$$

For example, if $f(t,t^{*})=t(1-t^{*})$, then the above inequality becomes $1+0>0+0$, and this function is submodular. This simple functional form is reminiscent of a more general game whereby the actions are

[5] We elaborate a formal definition of submodularity in the following sections.

	C	D
C	(α, α)	(β, γ)
D	(γ, β)	(ϵ, ϵ)

Figure 2: A Generic Prisoners' Dilemma Game

strategic substitutes (such as a tariff-setting game, a Cournot quantity choice game, or some public good contribution games), and in the tariff-setting model we develop we first show that the tariff choices are strategic substitutes (which is equivalent to a submodular welfare function in the differentiable case) and then how that drives our main results.

Pairwise comparison of the payoffs in Figure 1 show that they are submodular. In addition, the payoffs in Figure 1 are increasing and concave in the player's own action and decreasing and convex in the opponent's action. These properties should be expected of many well-behaved welfare functions and the one we develop below also exhibits these common properties.

Still, many of our results require only submodularity and can be suggested by a simple two-by-two Prisoners' dilemma example without any mention of concavity or convexity. Consider, then, Figure 2. In the two-by-two case there is no medium deviation and, therefore, there is no difference between the Nash-reversion and the Unlinked-WEC reversion. Cross-retaliation, or Linked-WEC reversion, however, shows many of the same properties that we saw in the Figure 1 example. Solving the incentive constraints yields $\delta^N = \delta^U = \frac{\gamma-\alpha}{\gamma-\epsilon}$, $\delta^L = \frac{\gamma-\alpha}{\alpha-\beta}$, $\delta^{spL} = \frac{\varepsilon-\beta}{\gamma-\epsilon}$, and $\delta^{L \succ N} = \frac{\gamma-\alpha}{2\gamma-2\epsilon+\beta-\alpha}$. Note that $\beta < \epsilon < \alpha < \gamma$ holds because of a Prisoner's Dilemma structure and $\alpha + \epsilon < \beta + \gamma$ holds because of submodularity. Hence, $\alpha - \beta < \gamma - \epsilon$, so that $0 < \delta^{spL} < \delta^{L \succ N} < \delta^N = \delta^U < \delta^L < 1$ is satisfied (to see that $\delta^{spL} < \delta^{L \succ N}$ add $\beta + \gamma - \epsilon - \alpha > 0$ to the numerator and to the denominator of δ^{spL}).

1.2 Related Literature

Johnson (1953-1954) provides the first formalization of the terms-of trade rational for trade agreements and the strategic substitutability of tariffs. Recognizing that there are no international soldiers to enforce trade agreements, authors such as Dixit (1987) and Bagwell and Staiger (1990, 1999, 2002) began to look at trade agreements as self-enforcing outcomes in a repeated game framework. Bagwell and Staiger (1990, 2005) provide a rational for limited punishments after limited deviations. The paper closest to ours is Zissimos

(2007) who provides an excellent analysis of trade agreements under WEC strategies. He describes the equilibrium behavior of governments when tariffs are strategic substitutes and the limited punishment rule is applied. The focus of his paper is gradual trade liberalization and there is only one sector. We build on his analysis to analyze linkage across sectors.

This paper also relates to a small but distinguished literature on linkage in repeated games. Bernheim and Whinston (1990) show that firms act more cooperatively when there is multimarket interaction and firms and/or markets are asymmetric. This multimarket collusion effect arises from reciprocal exchange of unilateral concessions. Linkage, however, does not affect enforcement when markets and firms are symmetric. Spagnolo (1999) changes the last result by introducing interaction between the payoffs from independent markets via concavity in the firms' objective functions. The concavity generates scale economies and provides further collusion in both markets by reducing the incentives to act selfishly in both issues. Limão (2005) builds on Spagnolo to introduce explicit structural independence between two international issues. When tariffs and externality taxes are strategic complements, a simultaneous deviation in both policies grants the deviator less benefit than the sum of the gains in each policy independently. Therefore, the linkage incentive constraint is slack when evaluated at the no-linkage solution. A common element in these papers (see also Ederington (2001, 2003), and Conconi and Perroni (2002)) is that linking the issues cannot reduce the enforcement. Chisik (2010) introduces an environment where the degree of asymmetric information in different issues can cause linkage to reduce the aggregate enforcement. Governments observe partner's trade policy with noise, which can generate trade disputes. When the noise is imperfectly correlated between the issues, linking the issues may generate more disputes, decreasing cooperation. This doesn't hold when the noise is perfectly correlated across the issues. Similarly, Ederington (2002) uses information asymmetry to show that linking might be detrimental when countries incorrectly observe cheating, and it might be beneficial when they fail to detect cheating. A major methodological departure of our paper is the lack of structural or informational interdependence between the issues. Our results solely depend on the strategic substitutability of tariffs between governments and the choice of punishment strategies.

The present paper also fits into a body of research that investigate the economic implications of the current legal and institutional framework in international economic relations. Bown (2004) analyzes the WTO dispute settlement process from an economic perspective, and Bown and Hoekman (2005, 2008) focus on the legal aspects of it. Finally, Onder (2010) employs the WEC framework under strategic substitutability of policy variables to investigate the consequences of linking trade agreements with tax treaties and with environmental agreements.

In the next section we describe the economy of each country. In the third section we consider the tariff choices in the absence of a trade agreement. In the fourth section we introduces trade agreements under differing enforcement strategies. In the fifth section we show how the architects of the GATT/WTO were prescient in combining LCR with WEC. We consider some comparative statics in the sixth section and our conclusions are in the seventh section.

2 Economic Environment

We are interested in a two-country tariff-setting framework. To introduce cross-retaliation requires that each country have at least two export goods. In addition, we follow Johnson's (1953-1954) seminal analysis of tariff games which suggests a strategic dependence between the tariffs chosen by each country. In a traditional two-good general equilibrium framework the tariffs are strategic substitutes because the income effect from an increase in a foreign tariff generates a negatively sloped home tariff best response function. Our need to include at least four goods makes a traditional framework difficult to implement; however, home and foreign tariffs are generally independent in a partial equilibrium framework. Our model reintroduces strategic dependence of the tariffs in a tractable structure with a partial-equilibrium intuition.

We consider an environment with two countries, two sectors, and two goods in each sector. Each country has an export good and an import good in each sector (a and b). The home country exports the x goods in each sector (x_a and x_b) and imports the y goods (y_a and y_b). There is also a numeraire good z. Consumer preferences are represented by a quasilinear utility function, $U\left(q_z^d, q_{x_a}^d, q_{x_b}^d, q_{y_a}^d, q_{y_b}^d\right) = q_z^d + \sum_{i=a,b} u_i\left(q_{x_i}^d, q_{y_i}^d\right)$, where $q_{j_i}^d$ denotes the consumption of good j_i; $j \in \{x, y\}$ and $i \in \{a, b\}$. Subutility functions $u_a(.)$ and $u_b(.)$ are increasing and concave in each argument. Demand for the goods is related in each sector, but the sectors are independent. The subutility functions may be written as

$$u_i\left(q_{x_i}^d, q_{y_i}^d\right) = A(q_{x_i}^d + q_{y_i}^d) - B(q_{x_i}^d)^2 - B(q_{y_i}^d)^2 - b q_{x_i}^d q_{y_i}^d, \tag{1}$$

where A, B, and b are all positive constants. We start by assuming symmetry between the countries and sectors, but we relax this assumption in later sections. In this case, the goods are substitutes in consumption and the demand function for good y can be written as $q_{y_i}^d\left(p_{y_i}, p_{x_i}\right) \equiv \xi_{x_i}\left(p_{x_i}\right) - \xi_{y_i}\left(p_{y_i}\right)$ with a similar expression for good x.

The numeraire good is produced under a constant returns to scale technology using a single unit of labor per output. The labor supply in each country is sufficiently large, therefore, the numeraire is produced, and the wage is equal to one, in both countries. The other goods are produced under increasing marginal costs using labor only. Costs of production are given by the strictly convex functions $C_{j_i}\left(q^s_{j_i}\left(p_{j_i}\right)\right)$, where $q^s_{j_i}$ denotes the production of good j_i. Producers maximize profits given technologies and equilibrium prices, which equalizes the producer price of a good to its marginal cost. The home marginal costs are lower for the x goods and higher for the y in each sector, so that home has a comparative advantage in the x goods. The cost functions may be written as (where a superscript star denotes Foreign country values):

$$\begin{array}{c} C_{x_i}\left(q^s_{x_i}\right) = c\left(q^s_{x_i}\right)^2; \quad C_{y_i}\left(q^s_{y_i}\right) = Fq^s_{y_i} + c\left(q^s_{y_i}\right)^2; \\ C^*_{x_i}\left(q^{s*}_{x_i}\right) = Dq^{s*}_{x_i} + c\left(q^{s*}_{x_i}\right)^2; \quad C^*_{y_i}\left(q^{s*}_{y_i}\right) = c\left(q^{s*}_{y_i}\right)^2. \end{array} \tag{2}$$

We start by assuming symmetry between the countries (given identical preferences, this assumption implies symmetric cost functions so that $D = F$) but we relax this assumption in later sections.

Governments choose tariffs, τ_a and τ_b, on imported goods in each sector to maximize domestic welfare.[6] There are no export taxes or subsidies. Tariffs generate a wedge between domestic and international prices so that $p_{y_i} = p^*_{y_i} + \tau_i$ and $p^*_{x_i} = p_{x_i} + \tau^*_i$. Equilibrium prices in each sector are, therefore, only a function of market clearing conditions in their own sector: $q^d_{y_i}\left(p_{y_i}, p_{x_i}\right) - q^s_{y_i}\left(p_{y_i}\right) = q^{*s}_{y_i}\left(p^*_{y_i}\right) - q^{*d}_{y_i}\left(p^*_{y_i}, p^*_{x_i}\right)$ and $q^s_{x_i}\left(p_{x_i}\right) - q^d_{x_i}\left(p_{x_i}, p_{y_i}\right) = q^{*d}_{x_i}\left(p^*_{x_i}, p^*_{y_i}\right) - q^{*s}_{x_i}\left(p^*_{x_i}\right)$. Hence, prices, and quantities, can be written as a function of own sector tariff choices. The welfare of the home country can then be written as:

$$\begin{array}{c} \vartheta\left(\tau_{y_a}, \tau^*_{x_a}, \tau_{y_b}, \tau^*_{x_b}\right) = \vartheta_a\left(\tau_{y_a}, \tau^*_{x_a}\right) + \vartheta_b\left(\tau_{y_b}, \tau^*_{x_b}\right) \\ = \sum_i \left\{u_i\left[q^d_{x_i}\left(p_{x_i}, p_{y_i}\right), q^d_{y_i}\left(p_{y_i}, p_{x_i}\right)\right] - \sum_j \left[p_{j_i} \cdot q^d_{j_i}\left(p_{j_i}, p_{-j_i}\right)\right]\right\} \\ + \sum_i \left\{\sum_j \left[p_{j_i}. q^s_{j_i} - C_{j_i}\left(q^s_{j_i}\left(p_{j_i}\right)\right)\right] + \tau_i \cdot \left[q^d_{y_i}\left(p_{y_i}, p_{x_i}\right) - q^s_{y_i}\left(p_{y_i}\right)\right]\right\} + w \cdot l \end{array} \tag{3}$$

Note that because the sectors are not related the indirect utility function is separable in the policy variables.

