Limited Incremental Linking and Unlinked Trade Agreements

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Abstract: The broadened scope of the GATT/WTO through successive rounds of trade liberalization is explained as a result of trade-partner specificity, linked agreements, and cross retaliation. In more recent years, however, countries have pursued trade liberalization through sector specific zero-for-zero agreements and preferential trade agreements, both of which have a reduced chance of suffering cross retaliation. This increase in unlinked agreements is explained by imperfect observability of trade policies generating gratuitous trade disputes and unjustified cross retaliation. If the dispute generating noise is perfectly correlated across sectors, however, then it provides no reason not to link agreements in a static sense and in many cases incremental linking still produces more liberalization than static linking. It is only when the noise is imperfectly correlated that linking and cross retaliation are problematic so that some sectors can enforce more liberalization in an unlinked agreement. If the correlation drops, the noise increases, or the number of sectors already covered is large, then incremental linking of more sectors is inefficient and countries pursue unlinked agreements.

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1. Introduction

The GATT/WTO has presided over an impressive reduction in average tariffs since its inception in 1947. This reduction occurred through successive reductions in the tariffs of already covered sectors and also through the gradual increase in the number of sectors included in the agreement. It has also broadened its reach to liberalize trade in services and to establish rules for the international protection of intellectual property. In a more recent trend, subgroups of WTO signatories have liberalized trade on well-defined groups of goods though sector-specific zero-for-zero agreements.[1] Furthermore, almost 400 subgroups of WTO members have rushed to develop an astounding array of overlapping Preferential Trade Agreements (PTAs), with the great majority being formed in recent years.[2]

In this paper we provide a unified explanation for the initial increase in the breadth of the GATT/WTO as well as more recent attempts at trade liberalization that exist partially beyond the auspices of the WTO. Our idea is of two parts. First, when cross retaliation is possible each additional linked sector increases the enforcement capability of the trade agreement and permits liberalization in still more sectors. Second, imperfect observability of trade policies can generate trade disputes and unwarranted cross retaliation. More recent trade agreements are unlinked, in part, to avoid cross retaliation. Interestingly, trade disputes only matter if the dispute generating noise is not perfectly correlated across sectors. As the correlation drops and/or the noise increases, cross retaliation is more prevalent and some sectors only pursue liberalization through unlinked agreements. The number of sectors already covered is eventually the biggest impediment to future linking. There is a natural limit to the number of linked agreements (that depends on the correlation between the noise terms) so that when the existing agreement is mature and links many sectors, further liberalization is pursued through unlinked agreements.

[1] Examples are the 1995 pharmaceutical tariff elimination agreement, the 1997 financial services agreement, and the 1997 information technology agreement. Other sector specific agreements, such as the multifiber agreement on textiles were much different in that they had a quota and a termination date for that quota (Hoekman and Kostecki, 2001). Many agricultural zero-for-agreements only levy zero tariffs up to the level of the quota. When we refer to zero-for-zero agreements in this paper we will only be referring to the first group,.

[2] As of December 15, 2008 close to 400 PTAs were notified to the WTO of which 230 were still in force (195 of these 230 came into force since January 1, 1994 (the inception date of NAFTA and the EEA) and more than half came into force since January 1, 2002. Mongolia is the only GATT/WTO signatory that has not joined a PTA, choosing instead a "Buddhist path of self-perfection and good WTO-consistent behaviour, without regard to whether other countries were doing the same". (Economist, 2006).

Cross retaliation in sectors other than the one where the dispute originated is allowed for in the WTO's dispute settlement understanding (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.[3] 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". Paragraph 5 of article 22 prohibits cross retaliation if the covered agreement does not allow for suspension of concessions. Other than these guidelines in paragraphs 3 and 5, the DSU provides no hard and fast rule on cross retaliation in zero-for-zero sector specific agreements or even in PTAs. Cross retaliation in these agreements, however, is much less likely and we use this fact in referring to them as unlinked agreements.[4,5] Our idea is that as the initial agreement becomes broader, these unlinked agreements become more popular.

Our analysis draws upon several distinct elements. 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. We follow their idea and consider trade agreements as infinitely repeated games where the hope of future cooperation can enforce current trade liberalization. Bernheim and Whinston (1990) – hereafter referred to as BW – analyzed how firms that link infinitely repeated pricing games can enforce more collusive outcomes in each market. As in BW, cross retaliation can enforce more cooperative outcomes when the sectors are less similar. The BW linking result is in a noiseless framework and all of the linking occurs at

[3] Article 22.3 of the DSU never explicitly uses the word "cross-retaliation", however, the WTO's (2003) briefing for its fifth Cancún ministerial conference explains that it is the "short hand" word for what is described in article 22.3.
[4] There are a few examples of retaliation across agreements. The WTO dispute settlement board has accepted Brazil's request to cross retaliate U.S. cotton subsidies by withdrawing equivalent concessions in the GATS and TRIPS. It has allowed Antigua to cross retaliate the prohibition of international internet gambling (a violation of GATS) by withdrawing concessions in TRIPS. There has not yet been cross-retaliation in zero-for-zero sector specific agreements or in goods only covered in a PTA and not the WTO. As mentioned above these retaliations are not prohibited only highly subordinated. There may at present be a separate implicit arrangement to not cross retaliate in these other agreements – the analysis of which may present an interesting direction for further research.
[5] The U.S. and Mexico have both brought NAFTA cases to the WTO when the good is covered by both agreements. No cross retaliation in sectors that are covered only in NAFTA and not the WTO have been asked for or approved by the WTO. The relationship between dispute settlement in the WTO and PTAs is well beyond the scope of this paper, however, it is an important area for further research.

the same time, therefore, we refer to it is static noiseless linking. Our third element draws upon the idea that participating in export markets requires ongoing trade and export promotion costs.[6] These irreversible costs change the structure of the trade agreement so that more and more sectors can be linked to the trade agreement over time. In particular, sectors that cannot enforce free trade by themselves or as part of a static link can enforce free trade when incrementally linked in a later period. Incremental noiseless linking is shown to enforce free trade in more groups than does static noiseless linking.

Our fourth component is the inclusion of noise in observing partners' trade policies. This noise is a product of macroeconomic instability or preference fluctuations and it can generate trade disputes in equilibrium. Imperfect observability generating temporary suspensions of cooperation was first analyzed in the context of colluding firms by Green and Porter (1984) and generalized by Abreu et al (1990). In our framework, whenever the producer price falls below a certain level it triggers a trade dispute and a temporary withdrawal of concessions.[7] The most important aspect of the noise in our framework is its correlation across sectors. If it is not perfectly correlated across sectors, then disputes spill over to other linked sectors and cross retaliation causes each sector to suffer more trade disputes than if it was unlinked. On the other hand, if this noise is perfectly correlated across sectors, then although disputes spill over across sectors each sector would be in a dispute at the same time whether or not they were linked. Hence, perfectly correlated noise does not impede the potential for static and incremental linking. As the correlation decreases, however, both types of linking generate an increasing number of trade disputes. If the noise is not perfectly correlated, then there will also be more disputes when the number of sectors already covered by the agreement is large. To avoid potential cross retaliation, additional sectors may only be able to enforce free trade through unlinked agreements. Unlinked side agreements are, therefore, predicted to be more prevalent in mature agreements.

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[6] Roberts and Tybout (1997) and Das et al. (2007) provide evidence of these costs for Columbia. Evidence for France is provided by Eaton, Kortum, and Kramarz (2006). These costs are related to the theories of export hysteresis developed by Baldwin and Krugman (1989), and Dixit (1989), and, more recently, by Alessandria et al. (2008).

[7] Hungerford (1991), Riezman (1991), and Maggi (1999) also consider imperfect observability of trade barriers that could generate trade wars in equilibrium. More recent work by Bagwell and Staiger (2005), Park (2006), Lee (2007), and Martin and Vergote (2007) consider trade disputes in equilibrium arising in frameworks with private information about domestic concerns, political pressure, and the observability of trade barriers. The focuses of these papers are different and they do not consider the incremental addition of more sectors.

Our model generates three interesting empirical predictions about the types of sectors that are most likely to pursue trade liberalization through unlinked agreements. Sectors that have stable demand and more easily observable trade related policies would suffer fewer disputes in an unlinked agreement, and would benefit less from being linked to a mature agreement with many disputes. In addition, sectors whose noise is less correlated with that in the existing agreement would be most likely to pursue unlinked agreements. Third, it predicts that we will see more zero-for-zero agreements as time progresses. It is interesting to note that all of these conditions would seem to be met for the information technology and pharmaceutical zero-for-zero agreements. Furthermore, our model suggests that countries may choose unlinked liberalization in certain groups by the use of selective preferential trading arrangements.