3 Unilateral Policy in the Absence of Trade Agreements

In the absence of a trade agreement, governments maximize domestic welfare unilaterally given the policy variable chosen by the other government.

$$\frac{\partial \vartheta_i(.)}{\partial \tau_i} = \frac{\partial p_{y_i}}{\partial \tau_i}\left[q^d_{x_i 2} \cdot \left(u_1 - p_{x_i}\right) + q^d_{y_i 1} \cdot \left(u_2 - p_{y_i}\right) + q^s_{y_i 1}\left(p_{y_i} - C'_{y_i}\right)\right] + \left(1 - \frac{\partial p_{y_i}}{\partial \tau_i}\right) \cdot M_i + \tau_i \cdot \frac{\partial M_i}{\partial \tau_i} = 0 \tag{4}$$

[6] Given the equilibrium prices of the goods and their income, consumers maximize their utilities by choosing optimal consumption bundles in each sector: $\max_{q^d_{j_i}, q^d_z} U(.)\ s.t.\ q^d_z + \sum_{j,i} p_{j_i} \cdot q^d_{j_i} \leq I$, where the price of the numeraire good is normalized to one. Consumer income is given by the sum of wage earnings, profit share and redistributed tariff revenues. Two stage budgeting provides the following demand structure: $q^d_{x_i} \equiv q^d_{x_i}\left(p_{x_i}, p_{y_i}\right)$ and $q^d_{y_i} \equiv q^d_{y_i}\left(p_{y_i}, p_{x_i}\right)$, where $\frac{\partial q^d_{x_i}}{\partial p_{x_i}}, \frac{\partial q^d_{yi}}{\partial p_{y_i}} < 0$.

where $M_i \equiv q^d_{y_i}(p_{y_i}, p_{x_i}) - q^s_{y_i}(p_{y_i})$ is Home's import demand function, a prime indicates a derivative, and numbers in subscripts denote the ordered derivatives when the function has more than one parameter. Each term in the square brackets is equal to zero by the Envelope Theorem and the first order conditions from the producer and consumer maximization problems. The unilaterally optimal tariff is, therefore, given by:

$$\hat{\tau}_i(\tau_i^*) = \frac{M_i \cdot \left(1 - \frac{\partial p_{y_i}}{\partial \tau_i}\right)}{-\frac{\partial M_i}{\partial \tau_i}} \tag{5}$$

Note that when goods are related in a given sector, Home's import demand is a function of the foreign tariff. Therefore, the unilaterally optimal tariff is also a function of the foreign tariff. The following proposition provides some useful characteristics of how welfare is affected by tariff policies.

Proposition 1. *Suppose the consumer utilities are given in quasilinear form* $U\left(q^d_z, q^d_{x_a}, q^d_{x_b}, q^d_{y_a}, q^d_{y_b}\right) = q^d_z + \sum_{i=a,b} u_i\left(q^d_{x_i}, q^d_{y_i}\right)$ *with the subutility functions given by equation (1) and the cost functions given by equation (2). The sector specific social welfare function has the following characteristics when countries are symmetric:*

(i.) $\vartheta_i(\tau_i, \tau_i^*)$ *is concave, increasing in own tariff, and convex, decreasing in Foreign tariff;* $\vartheta_{i1}(\tau_i, \tau_i^*) > 0$, $\vartheta_{i11}(\tau_i, \tau_i^*) < 0$ *and* $\vartheta_{i2}(\tau_i, \tau_i^*) < 0$, $\vartheta_{i22}(\tau_i, \tau_i^*) > 0$

(ii.) Home and Foreign tariffs are strategic substitutes, $\vartheta_{i12}(\tau_i, \tau_i^*) < 0$

(iii.) Free trade is the global optimum; $\vartheta_{i1}(\tau_i, \tau_i^*) + \vartheta_{i2}(\tau_i, \tau_i^*) = 0$ *for* $\tau_i = \tau_i^* = 0$ *and* $\vartheta_{i1}(\tau_i, \tau_i^*) + \vartheta_{i2}(\tau_i, \tau_i^*) < 0$ *for all* $\tau_i, \tau_i^* > 0$

(iv.) $\vartheta_{i11}(\tau_i, \tau_i) + \delta \cdot \vartheta_{i22}(\tau_i, \tau_i) < 0$

Proof. Suppose the subutility functions are of the form given in equation 1:

$$u_i\left(q^d_{x_i}, q^d_{y_i}\right) = \frac{1}{1-b^2}\left[A(1+b)(q^d_{x_i} + q^d_{y_i}) - \frac{1}{2}(q^d_{x_i})^2 - \frac{1}{2}(q^d_{y_i})^2 - b q^d_{x_i} q^d_{y_i}\right].$$

Solving for the consumer and producer maximization problems and plugging in the indirect utility function provides us the following value:

$$\vartheta_i(\tau_i, \tau_i^*) = \frac{1}{1-b^2}\left[\frac{1}{2}\left(q^d_{x_i}\right)^2 + \frac{1}{2}\left(q^d_{y_i}\right)^2 + b q^d_{x_i} q^d_{y_i}\right] + \tau_i M_i + \frac{1}{2}\left(q^s_{x_i}\right)^2 + \frac{1}{2}\left(q^s_{y_i}\right)^2$$

where $q^d_{x_i} = A - p_{x_i} + b p_{y_i}$, $q^d_{y_i} = A - p_{y_i} + b p_{x_i}$, $q^s_{x_i} = \frac{p_{x_i}}{2c}$ and $q^s_{y_i} = \frac{p_{y_i} - F}{2c}$. Now we can show the changes in social welfare as a response to a marginal change in policy variables.

$$(i.)\ \frac{\partial\vartheta_i(\tau_i,\tau_i^*)}{\partial\tau_i} = \frac{1}{2}M_i - \tau_i > 0\ for\ \tau_i < \tau_i^N; \quad \frac{\partial^2\vartheta_i(\tau_i,\tau_i^*)}{\partial(\tau_i)^2} = \frac{1}{2}\frac{\partial M_i}{\partial\tau_i} - 1 < 0;$$
$$\frac{\partial\vartheta_i(\tau_i,\tau_i^*)}{\partial\tau_i^*} = -\frac{1}{2}\left[q_{x_i}^s - q_{x_i}^d\right] - \frac{1}{2}b\tau_i < 0; \quad \frac{\partial^2\vartheta_i(\tau_i,\tau_i^*)}{\partial\left(\tau_i^*\right)^2} = -\frac{1}{2}\frac{\partial\left[q_{x_i}^s - q_{x_i}^d\right]}{\partial\tau_i^*} > 0;$$
$$(ii.)\ \frac{\partial^2\vartheta_i(\tau_i,\tau_i^*)}{\partial\tau_i^*\partial\tau_i} = -\frac{1}{4}b < 0;$$
$$(iii.)\ \vartheta_{i1}(\tau_i,\tau_i^*) + \vartheta_{i2}(\tau_i,\tau_i^*) = \begin{cases} \frac{1}{2}\left[q_{y_i}^d - q_{y_i}^s\right] - \frac{1}{2}\left[q_{x_i}^s - q_{x_i}^d\right] = 0 & for\ \tau_i = \tau_i^* = 0 \\ -\tau_i - \frac{1}{2}b\tau_i < 0 & for\ \tau_i, \tau_i^* > 0 \end{cases}$$
$$(iv.)\ \vartheta_{i11}(\tau_i,\tau_i) + \delta\cdot\vartheta_{i22}(\tau_i,\tau_i) = -\frac{1}{2}\left(\frac{1+2c}{2c}\right)\left[\frac{\partial p_{y_i}}{\partial\tau_i} + \delta\frac{\partial p_{x_i}}{\partial\tau_i^*}\right] - 1 = -\frac{1}{4}\left(\frac{1+2c}{2c}\right)(1-\delta) - 1 < 0$$

□

When tariffs are strategic substitutes, each government has less incentive to increase its tariff unilaterally when its exports are subject to greater tariffs in the destination country. The idea here is that both foreign and home tariffs reduce the relative price of the export good in the home country. A lower export price diminishes the effect of a tariff hike in the home country when the goods are substitutes in consumption. We also see that unilaterally optimal policies aren't globally efficient. In the absence of cooperation between the governments, the applied tariffs are too high and the trade volume is too low as compared to the free trade levels. However, since cooperation is mutually beneficial and the interaction between governments is repeated, there is scope for a cooperative relationship. The next section will investigate alternative cooperation schemes.

4 Structure of Cooperation in Trade Agreements

A trade agreement in sector i specifies a maximum tariff rate (τ_i^c) to be applied by both governments in that sector. In the absence of an external enforcement mechanism, this cooperative tariff needs to be incentive compatible (i.e. a one shot gain by betraying at any point in time needs to be (weakly) lower than the cost of future punishments). Therefore, the actual punishment strategies determine the structure of cooperation. We focus on two types of punishment strategies in this paper. First, we investigate a trade agreement when a limited punishment strategy (WEC) and limited cross-retaliation (LCR) is applied. Next, we allow for cross-sector and cross-agreement retaliation. Our focus is to compare same-sector versus cross-sector retaliation under these limited punishment strategies. As a benchmark case we start by analyzing the well-known Nash-reversion punishment strategies.

We consider the following timing of events:

1. In period 0, governments agree on a type of agreement $\theta \in \left\{\theta^L, \theta^U\right\}$ (linked or unlinked), and then specify the cooperative tariff rates for each sector: τ_i^c, $i \in \{a, b\}$
2. In the beginning of each period, t, governments observe the action history, then simultaneously announce the tariff rate to be applied: τ_i^t, τ_i^{*t}, $i \in \{a, b\}$.
3. Production and consumption take place upon observing the announced tariffs and prices adjust to clear markets.

Formally, the trade agreement uses history-dependent strategies. A history through period t provides the complete information of all previous tariff choices by both countries and also the type of the agreement, $H^t = \left\{\theta, \tau_i^T, \tau_i^{*T}\right\}$ where $\theta \in \left\{\theta^L, \theta^U\right\}$, $\tau_i^T = \left\{\tau_i^1, \tau_i^2, ..., \tau_i^{t-1}\right\}$, and $i \in \{a, b\}$. The trade agreement then specifies a transformation rule that conditions the actions to be chosen in the current period t upon the observed history, $\mathrm{T}\left(\mathrm{H}^{\mathrm{t}}\right) \rightarrow \left(\tau_i^t\right) \in \mathbb{R}_+^2$.

In the cooperative phase both countries levy $\{\tau_i^c, \tau_i^{*c}\}$and the value to the home country is $\Omega = \vartheta_i\left(\tau_i, \tau_i^*\right)$. We now analyze how Ω interacts with $\Psi\left(\tau_i, \tau_i^*, \delta\right)$ which is the continuation value of a deviation and the subsequent punishment strategies. We perform this analysis for each of the considered punishment strategies and we describe the differing levels of cooperation $\{\tau_i^c, \tau_i^{*c}\}$ that are obtainable by each punishment regime.

In the repeated game implied by the trade agreement we consider the discounted average payoffs $\tilde{\vartheta}_i\left(\tau_i, \tau_i^*\right)$= $(1-\delta)\vartheta_i\left(\tau_i, \tau_i^*\right)$, where δ is the common factor by which governments discount future payoffs. Hence, starting in any period s we have $\sum_{t=s}^{\infty} \delta^{t-s} \tilde{\vartheta}_i\left(\tau_i, \tau_i^*\right)$=$\vartheta_i\left(\tau_i, \tau_i^*\right)$.

4.1 Cooperation under Nash Reversion Strategies

Given that the sectors are identical there is no cost or benefit to linking in this regime. This claim is a version of the well-known Bernheim and Whinston (1990, p.5) irrelevance result. Hence, we make no distinction between the linked or unlinked case in the Nash-reversion regime. Under Nash reversion, governments apply cooperative tariffs as long as there is no deviation in the current history of the agreement in a given sector, however, both governments apply the static Nash equilibrium tariff forever upon observing a deviation at any point in time. The cooperative tariff rate in sector i, therefore, needs to satisfy the following incentive constraint

$$\Psi_i^N = (1-\delta) \cdot \vartheta_i^d\left(\tau_i^d, \tau_i^{*c}\right) + \delta \cdot \vartheta_i^p\left(\tau_i^n, \tau_i^{*n}\right) \leq \vartheta_i^c\left(\tau_i^c, \tau_i^{*c}\right) = \Omega_i^N \tag{6}$$

where superscripts d, p, n, and c, denote deviation, punishment, Nash, and cooperative values, respectively.

The left hand side of this inequality is the normalized sum of the discounted payoff stream when the home government deviates in the current period and both governments apply Nash tariffs in the remaining periods.

Proposition 2. *The optimal deviation tariff under the Nash Reversion rule is a strictly decreasing function of the cooperative tariff:* $\tau_i^{dN} \equiv \tau_i^d\left(\tau_i^{*c}\right)$ *and* $\frac{d\tau_i^{dN}}{d\tau_i^{*c}} < 0$.

Proof. The optimal deviation solves the first order condition from the maximization of Ψ_i^N given in equation (6):

$$\frac{\partial \Psi_i^N}{\partial \tau_i^d} = \vartheta_{i1}^d\left(\tau_i^d, \tau_i^{*c}\right) = 0 \tag{7}$$

Totally differentiating this condition with respect to τ_i^{*c} and τ_i^d and rearranging yields:

$$\frac{d\tau_i^{dN}}{d\tau_i^{*c}} = \frac{-\vartheta_{i12}^d\left(\tau_i^d, \tau_i^{*c}\right)}{\vartheta_{i11}^d\left(\tau_i^d, \tau_i^{*c}\right)} < 0$$

where, the denominator is negative by concavity of the indirect utility function (Proposition 1.*i*) and the numerator is positive since the tariffs are strategic substitutes (Proposition 1.*ii*). □

This proposition is illustrated in Figure 3. It shows that when the magnitude of the punishment is independent from the magnitude of deviation, then governments maximize the stage game payoff regardless of how they discount future welfare. The deviation tariff is decreasing in the cooperative tariff at a given point in time only because Home's best response tariff in a static set up is decreasing in the Foreign tariff due to strategic substitutability.

4.2 Cooperation under Unlinked Limited Punishment Strategies

Under limited punishment strategies, governments are restrained by the *Withdrawal of Equivalent Concessions (WEC)* rule in the spirit of GATT Article XXVIII: if any government applies a tariff greater than the agreed cooperative rate, $\tau_i^d > \tau_i^c$, then the other government is allowed to retaliate only by the same amount, $\tau_i^{*d} = \tau_i^d$ in the future periods as long as the initial deviation is no larger than the static Nash tariff,$\tau_i^d \leq \tau_i^n$. Deviations greater than the static Nash tariff are considered *egregious* and both countries apply the static Nash tariffs forevermore. Incentive compatibility, therefore, needs to address two issues. First, each government decides on the optimal level of deviation given the cooperative tariff rate applied by the partner. Second, they decide whether it is optimal to deviate from the agreement using the optimal deviation tariff. For $\tau_i^d > \tau_i^n$ the incentive constraint is the same as in equation (6). More importantly,

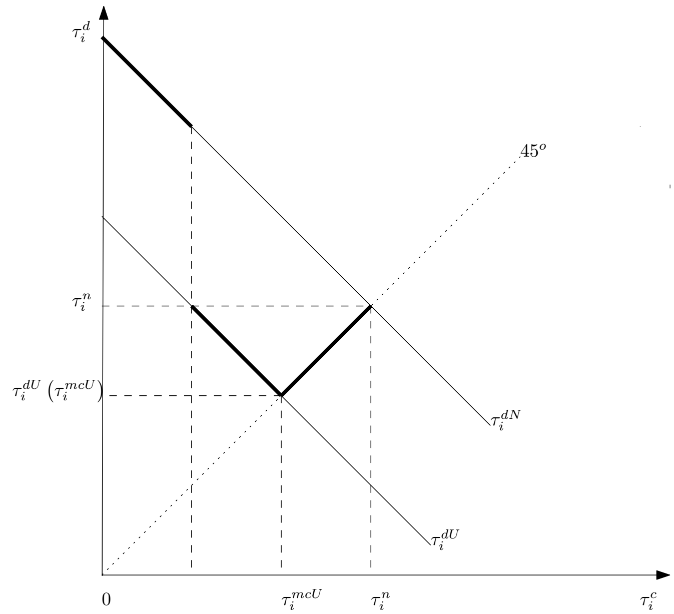

Figure 3: Structure of Deviation under Nash Reversion and Unlinked-WEC Strategies

for $\tau_i^d \leq \tau_i^n$ the incentive constraint under the unlinked limited punishment rule reflects the effect of the deviation level on future punishments:

$$\Psi_i^U = (1-\delta) \cdot \vartheta_i^d \left(\tau_i^d \left(\tau_i^{*c}\right), \tau_i^{*c}\right) + \delta \cdot \vartheta_i^p \left(\tau_i^d \left(\tau_i^{*c}\right), \tau_i^{*d} \left(\tau_i^c\right)\right) \leq \vartheta_i^c \left(\tau_i^c, \tau_i^{*c}\right) = \Omega_i^U \tag{8}$$

As in the Nash Reversion case, the left hand side of this inequality is the normalized sum of the discounted payoff stream when the home government deviates in the current period. As opposed to the former case, however, the initial deviation determines the payoff stream during the punishment phase under WEC rule. Notice that in the unlinked case, both the deviation and the punishment take place in the same sector and because of symmetry between the sectors it is immaterial which sector is chosen. Given the cooperative tariff rate, the τ_i^{dU} solves:

$$\tau_i^{dU} \equiv \arg\max_{\tau_i^d} \ \Psi_i^U \left(\tau_i^{*c}, \delta\right) \tag{9}$$

As seen in figure 3, and described in proposition 3 below, the best response tariff $\tilde{\tau}_i^{dU}$ includes τ_i^{dU}; however, it is more complicated than τ_i^{dU}. The following proposition provides the analytical results regarding the behavior of τ_i^{dU} and the best response tariff, $\tilde{\tau}_i^{dU}$, in the Unlinked-WEC regime.

Proposition 3. *(i.)* τ_i^{dU} *is a strictly decreasing function of the cooperative tariff rate and the discount factor:* $\tau_{i1}^{dU}\left(\tau_i^{*c}, \delta\right) < 0$ *and* $\tau_{i2}^{dU}\left(\tau_i^{*c}, \delta\right) < 0$.

(ii.) For any level of the cooperative tariff, $\tau_i^{dU}(\tau_i^c) < \tau_i^{dN}(\tau_i^c)$.

(iii.) There exists a unique τ_i^{mcU} *such that* $\tau_i^{dU}(\tau_i^{mcU}) = \tau_i^{mcU}$. *If* $\tau_i^c < \tau_i^{mcU}$, *then* $\tau_i^c < \tau_i^{mcU} < \tau_i^{dU}(\tau_i^c)$. *If* $\tau_i^c > \tau_i^{mcU}$, *then* $\tau_i^{dU}(\tau_i^c) < \tau_i^{mcU} < \tau_i^c$.

(iv.) If $\tau_i^{dU}(\tau_i^c) < \tau_i^{mcU}$, *then* $\tilde{\tau}_i^{dU}(\tau_i^c) = \tau_i^c > \tau_i^{mcU}$. *If* $\tau_i^{dU}(\tau_i^c) > \tau_i^n$, *then* $\tilde{\tau}_i^{dU}(\tau_i^c) = \tau_i^{dN}(\tau_i^c)$. *If* $\tau_i^c \leq \tau_i^{dU}(\tau_i^c) \leq \tau_i^n$, *then* $\tilde{\tau}_i^{dU}(\tau_i^c) = \tau^{dU}(\tau_i^c)$.

Proof. (i.) The first order condition for the maximization problem (9) is given by:

$$\frac{\partial \Psi_i^U}{\partial \tau_i^d} = (1-\delta) \cdot \vartheta_{i1}^d\left(\tau_i^d\left(\tau_i^{*c}\right), \tau_i^{*c}\right) + \delta \cdot \left[\vartheta_{i1}^p\left(\tau_i^d\left(\tau_i^{*c}\right), \tau_i^{*d}\left(\tau_i^{*c}\right)\right) + \vartheta_{i2}^p\left(\tau_i^d\left(\tau_i^{*c}\right), \tau_i^{*d}\left(\tau_i^c\right)\right)\right] = 0 \tag{10}$$

which provides the solution for the optimal deviation tariff as $\tau_i^{dU} \equiv \tau_i^{dU}(\tau_i^{*c}, \delta)$. Totally differentiating this first order condition with respect to the cooperative tariff and the deviating tariff and using the implicit function theorem yields:

$$\frac{d\tau_i^{dU}}{d\tau_i^{*c}} = \frac{-(1-\delta) \cdot \vartheta_{i12}^d\left(\tau_i^d, \tau_i^{*c}\right)}{(1-\delta) \cdot \vartheta_{i11}^d\left(\tau_i^d, \tau_i^{*c}\right) + \delta \cdot \left[\vartheta_{i11}^p\left(\tau_i^d, \tau_i^{*d}\right) + 2\vartheta_{i12}^p\left(\tau_i^d, \tau_i^{*d}\right) + \vartheta_{i22}^p\left(\tau_i^d, \tau_i^{*d}\right)\right]} < 0$$

where the denominator is the second order condition and negative, and the numerator is positive by strategic substitutability.

Similarly, totally differentiating this first order condition with respect to the discount factor and the deviating tariff and rearranging yields:

$$\frac{d\tau_i^{dU}}{d\delta} = \frac{\vartheta_{i1}^d\left(\tau_i^d, \tau_i^{*c}\right) - \left[\vartheta_{i1}^p\left(\tau_i^d, \tau_i^{*d}\right) + \vartheta_{i2}^p\left(\tau_i^d, \tau_i^{*d}\right)\right]}{(1-\delta) \cdot \vartheta_{i11}^d\left(\tau_i^d, \tau_i^{*c}\right) + \delta \cdot \left[\vartheta_{i11}^p\left(\tau_i^d, \tau_i^{*d}\right) + 2\vartheta_{i12}^p\left(\tau_i^d, \tau_i^{*d}\right) + \vartheta_{i22}^p\left(\tau_i^d, \tau_i^{*d}\right)\right]} < 0$$

where the term in brackets in the numerator is negative by the property that free trade is globally efficient.