Recent work by Ederington (2001, 2003), Conconi and Perroni (2002), and Limao (2005) analyze the costs and benefits of linking trade policy and non-trade objectives. Whereas these authors are concerned with the relationships between the objectives (Limao, for example, shows that optimal linking depends on whether the trade and non-trade objective are strategic complements or substitutes) we are concerned with the relationship between each sector's noise. We assume that the traded sectors are independent (and that some of them have slack enforcement capability at free trade) so that we can concentrate on the effect of noisy observability. Although we only analyze differing production sectors it should be possible to extend our model to non-trade objectives and in this way our model, by focusing on observability, can be considered complementary to these other papers.[8] Ederington (2002) explicitly considers noisy observability in linking trade and environmental policy. In his paper (as in this one), linking can be detrimental if countries make type 1 errors and incorrectly observe cheating, however, he shows that linking can be useful if countries make type 2 errors and fail to detect cheating. Our paper differs from Ederington (2002) in several respects. Trade partner specificity allows us to consider a gradual or incremental increase in the number of covered sectors and it is this large number of sectors that generates more (uncorrelated) observational errors so that eventually they overshadow the trade partner

[8] One conclusion from our paper is that linking can be detrimental if the trade policy and non-trade objective have uncorrelated observation noise or if one of the two is much noisier than the other. On the other hand, if their noise is perfectly correlated, then noise presents no limitations to linking. For example, it is probably imprudent to link nuclear war to dumping in trade agreements, however, if the noise is perfectly correlated so that every time a nuclear attack is mistakenly observed dumping is also mistakenly observed, then linking would not make things any worse.

specificity and make linking undesirable. In addition to considering many linked sectors we also specifically consider the correlation between the observational errors. Furthermore, we consider temporary punishment stages and dispute resolution as opposed to infinite grim reversion to the one-shot Nash equilibrium.

In addition to Ederington (2002), there is also a recent literature that considers the limitations of multimarket contact in other frameworks. Thomas and Willig (2006) show that in the case of a noisy prisoners' dilemma the BW multimarket result may lead to contagion and a worse outcome than not linking. Matsushima (2001) shows that if there is a very large number of other markets and players use information from these other markets, then it should be possible to minimize erroneous observations of cheating so that linking is not detrimental. This result suggests a role for information gathering and a direction for dispute adjudication in the WTOs dispute settlement board. Still, the current reality is that disputes are currently decided on their own merits (which is in accordance with most national legal systems) and we abstract from the possibility of collective inference in this paper.

This paper is also related to the literature on the hold-up problem in international trade and that on trade agreements. Lapan (1988) was the first to recognize that the optimal tariff after production has occurred is greater than the ex-ante optimal tariff. In McLaren (1997), production precedes a trade agreement and, because governments can give side payments, agents do not internalize the erosion in national bargaining power caused by their actions. Hence, if free trade is expected, then factors will accumulate in the export sector generating a very large optimal tariff that could be levied against this country. In this case, the resulting side payment in the trade agreement may be so large as to leave the country worse off under an optimistic expectation of free trade than under an expectation of a trade war. Chisik (2003) does not allow for side payments as in McLaren (1997) and shows that this can cause countries to liberalize slowly, however, as the export capacity is developed over time countries become more integrated and trade barriers are gradually eroded. Hence, in the Chisik (2003) case the hold-up problem is gradually mitigated by successful past liberalizations.

Past liberalizations generating a gradual reduction in trade barriers through the evolution of an endogenously determined state variable is also demonstrated by Staiger (1995), Devereux (1997), and

Furusawa and Lai (1998). Alternative explanations for the gradual reduction of trade barriers are provided by Bond and Park (2002), Maggi and Rodríguez-Clare (2007) and Zissimos (2007). Whereas these previous papers all consider reduced trade barriers in one sector, Baldwin (2006) shows how the creation and destruction of lobbyists can generate the gradual inclusion of additional sectors. Multi-sector gradualism is also analyzed by Onder (2009) who shows how incomplete information and learning causes countries to start slow and then eventually add more sectors to the trade agreement. None of these other authors consider eventual limitations to gradualism, which is the main focus of this paper.

In the next section of the paper we describe our framework in a noiseless environment and establish the possibility of incremental linking. The third section shows the limitations of incremental linking in a noisy world. The fourth section considers some extensions of the model and the fifth section contains our conclusions.

2. Incremental Linking with Perfectly Observable Trade Policies

The Economic Environment

We start by considering a perfect information version of a model of trade and production between two countries. The home and foreign countries are indexed by $i \in \{h, f\}$ and can each produce N_i goods for export as well as a numeraire good that can be used to rectify trade imbalances. Foreign has a value of α_{hj} for one unit of each home good *hj* that is exported. Home can choose to produce up to one unit of the good for export at a per-period unit cost of β_{hj}. The gains from trade on each good exported by home are denoted as $\theta_{hj} = \alpha_{hj} - \beta_{hj}$. Similarly, the gains from trade on each foreign export are $\theta_{fj} = \alpha_{fj} - \beta_{fj}$. Each country chooses tariffs to maximize a utilitarian social welfare function that sums the producer surplus on each export good and the consumer surplus and tariff revenue on each import good.