(ii.)To show this, we compare the first order conditions for the optimal deviation tariffs under Nash reversion and Unlinked WEC strategies, (7) and (10), respectively. The term in brackets in the latter one is smaller than zero, therefore $\vartheta_{i1}^d\left(\tau_i^{dN}\left(\tau_i^{*c}\right), \tau_i^{*c}\right) = 0 < \vartheta_{i1}^d\left(\tau_i^{dU}\left(\tau_i^{*c}\right), \tau_i^{*c}\right)$ for identical cooperative tariff rates. This implies that $\tau_i^{dU}(\tau_i^{*c}) < \tau_i^{dN}(\tau_i^{*c})$ at all identical τ_i^{*c} by concavity of the indirect utility function in its own tariff (Proposition 1.*ii*).

(iii.) From part (i.) τ_i^d is monotonic decreasing in τ_i^{*c}. Hence, when $\tau_i^c = \tau_i^{mcU}$ we have that $\tau_i^{dU}(\tau_i^c) = \tau_i^c$. From part (i.) for $\tau_i^c < \tau_i^{mcU}$ we have $\tau_i^c < \tau_i^{mc} < \tau_i^{dU}(\tau_i^c)$ and for $\tau_i^c > \tau_i^{mcU}$ we have $\tau_i^c > \tau_i^{mc} > \tau_i^{dU}(\tau_i^c)$.

(iv.) Tariff reductions are not subject to retaliation (reciprocation), therefore, there is no profitable one shot deviation for $\tau_i^c > \tau_i^{mcU}$. Hence, $\tilde{\tau}_i^{dU}(\tau_i^c) = \tau_i^c$ in that region. If $\tau_i^{dU}(\tau_i^c) > \tau_i^{dN}(\tau_i^c)$, then the deviation is egregious and the punishment is given by the Nash-reversion regime, therefore, the best response is given as in proposition 2: $\tilde{\tau}_i^{dU}(\tau_i^c) = \tau_i^{dN}(\tau_i^c)$. If $\tau_i^c \leq \tau_i^{dU}(\tau_i^c) \leq \tau_i^{dN}(\tau_i^c)$, then the best response is given by equation (9) so that $\tilde{\tau}_i^{dU}(\tau_i^c) = \tau^{dU}(\tau_i^c)$. □

This proposition shows first of all that when punishment is tailored to the initial deviation, the optimal deviation tariff is no longer a static best response to the current cooperative tariff rate. The optimality condition in this case states that a deviating government increases the deviation tariff until the marginal gain in the current payoff becomes equal to the losses in the future punishment phase. In this way, the optimal deviation takes account of its effect on the future punishment and, therefore, it is lower than it would be in the Nash reversion regime.

The proposition is illustrated in figure 3. We see there that both $\tau_i^{dU}(\tau_i^c)$and $\tau_i^{dN}(\tau_i^c)$ are declining in τ_i^c . Furthermore, for any τ_i^c we have that $\tau_i^{dU}(\tau_i^c) \leq \tau_i^{dN}(\tau_i^c)$. When each function crosses the 45-degree line, then the function provides a best response to itself. In the Nash-reversion regime regime τ_i^{dN} crosses the 45-degree line at the static Nash tariff, τ_i^n, because $\tau_i^n$is a static best response to itself. If $\tau_i^{dU}(\tau_i^c) > \tau_i^n$, then the deviation is considered *egregious* and the punishment is given by the Nash regime. In this case the best response $\tilde{\tau}_i^{dU}(\tau_i^c)$ jumps up to τ_i^{dN}. The bold part of the graph is the best response function. For very high τ_i^c the best response would be a tariff reduction if it would be matched in the future, however, WEC only applies to tariff increases, so that the tariff reduction would not be matched. In this case the best response is to match the tariff increase, but not to supersede it, and this part of the best response function is the bold part of the 45-degree line from where τ_i^{dU} crosses it until it reaches the static Nash tariff. Finally it is interesting to note how τ_i^{dU} and, therefore, the best response tariff $\tilde{\tau}_i^{dU}$ change with the discount factor δ. First notice that when countries care more about the future, and δ increases, the second term in Ψ_i^U has a higher weighting so that the τ_i^{dU} shifts down. It eventually shifts down enough so that τ_i^{dU} is always less than τ_i^n and there is no discontinuity in the best response tariff. In the limit as δ approaches one, we can see from equation (10) that the best response is free trade. Similarly, as δ approaches zero, the τ_i^{dU} shifts up so that the best response is the static Nash tariff.

The following proposition is very useful because it shows that the most cooperative tariff in the Unlinked-WEC case can be characterized by where the optimal deviation tariff crosses the 45 degree line. This result is crucial to our later analysis. In particular, we will also show that the most cooperative tariff in the Linked-WEC case can be characterized in the same manner and in this way we will be able to compare the level of cooperation under the two regimes. In addition the proposition shows that for any level of the cooperative tariff, the optimal deviation tariff in the Unlinked-WEC case is less than in the Nash reversion case. We can not characterize the most cooperative tariff in the Nash reversion case in the same manner and, therefore, we make no comparisons between the maximum level of cooperation in the Nash reversion regime.

Proposition 4. *There exists a unique most cooperative tariff under Unlinked-WEC strategies, $\tau_i^{mcU} \equiv \tau_i^{dU}\left(\tau_i^{mcU}\right)$, which is decreasing in the discount factor δ.*

Proof. (i.) In order to prove the existence of a unique most cooperative tariff, we will that $\Psi_i^U = \Omega_i^U$ at all $\tau_i^c \geq \tau_i^{mcU}$ (from Proposition 3.iii) and show that $\frac{\partial \Psi_i^U}{\partial \tau_i^c} < \frac{\partial \Omega_i^U}{\partial \tau_i^c} < 0$ for $\tau_i^c < \tau_i^{mcU}$, which shows that $\Psi_i^U > \Omega_i^U$ for all $\tau_i^c < \tau_i^{mcU}$. Hence, τ_i^{mcU} is the lowest self-enforcing tariff in the Unlinked-WEC regime. Using the first order condition and the Envelope Theorem, this condition is reduced to showing:

$$(1-\delta)\cdot\vartheta_{i2}^d\left(\tau_i^{dU}\left(\tau_i^{*c}\right),\tau_i^{*c}\right) < \vartheta_{i1}^c\left(\tau_i^c,\tau_i^{*c}\right) + \vartheta_{i2}^c\left(\tau_i^c,\tau_i^{*c}\right) < 0 \tag{11}$$

Now, since $\vartheta_{i2}^d\left(\tau_i^{dU}\left(\tau_i^{*c}\right),\tau_i^{*c}\right) < \vartheta_{i2}^d\left(\tau_i^c,\tau_i^{*c}\right)$ by strategic substitutability of tariffs, we will replace the left hand side of this inequality and rearrange to get:

$$0 < \vartheta_{i1}^c\left(\tau_i^c,\tau_i^{*c}\right) + \delta\cdot\vartheta_{i2}^c\left(\tau_i^c,\tau_i^{*c}\right).$$

For $\tau_i^c < \tau_i^{mcU}$ the above expression can be expressed as:

$$-\int_{\tau_i^c}^{\tau_i^{mc}}\left[\vartheta_{i11}^c\left(\tau_i^c,\tau_i^{*c}\right) + (1+\delta)\cdot\vartheta_{i12}^c\left(\tau_i^c,\tau_i^{*c}\right) + \delta\cdot\vartheta_{i22}^c\left(\tau_i^c,\tau_i^{*c}\right)\right] > 0.$$

The term inside the brackets is negative because of Proposition (1.iv) which shows that $\vartheta_{i11}^c + \delta\cdot\vartheta_{i22}^c < 0$ and Proposition (1.ii) which shows that $\vartheta_{i12}^c < 0$. Therefore, the above condition is satisfied, completing the proof. □

4.3 Linking the Agreements under Limited Punishment Rule

In this section we analyze how WEC as stated in the GATT Article XXVIII interacts with the WTO DSU Article 22.3, which allows for but also limits cross retaliation. In particular, we investigate the consequences of linking the agreements under the limited punishment rule in terms of its welfare and enforcement implications. Linking enables the governments to undertake cross retaliation (i.e. betrayal in one agreement generates a punishment phase in the other one). Our idea is rather general in that cross retaliation may entail cross-sector retaliation as in DSU Article 22.3 paragraph (b), or it may be cross-agreement retaliation as in DSU Article 22.3 paragraph (c). The key is that goods in the same sector exhibit strategic substitutability and goods across sectors (or agreements) are strategically independent. We continue to assume that the WEC rule is applicable only when the initial deviation is not egregious. We characterize two types of egregious deviations, both of which call for different treatment in punishment stage. First, deviation in both policies or deviation from the punishment path generate Nash Reversion in both policies. Second, a deviating tariff greater than the static Nash tariff brings a cross-retaliation using Nash Tariffs, (i.e. if the Home government applies $\tau_i^d > \tau_i^c$ then home government will apply τ_i^N and τ_{-i}^c, whereas the foreign government will apply τ_i^{*c} and τ_{-i}^{*N}, $i \in \{a, b\}$, forevermore. For a non-egregious deviation we can, therefore, write the Linked-WEC incentive constraint as follows:

$$\Psi_i^L = (1-\delta) \cdot \left[\vartheta_a^d \left(\tau_a^d \left(\tau_a^{*c}\right), \tau_a^{*c}\right) + \vartheta_b^c \left(\tau_b^c, \tau_b^{*c}\right)\right] + \delta \cdot \left[\vartheta_a^d \left(\tau_a^d \left(\tau_a^{*c}\right), \tau_a^{*c}\right) + \vartheta_b^p \left(\tau_b^c, \tau_b^{*d}\left(\tau_b^c\right)\right)\right] \\ \leq \left[\vartheta_a^c \left(\tau_a^c, \tau_a^{*c}\right) + \vartheta_b^c \left(\tau_b^c, \tau_b^{*c}\right)\right] = \Omega_i^L. \tag{12}$$

Being symmetric, deviation in either sector is possible and both deviations are equal. We decided the most natural was to write the constraint for Home deviating in sector a. The deviation tariff is derived from:

$$\tau_a^{dL}\left(\tau_a^c\right) \equiv \arg\max_{\tau_i^d} \ \Psi_i^L\left(\tau_i^{*c}, \delta\right) \tag{13}$$

A deviation in sector a generates a stream of gains in that sector, however it also generates a future stream of losses in sector b due to cross retaliation by the partner. The first order condition for this optimization problem is given by:

$$\vartheta_{a1}^d \left(\tau_a^d \left(\tau_a^{*c}\right), \tau_a^{*c}\right) + \delta \cdot \vartheta_{b2}^p \left(\tau_b^c, \tau_b^{*d}\left(\tau_b^c\right)\right) = 0 \tag{14}$$

where the second term shows the discounted change in sector b payoffs due to a marginal increase in the deviation tariff in sector a. The following proposition elaborates the characteristics of cooperation under a Linked-WEC agreement and is directly comparable to Propositions 3 and 4.

Proposition 5. *The Linked-WEC agreement has the following characteristics:*

(i.) The deviation tariff, τ_i^{dL} *is strictly decreasing in the cooperative tariff rate,* $\frac{d\tau_i^{dL}(\tau_i^{*c})}{d\tau_i^{*c}} < 0$ *and in the discount factor* $\frac{d\tau^{dL}(\tau_i^{*c})}{d\delta} < 0$.

(ii.) There exists a most cooperative tariff $\tau_i^{mcL} \equiv \tau_i^{dL}\left(\tau_i^{mcL}\right)$*, which decreases in the discount factor* δ.

(iii.) If $\tau_i^c \leq \tau_i^{dL}\left(\tau_i^c\right) \leq \tau_i^n$*, then the best response* $\tilde{\tau}_i^{dL}\left(\tau_i^c\right) = \tau_i^{dL}\left(\tau_i^c\right)$*. If* $\tau_i^c > \tau_i^{mcL}$*, then* $\tilde{\tau}_i^{dL}\left(\tau_i^c\right) = \tau_i^c$*. If* $\tau_i^{dL}\left(\tau_i^c\right) > \tau_i^n$*, then* $\tilde{\tau}_i^{dL}\left(\tau_i^c\right) = \tau_i^{dN}\left(\tau_i^c\right)$.

Proof. (i.) The first part follows from totally differentiating the first order condition (14) with respect to the cooperative, and the deviating, tariff and using the implicit function theorem to obtain:

$$\frac{d\tau_a^d\left(\tau_i^{*c}\right)}{d\delta}=\frac{-\left[\vartheta_{a12}^d\left(\tau_a^d\left(\tau_a^{*c}\right),\tau_a^{*c}\right)+\delta\cdot\vartheta_{b21}^p\left(\tau_b^c,\tau_b^{*d}\left(\tau_b^c\right)\right)\right]}{\left[\vartheta_{a11}^d\left(\tau_a^d\left(\tau_a^{*c}\right),\tau_a^{*c}\right)+\delta\cdot\vartheta_{b22}^p\left(\tau_b^c,\tau_b^{*d}\left(\tau_b^c\right)\right)\right]}<0$$

where the cross-partials are negative by strategic substitutability. The second derivative with respect to own tariff is negative by concavity, moreover, from Proposition 1.iv, it dominates the positive sign of the second derivative with respect to the foreign tariff. Therefore, the numerator is positive and denominator is negative. Similarly, totally differentiating the first order condition (14) with respect to the discount factor and the deviating tariff yields:

$$\frac{d\tau_a^d\left(\tau_i^{*c}\right)}{d\tau_a^{*c}}=\frac{-\left[\vartheta_{b2}^p\left(\tau_b^c,\tau_b^{*d}\left(\tau_b^c\right)\right)\right]}{\left[\vartheta_{a11}^d\left(\tau_a^d\left(\tau_a^{*c}\right),\tau_a^{*c}\right)+\delta\cdot\vartheta_{b22}^p\left(\tau_b^c,\tau_b^{*d}\left(\tau_b^c\right)\right)\right]}<0$$

(ii.) We will use two lemmas in order to prove part (ii.).

LEMMA 1. $\frac{\partial\Omega_i^L}{\partial\tau_i^c}<0$ *and* $\frac{\partial\Psi_i^L}{\partial\tau_i^c}<0$ *for all* $\tau_i^c<\tau_i^{mcL}$.

To show this, remember that $\frac{\partial\Omega_i}{\partial\tau_i^c}=\vartheta_{i1}^c\left(\tau_i^c,\tau_i^{*c}\right)+\vartheta_{i2}^c\left(\tau_i^c,\tau_i^{*c}\right)<0$ for all $\tau_i^c>0$ by Proposition (1.iii). Using the first order condition for τ_i^{dL} from equation (14) and the Envelope Theorem, we get:

$$\frac{\partial\Psi_i^L}{\partial\tau_a^c}=(1-\delta)\cdot\left[\underbrace{\vartheta_{b1}^c\left(\tau_b^c,\tau_b^{*c}\right)+\vartheta_{b2}^c\left(\tau_b^c,\tau_b^{*c}\right)}_{(-)}\right]+\left[\underbrace{\delta\cdot\vartheta_{b1}^p\left(\tau_b^c,\tau_b^{*d}\right)+\vartheta_{a2}^d\left(\tau_a^d,\tau_a^{*c}\right)}_{(-)}\right]<0$$

The sign of the first bracketed term is given by the global efficiency of free trade (Proposition (1.iii)). To see the sign of the second bracketed term remember that $\vartheta_{b1}^p\left(\tau_b^c,\tau_b^{*d}\right)<\vartheta_{b1}^c\left(\tau_b^c,\tau_b^{*c}\right)$ and $\vartheta_{a2}^d\left(\tau_a^d,\tau_a^{*c}\right)<\vartheta_{a2}^c\left(\tau_a^c,\tau_a^{*c}\right)$ by strategic substitutability. We sum these two inequalities up to get

$$\vartheta_{b1}^p\left(\tau_b^c,\tau_b^{*d}\right)+\vartheta_{a2}^d\left(\tau_a^d,\tau_a^{*c}\right)<\vartheta_{b1}^c\left(\tau_b^c,\tau_b^{*c}\right)+\vartheta_{a2}^c\left(\tau_a^c,\tau_a^{*c}\right)<0$$

for all $\tau_i^c>0$. Now, since the above inequality is true, then $\delta\cdot\vartheta b_1^p\left(\tau_b^c,\tau_b^{*d}\right)+\vartheta_{a2}^d\left(\tau_a^d,\tau_a^{*c}\right)<0$ must also be true since $\vartheta_{b1}^p\left(\tau_b^c,\tau_b^{*d}\right)>0$ and $\delta\in[0,1]$.

LEMMA 2. $\frac{\partial\Psi_i^L}{\partial\tau_i^c}<\frac{\partial\Omega_i^L}{\partial\tau_i^c}<0$ *for all* $\tau_i^c\in\left[0,\tau_i^{mcL}\right]$ *and* $\frac{\partial\Psi_i^L}{\partial\tau_i^c}=\frac{\partial\Omega_i^L}{\partial\tau_i^c}$ *for all* $\tau_i^c\geq\tau_i^{mcL}$*, so that* $\Psi_i^L>\Omega_i^L$ *for all* $\tau_i^c\in\left[0,\tau_i^{mcL}\right]$ *and equal for all* $\tau_i^c\geq\tau_i^{mcL}$.

Using the derivatives from the previous part, and rearranging, the required condition for this claim can be written as

$$\delta\cdot\vartheta_{b1}^p\left(\tau_b^c,\tau_b^{*d}\right)+\vartheta_{a2}^d\left(\tau_a^d,\tau_a^{*c}\right)<(1+\delta)\cdot\left[\vartheta_{b1}^c\left(\tau_b^c,\tau_b^{*c}\right)+\vartheta_{a2}^c\left(\tau_a^c,\tau_a^{*c}\right)\right]\tag{15}$$

Remember that $\vartheta_{b1}^p\left(\tau_b^c,\tau_b^{*d}\right)<\vartheta_{b1}^c\left(\tau_b^c,\tau_b^{*c}\right)$ and $\vartheta_{a2}^d\left(\tau_a^d,\tau_a^{*c}\right)<\vartheta_{a2}^c\left(\tau_a^c,\tau_a^{*c}\right)$ by strategic substitutability.

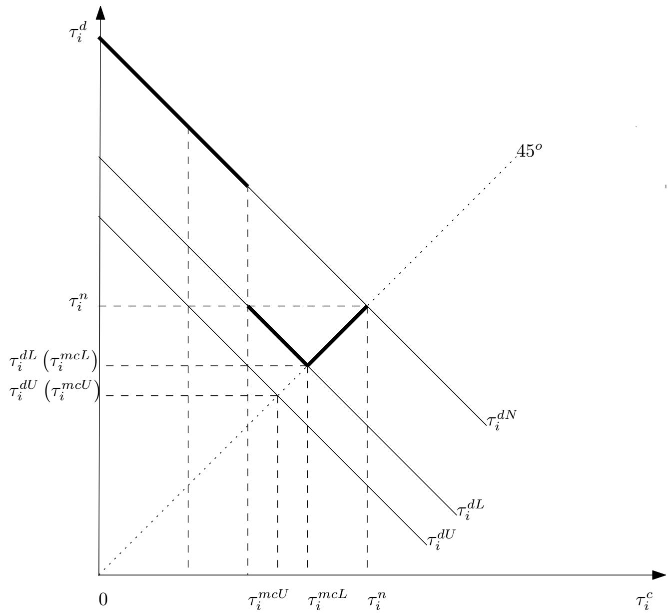

Figure 4: Deviation under Linked-WEC Strategy

Therefore we replace the left hand side of the above inequality. It is sufficient to prove the following condition:

$$\delta \cdot \vartheta_{b1}^c\left(\tau_b^c, \tau_b^{*c}\right) + \vartheta_{a2}^c\left(\tau_a^c, \tau_a^{*c}\right) < (1+\delta) \cdot \left[\vartheta_{b1}^c\left(\tau_b^c, \tau_b^{*c}\right) + \vartheta_{a2}^c\left(\tau_a^c, \tau_a^{*c}\right)\right] \tag{16}$$

Rearranging, we get:

$$0 < \vartheta_{b1}^c\left(\tau_b^c, \tau_b^{*c}\right) + \delta \cdot \vartheta_{a2}^c\left(\tau_a^c, \tau_a^{*c}\right) \tag{17}$$

Using the first order condition, remember that the following holds at the intersection of the 45 degree line and the optimal deviation tariff line, $\vartheta_{\mathrm{a}1}^{\mathrm{d}}\left(\tau_a^d, \tau_a^{*c}\right) + \delta \cdot \vartheta_{b2}^p\left(\tau_b^c, \tau_b^{*d}\right) = 0$. However, since $\tau^d\left(\tau^{mcL}\right) = \tau^{mcL}$ at the intersection and sectors are symmetric, we can rewrite the first order condition as $\vartheta_{\mathrm{b}1}^{\mathrm{c}}\left(\tau_b^{mcL}, \tau_b^{*mcL}\right) + \delta \cdot \vartheta_{a2}^c\left(\tau_a^{mcL}, \tau_a^{*mcL}\right) = 0$.

for $\tau_i^c < \tau_i^{mcL}$ and symmetric issues, this can be written as:

$$-\int_{\tau_i^c}^{\tau_i^{mc}} \left[\vartheta_{i11}^c\left(\tau_i^c, \tau_i^{*c}\right) + (1+\delta) \cdot \vartheta_{i12}^c\left(\tau_i^c, \tau_i^{*c}\right) + \delta \cdot \vartheta_{i22}^c\left(\tau_i^c, \tau_i^{*c}\right)\right] > 0$$

which is satisfied since the term in brackets is negative because of Proposition (1.iv) which shows that $\vartheta_{i11}^c + \delta \cdot \vartheta_{i22}^c < 0$ and Proposition (1.ii) which shows that $\vartheta_{i12}^c < 0$.