Countries negotiate tariffs on each of the possible goods and firms choose which of the possible goods they wish to produce for export. The only restriction is that past production decisions constrain current output levels. If a good *ij* is produced in a previous period, then, at least $\rho_{ij} \in [0, 1]$ of a unit must be produced in the current period. We call ρ_{ij} as the measure of irreversibility.

The timing of the model is straightforward. In the first stage of each period the two governments decide on which goods they are going to liberalize trade. In the second stage exporting firms and importing consumers (or their agents) negotiate prices for each of the traded goods. This negotiation is performed through a standard bargaining solution with equal bargaining weights on exporters and importers.[9] The outcomes of the first two stages are perfectly observed by the firms in both countries. In the third stage governments are able to convey privately to their own firms whether or not they plan to abide by the agreement. In the fourth stage, firms choose to produce up to one unit of good ij, subject to the irreversibility condition that if past output was positive, then the current output must be at least ρ_{ij}. We assume that the export and domestic markets are segmented so that trade and trade policy have no effect on the domestic market. Hence we only consider export decisions. The production decisions are observed by both governments who choose tariffs in the fifth stage.

In the absence of tariffs, the standard bargaining solution with equal weights on the exporters and importers would equally split the gains from trade. In this case, the price of each good exported by country i would be $P_{ij} = (\alpha_{ij} + \beta_{ij})/2$, and consumer and producer surplus on each good exported by country i would both be equal to $\theta_{ij}/2$. Tariffs can serve to transfer surplus between producers, consumers, and governments and τ_{ij} is the import tariff levied on good ij. The standard bargaining solution also splits the payment of any planned cooperative tariff between the exporters and the importers so that the producer price is $P_{ij} = (\alpha_{ij} + \beta_{ij} - \tau_{ij})/2$ and producer and consumer surplus are $(\theta_{ij} - \tau_{ij})/2$. In this case the tariff revenue from good ij is equal to τ_{ij}.[10]

Instead of the planned cooperative tariffs it is possible that there will be surprise tariffs by the importing country in the fifth stage of the period. Because markets are segmented, and because tariffs are levied after production takes place, the unilaterally optimal, myopic tariff choice would expropriate the

[9] All of the results in our model would obtain in a more traditional framework with un-segmented markets, increasing opportunity costs of production, and a diminishing rate of marginal substitution in consumption. Irreversibility is the one novel part of the model and it is our key assumption. The presence of irreversibility, especially when considered with many goods, as well as imperfect observability and repeated interactions, renders the model more complex, and for that reason we chose the simplest possible formulation of supply and demand. For an example of irreversibility in a more traditional framework see Chisik (2003, 2009).

[10] Our results are not at all dependant on the split of the gains from trade or the payment of the tariffs. As long as the producer receives some of the surplus and has to pay at least some of the tariff all of our results would go through.

entire value of output. Put another way, once the exporting firm has sunk the production cost the static Nash-equilibrium tariffs only transfer surplus from the producers to the importing country. Hence, the unilaterally optimal tariff is the largest one that leaves the exporters indifferent between exporting and throwing their goods in the ocean. In this case the producer price P_{ij} is zero, the static Nash-equilibrium tariff $\tau_{ij}^{n} = \alpha_{ij}$, government revenue is equal to α_{ij}, and consumer surplus is zero. The producer surplus is given by the already sunk production cost of $-\beta_{ij}$.[11]

In the fourth stage of the period firms decide how many goods to produce for export. The number of goods j that firms in country i will produce will be seen to be determined by their expectation of the tariffs, the number of goods previously produced, the gains from trade, and the measure of irreversibility. This measure, ρ_{ij}, also directly affects future production decisions. In particular, in any period firms can choose to produce one unit of good ij for export. The restriction is that once a good is produced for export they are constrained to produce at least $\rho_{ij} \leq 1$ unit of the good in all future periods.[12]

The production irreversibility is perhaps best described as the need to maintain sales and infrastructure in the importing country.[13] Some of these expenses are sunk at the time of export expansion; however, many are also ongoing costs whose irreversibility stems from explicit contracts (such as advertising, brand name and sales infrastructure maintenance) and implicit contracts (such as maintaining networks and political favor). Roberts and Tybout (1997) and Das et al. (2007) provide evidence that, for Colombian firms, these costs are an important component of the decision to enter an export market. In this case ρ reflects the percentage of infrastructure that needs to be maintained even