The proof to part (iii.) is identical to the similar section in Proposition 3. □

Proposition 5 is illustrated in figure 4. We see there that τ_i^{dL} is negatively sloped as is τ_i^{dU}. Furthermore, we see that the best response, $\tilde{\tau}_i^{dL}$, has the same shape and the same three sections as does $\tilde{\tau}_i^{dU}$. Finally, we see that where τ_i^{dL} crosses the 45-degree line determines the most cooperative tariff in the Linked-WEC regime, τ_i^{mcL}. The most important part of figure 4 is that $\tau_i^{dL}(\tau_i^c) > \tau_i^{dU}(\tau_i^c)$ for all τ_i^c, so that $\tau_i^{mcL} > \tau_i^{mcU}$. This last claim is the most important result of our paper and is the subject of the following proposition.

Proposition 6. *(Main Result 1) For every level of the cooperative tariff, the optimal deviation tariff under the Linked-WEC agreement is greater than the one under the Unlinked-WEC agreement,* $\tau_i^{dL}(\tau_i^c) > \tau_i^{dU}(\tau_i^c)$. *Linkage, therefore, reduces cooperation in a given sector:* $\tau_i^{mcL} > \tau_i^{mcU}$.

Proof. We compare the first order conditions for separated and linked agreements to elaborate the results. Reorganize the conditions to get:

$$(1-\delta)\cdot\vartheta_{a1}^{dU}\left(\tau_a^{dU}\left(\tau_a^{*c}\right),\tau_a^{*c}\right)+\delta\cdot\left[\vartheta_{a1}^{pU}\left(\tau_a^{dU}\left(\tau_a^{*c}\right),\tau_a^{*dU}\left(\tau_i^{*c}\right)\right)+\vartheta_{a2}^{pU}\left(\tau_a^{dU}\left(\tau_i^{*c}\right),\tau_a^{*dU}\left(\tau_i^{c}\right)\right)\right]=0$$

$$(1-\delta)\cdot\vartheta_{a1}^{dL}\left(\tau_a^{dL}\left(\tau_a^{*c}\right),\tau_a^{*c}\right)+\delta\cdot\left[\vartheta_{a1}^{dL}\left(\tau_a^{dL}\left(\tau_a^{*c}\right),\tau_a^{*c}\right)+\vartheta_{b2}^{pL}\left(\tau_b^{c},\tau_b^{*dL}\left(\tau_b^{c}\right)\right)\right]=0$$

We prove the first part, $\tau_i^{dL}(\tau_i^c) > \tau_i^{dU}(\tau_i^c)$, by contradiction. Suppose not, so that $\tau_i^{dL}(\tau_i^c) \leq \tau_i^{dU}(\tau_i^c)$. Then $\vartheta_{a2}^{pU}\left(\tau_a^{dU}\left(\tau_i^{*c}\right),\tau_a^{*dU}\left(\tau_i^{c}\right)\right) < \vartheta_{b2}^{pL}\left(\tau_b^{c},\tau_b^{*dL}\left(\tau_b^{c}\right)\right)$ and $\vartheta_{a1}^{pU}\left(\tau_a^{dU}\left(\tau_a^{*c}\right),\tau_a^{*dU}\left(\tau_i^{*c}\right)\right) < \vartheta_{a1}^{dL}\left(\tau_a^{dL}\left(\tau_a^{*c}\right),\tau_a^{*c}\right)$ by strategic substitutability of tariffs and symmetry of issues. This shows that $\vartheta_{a1}^{dU}\left(\tau_a^{dU}\left(\tau_a^{*c}\right),\tau_a^{*c}\right) > \vartheta_{a1}^{dL}\left(\tau_a^{dL}\left(\tau_a^{*c}\right),\tau_a^{*c}\right)$ using the first order conditions. However, by concavity of payoffs, this implies that $\tau_a^{dU}\left(\tau_i^{*c}\right) < \tau_a^{dL}\left(\tau_i^{*c}\right)$, a contradiction. Therefore, the assumption is not correct.

The second part follows from the definition of most cooperative tariff and the result in the first part. Remember, $\tau_i^{mc} \equiv \tau_i^d\left(\tau_i^{mc}\right)$ in both linked and non-linked agreements. The result in the first part, $\tau_a^{dU}\left(\tau_a^{*c}\right) < \tau_a^{dL}\left(\tau_a^{*c}\right)$, implies that $\tau_a^{mcU} < \tau_a^{mcL}$ since τ_i^d is monotonously decreasing in τ_i^{*c} in both cases. ☐

The idea behind Proposition 6 comes from the strategic substitutability of tariffs in the same sector. Foreseeing a reciprocating punishment in the same sector generates a reduction in the same-sector optimal deviation. Across sectors, or agreements, there is strategic independence between the goods and the optimal deviation tariff is not mitigated by the strategic substitutability effect; therefore, for an equal deviation, the punishment hurts the deviating country by a larger amount in the Unlinked-WEC agreement and the optimal deviation is lower. Hence, (because the most cooperative tariff can be described as an invertible, and monotonic increasing function of the optimal deviating tariff) we have that the most cooperative tariff is larger in the Linked-WEC than in the Unlinked-WEC regime.

5 The Order of Preferred Retaliation in the DSU Article 22.3

In this section we analyze whether, given a deviation, each country prefers same-sector or cross-sector retaliation. We then consider whether their history dependent preferred action generates the best outcome for the entire trade agreement. As a first step in this analysis, we need to show that both punishment paths are subgame perfect. We next analyze which path is preferred after a deviation and which is preferred for the entire agreement.

5.1 Subgame Perfection of the Linked-WEC and Unlinked-WEC regimes

We now show that the both the Linked-WEC and Unlinked-WEC trade agreement strategies and payoffs are subgame perfect. In particular, we show that after any deviation, each country would adhere to the punishment strategies given by the chosen regime. We then provide conditions on the patience necessary to support cooperation in each regime. We also provide an alternative proof for our main result from Proposition 6: For any cooperative tariff the required patience is larger in the Linked-WEC regime.

Proposition 7. *(i.) For any cooperative tariff τ_i^c, there exists a $\delta^L(\tau_i^c) \in (0,1)$, such that for all $\delta \geq \delta^L(\tau_i^c)$, the Linked-WEC trade agreement strategies and payoffs constitute a subgame perfect equilibrium. (ii.) For any cooperative tariff τ_i^c, there exists a $\delta^U(\tau_i^c) \in (0,1)$, such that for all $\delta \geq \delta^U(\tau_i^c)$, the Unlinked-WEC trade agreement strategies and payoffs constitute a subgame perfect equilibrium. (iii.)* For any (τ_i^c), $\delta^L(\tau_i^c) >$ $\delta^U(\tau_i^c)$.

Proof. (i.) There are three cases to consider. First, if $\tau_i^c < \tau_i^{mcL}$ then $\tau_i^c < \tau_i^{mcL} < \tau_i^{dL}(\tau_i^c)$ by Proposition 5. Now, if $\tau_i^{dL}(\tau_i^c) \leq \tau_i^n$, then, given the symmetry of sectors, and that $\tau_i^{dL}(\tau_i^c)$ is an optimal deviation we have that $\tilde{\tau}_{-i}^{*dL}\left(\tau_{-i}^c\right) = \tilde{\tau}_i^{dL}(\tau_i^c)$ is a best response in the other sector as well. Still, if $\tau^{*d}\left(\tau_i^{dL}(\tau_i^{*c})\right) > \tau_i^{*c}$, then a country may consider deviating from the punishment path, however, this would generate τ^n in both sectors (and lower per period payoffs) forevermore. Hence, if countries care sufficiently about future payoffs, then they would not make this deviation. Second, when $\tau_i^n < \tau_i^{dL}(\tau_i^c)$, the Linked-WEC strategies call for the punisher to choose $\tau_{-i}^n$and the deviator to choose τ_i^n. A country may consider deviating from the punishment path to $\tau_i^{dL}(\tau_i^c) > \tau_i^n$ or to $\tau^d(\tau_i^n) > \tau_i^c$, but again this would generate $\left(\tau_i^n, \tau_{-i}^n\right)$in both sectors which is not preferred if δ is sufficiently high. Finally, if $\tau_i^c > \tau_i^{mcL}$, then $\tilde{\tau}_i^{dL}(\tau_i^c) = \tau_i^c > \tau_i^{mcL} > \tau_i^{dL}(\tau_i^c)$, since there is no beneficial deviation when $\tau_i^{dL} < \tau_i^c$. Therefore, $\tilde{\tau}_{-i}^{*dL}\left(\tau_{-i}^c\right) = \tilde{\tau}_i^{dL}(\tau_i^c) = \tau_i^c = \tau_{-i}^c$ is a best response in the continuation game.

To help see that the Linked-WEC retaliation strategies are subgame perfect, consider a contradiction. Suppose then that there exists a $\tau_i^{pd} \neq \tau_i^p$ and/or a $\tau_i^{cd} \neq \tau_i^c$, where τ_i^p is the strategy specified in the punishment path (τ_i^{dL} or τ_i^n) such that the following holds:

$$(1-\delta)\cdot\left[\vartheta_a^{pd}\left(\tau_a^{pd},\tau_a^{*c}\right)+\vartheta_b^p\left(\tau_b^{cd},\tau_b^{*p}\right)\right]+\delta\cdot\left[\vartheta_a^n\left(\tau_a^n,\tau_a^{*n}\right)+\vartheta_b^n\left(\tau_b^n,\tau_b^{*n}\right)\right]$$
$$>(1-\delta)\left[\vartheta_a^p\left(\tau_a^p,\tau_a^{*c}\right)+\vartheta_b^p\left(\tau_b^c,\tau_b^{*p}\right)\right]+\delta\cdot\left[\vartheta_a^p\left(\tau_a^d,\tau_a^{*c}\right)+\vartheta_b^p\left(\tau_b^c,\tau_b^{*d}\right)\right]$$

However, $\left[\vartheta_a^n\left(\tau_a^n,\tau_a^{*n}\right)+\vartheta_b^n\left(\tau_b^n,\tau_b^{*n}\right)\right] < \left[\vartheta_a^p\left(\tau_a^d,\tau_a^{*p}\right)+\vartheta_b^p\left(\tau_b^c,\tau_b^{*p}\right)\right]$, because $\tau_i^p \leq \tau_i^n$). Therefore, the above inequality is not satisfied for sufficiently patient governments, a contradiction. We can denote the necessary patience such that countries would adhere to the Linked-WEC retaliation strategies as $\delta^{SPL}(\tau_i^c)$.