[11] We could also adopt the approach that because these surprise tariffs are not planned for in the negotiated price, the producer pays the entire tariff. In this case the largest tariff that would leave the exporters indifferent between exporting and not, is $(\alpha_{ij} + \beta_{ij})/2$ so that the producer price is still zero and consumer surplus is $(\alpha_{ij} - \beta_{ij})/2$ as before. Given our utilitarian social welfare function the sum of consumer surplus and government revenue would still equal α_{ij} and producer surplus would still equal $-\beta_{ij}$.

[12] Firms could also choose to produce ρ_{ij} of a unit in the initial period, however, if it is optimal to produce, then it will be optimal to produce the entire unit. It would be interesting to consider the possibility that firms could reduce output to ρ_{ij} of the previous level in each future period so that during long trade disputes production would eventually approach zero. Although more realistic, this formulation would not change our results. Furthermore, when we introduce noise and randomly occurring trade disputes in a subsequent section we need to rely on the recursive formulation of the model in order to solve it. Hence, we preserve the recursive formulation from the outset of our presentation. Although each exporting industry's output is fixed to two levels we still consider an evolving state given by the number of industries that export.

[13] Alternatively, firms may have implicit contractual obligations with their workers or input suppliers arising from efficiency wage arrangements or explicit contractual obligations arising, for example, from union contracts.

during a period of lower profitability. We can then think of β_{ij} as the sales and infrastructure cost in every period and the marginal production cost is normalized to zero. Irreversibility may also arise from the need to fit exports to the standards of the importing country (see, for example, Chen and Mattoo, 2006). It may also be interpreted as reflecting the reduced price that would be received if the exporter was forced to sell the goods on the world market at less preferential terms than those available in the PTA.

The third stage allows for communication between the government and the firms in their own country. An assumption about this stage is necessary because there are, in effect, two decision makers in each country. That is, if the government plans to deviate from the cooperatively chosen tariffs, we assume that this deviation is anticipated by the domestic firms. This assumption is made because domestic firms have a better sense of the political pressures facing their own government and, therefore, are better able to anticipate when the agreement would be abrogated by deviating tariffs. In this way firms and the government are making a coordinated decision on two variables (tariffs and output) when considering a deviation.

The first stage allows governments to announce cooperative tariffs. When considering the constraints that arise in future stages, governments will also be able to affect the number of goods that are covered by the agreement. That is, in addition to altering the depth of the agreement by the choice of tariffs, governments will also be able to adjust the breadth of the agreement or the number of goods that are covered. It will be the combination of the depth and the breadth that will contribute to the overall level of integration between the countries.

In a sense we can think of this framework as describing a variation on an infinitely repeated prisoners' dilemma. Each pair of an import and an export good yields one prisoners' dilemma and the collection of possibly traded pairs of goods yield many such dilemmas. Within each pair, the production irreversibility indicates that the first period game will look different than the subsequent subgames.

The Trade agreement

To make matters concrete we start by considering the current and continuation payoffs that are generated by tariff choices in the goods that both home and foreign designate as group 1.

For the home country, adhering to the agreement yields consumer surplus of $(\theta_{f1} - \tau_{f1})/2$, producer surplus of $(\theta_{h1} - \tau_{h1})/2$, and government revenue τ_{f1}. Note that we use the good's country of origin in designating all variables, including tariffs. In addition, because we do not consider export policies, it is understood that τ_{f1} is the home per-unit tariff in period t on the foreign group 1 export. Home's expected value of abiding by the agreement on group 1 is:

$$V_{h1}^{c} = \theta_{f1}/2 + \theta_{h1}/2 + \tau_{f1}/2 - \tau_{h1}/2. \tag{2.1}$$

A deviation by the home country in the first period of liberalization in group 1 is given by the Nash-tariff $\tau_{f1}^{n} = \alpha_{f1}$. Consumer surplus is zero and government revenue is α_{f1}. Having anticipated their government's deviation home firms would not produce group 1 for export and producer surplus would then be zero. The deviation payoff in period 1 would then be:

$$V_{h11}^{d} = \alpha_{f1}. \tag{2.2}$$

After a home country deviation a credible punishment stage would be where both countries levy Nash-tariffs. Of course, if home never produces, then foreign would never gain any tariff revenue. On the other hand foreign would reduce output as much as possible, or to ρ_{f1}. In this case, home's expected per-period payoff in the continuation game triggered by their first period deviation is:

$$V_{h11}^{n} = \rho_{f1}\alpha_{f1}. \tag{2.3}$$

Note that a deviation in a later period ($t > 1$), after home has committed to group 1 production, yields deviation and continuation payoffs of $V_{h1t}^{d} = \alpha_{f1} + \theta_{h1}/2 - \tau_{h1}/2$ and $V_{h1t}^{n} = \rho_{f1}\alpha_{f1} - \rho_{h1}\beta_{h1}$.[14] A similar set of conditions can be written for the foreign country.