Finally, note that $\left[\vartheta_a^p\left(\tau_a^p\left(\tau_a^{*c}\right),\tau_a^{*c}\right)+\vartheta_b^p\left(\tau_b^c,\tau_b^{*p}\left(\tau_b^c\right)\right)\right] < \left[\vartheta_a^c\left(\tau_a^c,\tau_a^{*c}\right)+\vartheta_b^c\left(\tau_b^c,\tau_b^{*c}\right)\right]$ from Proposition 1, so that abiding by the cooperative path specified by the agreement and receiving

$\Omega_i^L = \left[\vartheta_a\left(\tau_a^c,\tau_a^{*c}\right)+\vartheta_b\left(\tau_b^c,\tau_b^{*c}\right)\right]$ must be greater than deviating and receiving

$\Psi_i^L = (1-\delta)\cdot\left[\vartheta_a^d\left(\tau_a^{dL}\left(\tau_a^{*c}\right),\tau_a^{*c}\right)+\vartheta_b^c\left(\tau_b^c,\tau_b^{*c}\right)\right]+\delta\cdot\left[\vartheta_a^p\left(\tau_a^p\left(\tau_a^{*c}\right),\tau_a^{*c}\right)+\vartheta_b^p\left(\tau_b^c,\tau_b^{*p}\left(\tau_b^c\right)\right)\right]$ if δ is sufficiently close to one. We denote this necessary discount factor as $\delta^L(\tau_i^c)$. We can also write $\delta^{L\succ N}(\tau_i^c)$ as the necessary discount factor so that a limited deviation in one sector followed by the Linked-WEC retaliation is preferred to a maximal deviation in both sectors followed by Nash-reversion. In addition, we can write $\delta^N(\tau_i^c)$ as the necessary discount factor to support cooperation by the threat of Nash-reversion. As in the introduction, if $\vartheta_i\left(\tau_i,\tau_i^*\right)$ is sufficiently concave in its own tariff, then $\delta^{SPL}(\tau_i^c) < \delta^{L\succ N}(\tau_i^c) < \delta^N(\tau_i^c) < \delta^L(\tau_i^c)$.

(ii.) First note that if $\tau_i^{dU} \geq \tau_i^n$ the Unlinked-WEC strategies specify τ_i^n forevermore. By definition $\tau_i^n$is a best response to τ_i^n. If $\tau_i^{dU} < \tau_i^n$, then we need to show that τ_i^{*dU} is a best response to τ_i^{dU}, and once in the punishment stage, neither government has an incentive to deviate from it by applying a greater tariff. For $\tau_i^c < \tau_i^{mcU}$, the deviation tariff is greater than the most cooperative tariff $\tau_i^c < \tau_i^{mcU} < \tau_i^{dU}\left(\tau_i^c\right)$ by Proposition 3. However, for $\tau_i^{dU}\left(\tau_i^c\right) > \tau_i^{mcU}$, $\tau_i^{*d}\left(\tau_i^{dU}\left(\tau_i^c\right)\right) = \tau_i^{dU}\left(\tau_i^c\right)$ is a best response by Proposition 3. Finally, if $\tau_i^c > \tau_i^{mcL}$, then $\tilde{\tau}_i^{dL}\left(\tau_i^c\right) = \tau_i^c > \tau_i^{mc} > \tau_i^{dL}\left(\tau_i^c\right)$ and $\tau_i^{*d}\left(\tilde{\tau}_i^{dL}\left(\tau_i^c\right)\right) = \tau_i^c$ is the best response.

In order to see that neither government has an incentive deviate from the punishment path we check the incentive constraint. Suppose not, so that there exists a $\tau_i^{pd} \neq \tau_i^p$ which satisfies the following:

$$(1-\delta)\cdot\vartheta_i^{pd}\left(\tau_i^{pd},\tau_i^{*p}\right)+\delta\cdot\vartheta_i^n\left(\tau_i^n,\tau_i^{*n}\right) > (1-\delta)\cdot\vartheta_i^p\left(\tau_i^p,\tau_i^{*p}\right)+\delta\cdot\vartheta_i^p\left(\tau_i^p,\tau_i^{*p}\right)$$

however, $\vartheta_i^p\left(\tau_i^p,\tau_i^{*p}\right) > \vartheta_i\left(\tau_i^n,\tau_i^{*n}\right)$ for $\tau_i^p < \tau_i^n$ (and equal for $\tau_i^p = \tau_i^n$, but then there is no profitable deviation in the punishment phase), therefore this condition is not satisfied for sufficiently patient governments, a contradiction.

Finally, note that from Proposition 1 we have $\vartheta_i\left(\tau_i^d\left(\tau_i^{*c}\right),\tau_i^{*d}\left(\tau_i^c\right)\right)<\vartheta_i\left(\tau_i^c,\tau_i^{*c}\right)$. Hence, examining equation (8) shows that for δ close to one we must have $\Psi_i^U\leq\Omega_i^U$. We denote this necessary discount factor as $\delta^U(\tau_i^c)$.

(iii.) From equation (8) we can write $\delta^U(\tau_i^c)=\frac{\vartheta_i^{dU}\left(\tau_i^{dU}\left(\tau_i^{*c}\right),\tau_i^{*c}\right)-\vartheta^c\left(\tau_i^c,\tau_i^{*c}\right)}{\vartheta_i^{dU}\left(\tau_i^{dU}\left(\tau_i^{*c}\right),\tau_i^{*c}\right)-\vartheta_i^{pU}\left(\tau_i^{dU}\left(\tau_i^{*c}\right),\tau_i^{*dU}\left(\tau_i^c\right)\right)}$.

Similarly, from equation (12) we have $\delta^L(\tau_i^c)=\frac{\vartheta_i^{dL}\left(\tau_i^{dL}\left(\tau_i^{*c}\right),\tau_i^{*c}\right)-\vartheta^c\left(\tau_i^c,\tau_i^{*c}\right)}{\vartheta^c\left(\tau_i^c,\tau_i^{*c}\right)-\vartheta_i^{pL}\left(\tau_i^c,\tau_i^{*dL}\left(\tau_i^c\right)\right)}$, where we use the symmetry between the sectors. Note that by Proposition 1

$$\vartheta_i^{dU}\left(\tau_i^{dU}\left(\tau_i^{*c}\right),\tau_i^{*c}\right)+\vartheta_i^{pL}\left(\tau_i^c,\tau_i^{*dL}\left(\tau_i^c\right)\right)>\vartheta_i^{pU}\left(\tau_i^{dU}\left(\tau_i^{*c}\right),\tau_i^{*dU}\left(\tau_i^c\right)\right)+\vartheta^c\left(\tau_i^c,\tau_i^{*c}\right).$$

Hence the denominator of $\delta^U(\tau_i^c)$ is larger than that of $\delta^L(\tau_i^c)$. In addition, note that by Proposition 6, $\tau_i^{dL}\left(\tau_i^{*c}\right)\geq\tau_i^{dU}\left(\tau_i^{*c}\right)$ so that $\vartheta_i^{dL}\left(\tau_i^{dL}\left(\tau_i^{*c}\right),\tau_i^{*c}\right)>\vartheta_i^{dU}\left(\tau_i^{dU}\left(\tau_i^{*c}\right),\tau_i^{*c}\right)$. Hence the numerator of $\delta^L(\tau_i^c)$ is larger than that of $\delta^U(\tau_i^c)$. □

5.2 DSU Article 22.3

Although for sufficiently patient governments both punishment paths are subgame perfect, the governments may prefer one path over the other after a deviation. In the next proposition we show that this is indeed the case. For the same reason that the optimal deviation is higher in the Linked-WEC regime, both countries prefer the Linked-WEC regime after a deviation. In particular, the strategic substitutability of within-sector tariffs generates lower payoffs when the punishment phase occurs only in one sector. The necessary step in the proof of the following Proposition is the following property of submodular functions.

Definition. (Topkis, 1998, p.43) *A real valued function* $f(x):\mathbb{R}^n\to\mathbb{R}$ *is supermodular in* $x\in\mathrm{X}$, *if:*

$$f(x')+f(x'')\leq f(\min(x',x''))+f(\max(x',x''))$$

for all x', $x''\in\mathrm{X}$. *It is strictly supermodular if the inequality is strict. It is (strictly) submodular if* $-f(x)$ *is (strictly) supermodular.*

For continuously differentiable functions, supermodularity and submodularity reduce to strategic complementarity and strategic substitutability. In the case of our welfare function, Proposition 1 shows that $\frac{\partial^2 v(.)}{\partial t\partial\tau}<0$, so that $\vartheta_i(\tau_i,\tau_i^*)$ is submodular in $\{\tau_i,\tau_i^*\}$.

Proposition 8. *(Main result 2.) After any deviation from the cooperative path by either country, both the deviating country and the retaliating country prefer the continuation path given by punishments in the Linked-WEC regime.*

Proof. The continuation path in the punishment stage of the Linked-WEC regime has discounted average payoffs of

$$(1-\delta)\left[\vartheta_a^p\left(\tau_a^d, \tau_a^{*c}\right) + \vartheta_b^p\left(\tau_b^c, \tau_b^{*d}\right)\right].$$

The continuation path in the punishment stage of the Unlinked-WEC regime has discounted average payoffs of

$$(1-\delta)\left[\vartheta_a^p\left(\tau_a^d, \tau_a^{*d}\right) + \vartheta_b^c\left(\tau_b^c, \tau_b^{*c}\right)\right].$$

By the submodularity of $\vartheta_i\left(\tau_i, \tau_i^*\right)$, and the above definition of submodularity we have that for any τ_i^d the punishment stage in the Linked-WEC regime generates higher discounted average payoffs. □

Proposition 8 is our second main result in that it shows that countries prefer the punishment path with less enforcement power. Although the Unlinked-WEC regime generates a higher level of cooperation (a lower most cooperative tariff), both countries would prefer the less punitive Linked-WEC regime after a deviation. In particular, the punishing country would choose to punish by cross-retaliation if possible and the deviating country would welcome this punishment choice. Given that countries recognize their time inconsistency in the punishment regime choice it would make sense for them to limit their retaliation regime from the outset. Remember that in the initial stage of the trade agreement countries decide on the Linked or Unlinked regime. The following proposition, which is a corollary of Propositions 6 and 8 states that in the symmetric case considered so far, the countries would choose to limit their punishment options and choose the Unlinked-WEC regime from the outset.

Proposition 9. *(Main result 3.) If countries place enough value on future payoffs, then in any subgame perfect equilibrium of the entire trade agreement the regime choice is always the Unlinked-WEC regime:* $\theta = \theta^U$.

Proof. From Proposition 1 we know that lower cooperative tariffs generate higher welfare. From Proposition 6 we know that the Unlinked-WEC regime generates lower cooperative tariffs. From Proposition 9 we know that, following any deviation, countries will choose linked punishments. Hence, welfare is improved by setting $\theta = \theta^U$ in the initial period. □

Propositions 8 and 9 justify the order of cross retaliation given in the WTO DSU Article 22.3 that was described in the introduction. Countries are encouraged to choose same sector retaliation if feasible, and only if not feasible can they consider cross-sector (and very rarely cross-agreement) retaliation. In the symmetric case considered here same-sector retaliation is feasible and this limitation is welfare enhancing.

6 Asymmetries and Comparative Statics

In this section we consider technological improvements that change the magnitude of comparative advantage and we analyze how these changes affect the most cooperative outcomes in the different trade agreement regimes. First, we introduce a symmetric change in the degrees of comparative advantage and then we consider asymmetric changes.

When these changes create asymmetries, we need to be certain that the previous results of our model obtain in the absence of symmetry. First note that the functional forms are all twice continuously differentiable and the results are all based on first and second derivative conditions. Hence, the results hold for small asymmetries.