Although reversion to the static Nash-equilibrium tariffs may be credible it is not renegotiation proof in this framework.[15] We will consider more groups of goods being added to the trade agreement in

[14] If both countries planned on deviating in the first period of the agreement, then no firms would ever plan on exporting and welfare in each country would be zero. This static Nash-equilibrium outcome is what would appear as a possible continuation if this game was formulated as a standard prisoners' dilemma. The irreversibility condition implies that this static Nash-equilibrium is not obtainable if one country deviates and cannot be used as an enforcement threat here. On the other hand, this static Nash-equilibrium outcome is the only outcome that is possible if countries cannot use history dependant strategies. As this outcome is clearly inefficient countries we will examine enforceable Pareto superior outcomes.

[15] For more on renegotiation in repeated games see Bernheim and Ray (1989), Farrell and Maskin (1989), and Van Damme (1989). International tariff setting games that employ renegotiation-proof strategies are analyzed by Ludema (2001) and Limão and Saggi (2008).

each successive period, therefore, the possibility of renegotiating punishments after a deviation should be addressed. We adopt Klimenko, Ramey, and Watson's (2008) idea of recurrent trade agreements to our framework.[16] The idea is that countries agree to allow disputes to be settled by a third party that acts with some delay. By turning dispute settlement over to a third party countries effectively tie their hands with respect to renegotiation. When a dispute flares up, both countries simultaneously suspend previously granted concessions and enter a trade war phase. In the trade war both countries act in their own short-term self-interest, knowing that their actions will be ignored once the dispute is settled. Hence, both countries levy Nash tariffs. For countries to be willing to forego the possibility of renegotiation the dispute must be finite. The recurrent trade agreement strategies of Klimenko et al. are not developed for the non-symmetric case or for the imperfectly observable tariffs that we consider here, therefore, our trade agreement strategies, should be considered as being in the spirit of their proposed recurrent trade agreement strategies. As is easily verified, our trade agreement strategies are sub-game perfect. Dispute resolution is, therefore, a delay in re-administering previously allowed concessions. If the countries are in a trade dispute in period *t*, then the probability that the dispute settlement is effective and they resolve the dispute by period *t+1* is given by π so that with probability $(1-\pi)$ the countries remain in a trade dispute in the following period.[17]

We start by describing the supergame payoff functions for group *j* when countries abide by the trade agreement strategies. Given the trade agreement strategies, cooperating yields an expected current and continuation payoff of $G_{ij}^c = V_{ij}^c + \delta\, G_{ij}^c$. The common factor with which both countries discount future payoffs is δ. Solving for G_{ij}^c yields:

$$G_{ij}^c = V_{ij}^c / (1-\delta) \ . \tag{2.4}$$

A deviation yields $V_{ij}^d + \delta\, G_{ij}^w$. The value of the withdrawal of concession stage, G_{ij}^w, also affords a recursive representation and is given by $G_{ij}^w = V_{ij}^n + \delta(\pi\, G_{ij}^c + (1-\pi)\, G_{ij}^w)$. When solved with (2.4) it yields:

$$G_{ij}^w = \frac{\delta\pi V_{ij}^c + (1-\delta)V_{ij}^n}{[1-\delta(1-\pi)][1-\delta]} . \tag{2.5}$$

[16] As the focus of the paper is linking it is important to note that all of our results on static and incremental linking would still obtain if we utilized renegotiation proof strategies. Recurrent trade agreement strategies allow for a clearer presentation notation and a seamless transition from the noiseless to the noisy case.
[17] We could also allow for finite and knowable delays so that the dispute is settled after T periods.

The home country's expected period 1 gain from deviating from the group 1 trade agreement is given by:

$$\Psi_{h11} = V_{h11}^{d} - V_{h11}^{c} = \alpha_{f1} - \theta_{f1}/2 - \theta_{h1}/2 - \tau_{f11}/2 + \tau_{h11}/2. \tag{2.6}$$

The expected future cost triggered by the period 1 deviation is:

$$\Omega_{h11} = \delta(G_{h1}^{c} - G_{h1}^{w}) = \frac{\delta(V_{h1}^{c} - V_{h1}^{n})}{1-\delta(1-\pi)} = \frac{\delta}{1-\delta(1-\pi)}[\theta_{f1}/2 + \theta_{h1}/2 + \tau_{f1t}/2 - \tau_{h1t}/2 - \rho_{f1}\alpha_{f1}] \tag{2.7}$$

If both countries adhere to the trade agreement, then their joint welfare is given by $\frac{\delta}{1-\delta}(V_{h1}^{c} + V_{f1}^{c})$. Given the simple structure of the model non-prohibitive tariffs enter linearly and, after the export decision has been sunk, have no effect on overall welfare along the cooperative path, as long as they are low enough to permit trade. If the social function was modified to include a weight on firm profits that took any value greater than unity, then each country would strictly prefer lower tariffs on its export goods. We, therefore, look for the lowest tariffs that satisfy the incentive constraints that neither country wishes to deviate from the trade agreement:

$$\Psi_{i11} \leq \Omega_{i11},\ i \in \{h, f\}. \tag{2.8}$$

The first thing to notice about the incentive constraints is that they cannot both be satisfied at free trade if $\rho_{f1} = \rho_{h1} = 1$. We state this as Result 1.

Result 1: *If $\rho_{f1} = \rho_{h1} = 1$, then free trade is not self-enforcing for group 1 for both countries.*

All proofs are contained in the appendix. Result 1 is reminiscent of Mayer's (1984) demonstration that free trade may not lie in the core. In the present case, however, it is potential gains from trade and irreversibility that cause a country to become like the "small" country in Mayer's analysis. It is to be expected that irreversibility, or trade partner specificity, reduces a countries bargaining power. On the other hand, it is of interest to note that export goods that provide more gains from trade can also make a country "small" or less powerful when it is combined with irreversibility.

Even when free trade is not self enforcing some level of tariff cooperation is possible as long as the measures of irreversibility are not too high.[18] In this case, the trade agreement will select the lowest

[18] It is straightforward to construct critical discount factors that permit some tariff reductions as well as permit free trade to be immediately self enforcing. These discount factors are functions of the parameters of the model and especially the measure of irreversibility. For any measure of irreversibility the necessary free trade discount factor is larger than the discount factor that permits some tariff reductions.

tariffs that are self-enforcing for each country. What is interesting here is that it will be possible to improve on these initial tariff reductions in later periods. This gradual reduction is possible because the firms' initial irreversible investment changes the costs and benefits of adhering to the agreement. The incentive constraint becomes slack and this permits lower tariffs. We develop this idea in Result 2.

Result 2: *An initial self-enforcing cooperative tariff of* $\tau^{c}_{-i1} > 0$ *can drop in a later period. This drop is more likely if country i's exports are more costly, if their production is more irreversible, or they ascribe a higher value to future payoffs.*

Result 2 may be useful in explaining gradual tariff reductions that are evidenced in successive rounds of negotiations. In the same way it may also explain the gradual tariff reductions that are written into the original agreement. Alternatively, result 2 suggests that even in the absence of future negotiations countries would wish to lower tariffs; therefore, it suggests a rationale for why many observed tariffs are less than their bound level.

Static Linking

We now allow countries to include more groups of goods in the original agreement. The idea here is that the enforcement capacity on one group of goods may generate tariff liberalization in another group of goods. Our first result in this section, however, is a non-result that is similar to the irrelevance result of BW. If all of the tariffs are chosen so that each of the incentive constraints is just binding in the absence of linking, then there is no benefit from linking. Although the deviation cost would increase, the benefit of deviation would increase as well because it would now be advantageous to deviate simultaneously in all markets. The aggregated benefit, therefore, would then still be just equal to the aggregated cost. Hence, if each constraint is just binding separately, then there is no benefit from linking them. Put another way, linking agreements can only increase enforcement capacity and allow for tariff liberalization in a larger group of goods if tariffs are not set at their lowest possible level.

Result 3: *If all tariffs are set at the lowest possible self-enforcing level, then there is no benefit from linking agreements on different groups of goods.*

We now consider the possibility of linking trade agreements when the incentive constraints are not all binding. One rationale for agreements such as these is that countries negotiate tariff reductions at an across the board rate. We follow this idea and assume that this rate is zero. That is, from this point on in the paper, tariff liberalization will imply free trade.[19] Note that for free trade to be self enforcing for at least one group implies, from result 1, that the extent of irreversibility is not too close to unity. In proposition 1 we show that linking groups of goods can generate a greater level of tariff liberalization. In particular, we show that if free trade is not enforceable for one group of goods and it is enforceable with a slack constraint for another group, then it is possible that it is enforceable for both together. We then generalize this result to an arbitrary number of goods.