We start by considering identical symmetric increases in comparative advantage in both countries and in both sectors: $dD_i = dF_i > 0$. Next we consider asymmetric changes, whereby $dD_i > 0$ and $dF_i = 0$, or $dD_i = 0$ and $dF_i > 0$ for $i \in \{a, b\}$. Notice that these changes can be interpreted as export-biased technological improvements, where the relative cost of production in the exporting country decreases. As we show in the following proposition, for a symmetric change there is no difference between the enforcement capability of the Linked-WEC and Unlinked-WEC regime, however, they both dominate the Nash-reversion regime. In particular, the most cooperative tariff does not change in either WEC regime and it increases in the Nash regime.

Proposition 10. *A symmetric increase in comparative advantage in both countries and in both sectors, $dD_i = dF_i > 0$, decreases cooperation under Nash-reversion strategies. Cooperation under Unlinked-WEC and Linked-WEC strategies remain unchanged.*

Proof. We start by proving the following lemma which establishes the comparative static properties of cost changes on the optimal deviation tariff in each regime.

LEMMA 3.

(i.) In the Nash-reversion regime the optimal Home deviation tariff increases for $dF_i > 0$ and remains

unchanged for $dD_i > 0$; whereas the Foreign deviation tariff remains unchanged for $dF_i > 0$ and increases for $dD_i > 0$.

(ii.) In the Unlinked-WEC regime the optimal Home deviation tariff increases for $dF_i > 0$ and decreases for $dD_i > 0$ by the same amount. Similarly, the foreign deviation tariff decreases for $dF_i > 0$ and increases for $dD_i > 0$ by the same amount.

(iii.) In the Linked-WEC regime the optimal Home deviation tariff increases for $dF_i > 0$ and decreases for $dD_i > 0$ by the same amount. Similarly, the foreign deviation tariff decreases for $dF_i > 0$ and increases for $dD_i > 0$ by the same amount.

Proof. We use the specific form of quasi-linear consumer utilities defined by equation (1) and convex cost technologies technologies defined by equation (2). We also impose the value $c = \frac{1}{2}$ for simplicity.

(i.) In order to prove the first part, we use the first order condition for the optimal deviation in the Nash-Reversion regime given in equation (7). Totally differentiating this equation with respect to τ_i^{dNR}, and F or D and using the Implicit Function Theorem yields:

$$\frac{\partial \tau_i^{dNR}}{\partial F_i} = \frac{\partial \tau_i^{*dNR}}{\partial D_i} = \frac{1}{6}, \quad and \quad \frac{\partial \tau_i^{*dNR}}{\partial F_i} = \frac{\partial \tau_i^{dNR}}{\partial D_i} = 0$$

(ii.) The second part follows from a similar application of the Implicit Function Theorem on the first order condition for the optimal deviation in the Unlinked-WEC regime given in equation (10):

$$\frac{\partial \tau_i^{dU}}{\partial F_i} = -\frac{\partial \tau_i^{dU}}{\partial D_i} = -\frac{\partial \tau_i^{*dU}}{\partial F_i} = \frac{\partial \tau_i^{*dU}}{\partial D_i} = \frac{1}{6 - \delta + 2b\delta} > 0$$

(iii.) The third part follows from a similar application of the Implicit Function Theorem on the first order condition for the optimal deviation in the Linked-WEC regime given in equation(14):

$$\frac{\partial \tau_i^{dL}}{\partial F_i} = -\frac{\partial \tau_i^{dL}}{\partial D_i} = -\frac{\partial \tau_i^{*dL}}{\partial F_i} = \frac{\partial \tau_i^{*dL}}{\partial D_i} = \frac{1}{6 - \delta} > 0$$

In order to see the changes in the most cooperative tariff under the Linked-WEC and Unlinked-WEC strategies, remember that $\tau_i^{dU}(\tau_i^{mcU}) = \tau_i^{mcU}$ and $\tau_i^{dL}(\tau_i^{mcL}) = \tau_i^{mcL}$. Proposition (*3.iii*) and Proposition (*4*) show that the most cooperative tariff is defined at the intersection of optimal deviation tariff and 45 degree-line. Therefore, a greater τ_i^d for a given τ_i^c implies a greater τ_i^{mc}. Things are different, however, in the Nash-reversion regime since the intersection of τ_i^{dN} with the 45-degree line designates the static Nash tariff and not the cooperative tariff. We use the incentive constraint to show the positive correlation between the deviation tariff and the most cooperative tariff in this case. Remember that the most cooperative tariff is defined at the point where the incentive constraint just binds under the Nash-reversion strategy:

$$(1-\delta)\cdot\vartheta_i^d\left(\tau_i^{dN},\tau_i^{*mc}\right)+\delta\cdot\vartheta_i^p\left(\tau_i^n,\tau_i^{*n}\right)-\vartheta_i^c\left(\tau_i^{mc},\tau_i^{*mc}\right)=0$$

now, differentiate this with respect to the most cooperative, and the deviation, tariff to get:

$$\frac{\partial\tau_i^{mc}}{\partial\tau_i^{dN}}=\frac{-\left(1-\delta\right)\vartheta_{i1}^d\left(\tau_i^{dN},\tau_i^{*mc}\right)}{\left(1-\delta\right)\vartheta_{i2}^d\left(\tau_i^d,\tau_i^{*mc}\right)-\left[\vartheta_{i1}^c\left(\tau_i^{mc},\tau_i^{*mc}\right)+\vartheta_{i2}^c\left(\tau_i^{mc},\tau_i^{*mc}\right)\right]}>0$$

where both the numerator and denominator are negative. In order to see this, we can rewrite the denominator as follows: $(1-\delta)\cdot\left[\vartheta_{i2}^d\left(\tau_i^d,\tau_i^{*mc}\right)-\vartheta_{i2}^c\left(\tau_i^{mc},\tau_i^{*mc}\right)\right]-\left[\vartheta_{i1}^c\left(\tau_i^{mc},\tau_i^{*mc}\right)+\delta\cdot\vartheta_{i2}^c\left(\tau_i^{mc},\tau_i^{*mc}\right)\right]$. Remember that $0<\vartheta_{i1}^c\left(\tau_i^{mc},\tau_i^{*mc}\right)+\delta\cdot\vartheta_{i2}^c\left(\tau_i^{mc},\tau_i^{*mc}\right)$ as shown in the proof of Proposition 5, and $\vartheta_{i2}^d\left(\tau_i^d,\tau_i^{*mc}\right)<\vartheta_{i2}^c\left(\tau_i^{mc},\tau_i^{*mc}\right)$ by strategic substitutability.

Finally looking at the results of Lemma 3 we see that symmetric changes in D and F are offsetting in both countries in either WEC regime, however, it generates a tariff increase in the Nash regime. □

This result provides a surprising justification of the WEC rule. In the Nash-reversion regime the future punishment is not directly tied to the original deviation. Being as the original deviation is an optimal tariff, and the point of an optimal tariff is to capture as much of the gains from trade as possible, then it is clear that the optimal deviation in the Nash-regime will fluctuate with the degree of gains from trade, or comparative advantage. Hence, changes in the gains from trade requires flexibility in the trade agreement to avoid generating serious trade wars (Bagwell and Staiger, 1990). In the WEC regimes, on the other hand, a larger Home deviating tariff allows the Foreign trading partner to also capture more of the gains from trade generated by Home's symmetric export-biased technological improvement. In the particular case considered here these effects are offsetting so the net effect is zero. Still, the intuition suggests that the result should hold in a more general model.

We now consider asymmetric changes and we analyze their affect on the most cooperative tariff in the Linked- and Unlinked-WEC regimes. We again use an increase in the cost disadvantage of the importing country to represent an export-biased technological improvement in the exporting country (or an increase in the gains from trade). We could also consider the opposite change, or an import biased technological improvement. Our main goal in this paper is to compare Linked- and Unlinked-WEC and in the particular case of a change in only one country we can show that Linked-WEC regime generates wider fluctuations than does the Unlinked-WEC regime.

Proposition 11. *A small export-biased (or import biased) technological improvement in only one country generates a larger change in the most cooperative tariff when countries abide by the Linked-WEC regime as opposed to Unlinked-WEC regime.*

Proof. Consider, for example, an export-biased technological improvement in the home country: $dD_i > 0$. The other cases are similar. From Lemma (3.ii) this increase generates changes in the optimal deviation tariff of $\frac{\partial \tau_i^{dU}}{\partial D_i} = -\frac{\partial \tau_i^{*dU}}{\partial D_i} = \frac{-1}{6-\delta+2b\delta} < 0$ in the unlinked case and $\frac{\partial \tau_i^{dL}}{\partial D_i} = -\frac{\partial \tau_i^{*dL}}{\partial D_i} = \frac{-1}{6-\delta} < 0$ in the linked case. For $b > 0$ we have that $\mid \frac{-1}{6-\delta+2b\delta} \mid < \mid \frac{-1}{6-\delta} \mid$ and the difference is increasing in b. Finally, from Propositions (3.iii) and 4 we know that $\tau_i^{mcU}(\tau_i^{dU})$ and $\tau_i^{mcL}(\tau_i^{dL})$ increase at the same rate. □

Proposition 11 shows that when the same-sector goods are strategic substitutes, then linking agreements generates wider fluctuations in the most cooperative tariffs. This result occurs because technology changes generate changes in comparative advantage and the gains from trade. These changes in the gains from trade alter the benefits from an optimal deviation tariff and, therefore, change the level of obtainable cooperation. The key is that the optimal deviation tariff is mitigated in the WEC regimes, because the level of deviation affects the permissible retaliation. This effect is captured by δ in the above derivatives. In the Linked-WEC regime retaliation takes place in the other sector so the deviation does not impinge on the benefit of the deviation. In the Unlinked-WEC regime this retaliation takes place in the same sector and because of strategic substitutability the future benefit of the deviating tariff is declining in the level of the retaliation. This effect is captured by b in the above derivatives. If $b = 0$, then the goods are independent and the two regimes are identical. As b increases the substitutability increases and the difference between the regimes grows.

7 Conclusion

In this paper we consider two prominent institutional rules in the international trading system that are designed to limit the countermeasures upon a violation. One rule limits the composition of retaliation and the other limits the magnitude of retaliation. Although seemingly unrelated, the limited cross-retaliation rule complements the limited punishment rule in constraining the scope *and* the magnitude of punishment in international trade disputes. Specifically, we elaborate a mechanism through which the limited cross-retaliation rule also helps limit the incentives to violate the trade agreement when the limited punishment rule prevails.

We start by showing that if the import and export goods are substitutes in consumption, then the underlying preferences generate a welfare function whereby tariffs are strategic substitutes. Given strategical substitutability the limited retaliation rule reduces the deviation magnitude by a larger amount when cross-retaliation is not allowed. On the other hand, once a limited deviation has occurred countries prefer cross-retaliation over same-sector retaliation. This preference can create a problem in that countries will expect cross retaliation ex-post and increase the level of deviation ex-ante. By subordinating more distant cross-retaliations the WTO DSU Article 22.3 was prescient in foreseeing this time-inconsistency problem and, in fact, cross-agreement retaliation has only been permitted three times in the history of the WTO (out of nine requests).

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