Proposition 1: *Linking groups of goods in a trade agreement, so that a deviation can be punished by retaliation in all linked groups, can permit tariff liberalization in a larger set of goods.*

With a few small changes it is easy to extend proposition 1 to the case when liberalized tariffs are positive, but still uniform. Additionally, it is straightforward to show that, for any arbitrary number of goods, the lowest uniform tariff that can be enforced if the goods are not linked is greater than the lowest uniform tariff that is self-enforcing when the goods are linked. This occurs because linking with the goods that could enforce lower tariffs and "borrowing" their slack enforcement capability permits a greater degree of tariff reductions in the remaining goods. Proposition 1 and its extensions are not surprising. They are merely an adaptation of BW to our tariff setting framework.

A more novel extension is suggested by the dynamic effect that is highlighted in result 2. Together with proposition 1, it suggests a dynamic interplay between the number of goods that are covered and the depth of liberalization on each good. We build on the idea that past successful liberalizations introduce more slack in the incentive constraints and we consider the possibility that this slack could be taken up by the gradual inclusion of more goods in the agreement.

[19] Our results would obtain with any other uniform tariff choice, but zero tariffs simplify the presentation in two respects. First, zero tariffs un-clutter the notation. Second, if liberalization implies free trade than there is no possibility for further reductions for each group as in result 2. Hence, the cost of deviating is stationary for each group although, as will be seen, the number of groups may increase over time.

Incremental Linking

We now consider how the incentive constraint changes when other groups are to be potentially added to the agreement. We start by assuming that future negotiations are not anticipated in the current period. In this case deviations and trade disputes have no effect on the possibility of future groups being added to the agreement. We start in this way to demonstrate our results in a framework that is as simple as possible. In section 4 we consider the alternative idea, that current deviations and disputes affect the possibility of further liberalization. We show there that all of our results hold in that case subject to some interesting conditions, however, the added complication does generate some additional insights.

In some period after the period 1 costs are sunk, it will be possible to add group 2. We refer to this period as T_2 and we denote it as 2 when used as a time subscript to economize on notation. The gain to deviating to the agreement in period T_2 when the group 2 goods are to be added is:

$$\Psi_{h22} = \alpha_{f1} - \theta_{f1}/2 - \theta_{h1}/2 - \rho_{f1}\beta_{f1} + \alpha_{f2} - \theta_{f2}/2 - \theta_{h2}/2. \tag{2.9}$$

Note that a deviation in the new group will attract immediate retaliation in the existing group 1, therefore, the deviating home country would reduce output in group 1. The incremental change to the gain from deviating from the agreement is:

$$\Psi_{h22} - \Psi_{h11} = \alpha_{f2} - \theta_{f2}/2 - \theta_{h2}/2 - \rho_{f1}\beta_{f1}. \tag{2.10}$$

More generally, the gain from deviating in any period T_J when the group J goods would be added to the agreement is:

$$\Psi_{hJJ} = [\sum_{j=1}^{J-1} \alpha_{fj} - \theta_{fj}/2 - \theta_{hj}/2 - \rho_{fj}\beta\,] + [\alpha_{fJ} - \theta_{fJ}/2 - \theta_{hJ}/2]. \tag{2.11}$$

The incremental gain is given as:

$$\Psi_{hJJ} - \Psi_{h(J\text{-}1)(J\text{-}1)} = \alpha_{fJ} - \theta_{fJ}/2 - \theta_{hJ}/2 - \rho_{f(J\text{-}1)}\beta_{f(J\text{-}1)}. \tag{2.12}$$

As shown in the appendix, the marginal gain to deviating in the incremental linking case is lower than in the static linking case by the amount of the increased irreversible sunk cost committed to in the previous period: $\rho_{f(J\text{-}1)}\beta_{f(J\text{-}1)}$.

Now consider the cost of deviating from the agreement. If another group is to be added to the agreement in period T_2, then home's cost of deviating is:

$$\Omega_{h22} = \tfrac{\delta}{1-\delta(1-\pi)}\,[\theta_{f1}/2 + \theta_{h1}/2 - \rho_{f1}\alpha_{f1} + \rho_{h1}\beta_{h1} + \theta_{f2}/2 + \theta_{h2}/2 - \rho_{f2}\alpha_{f2}]. \tag{2.13}$$

The incremental change in the cost of deviating is:

$$\Omega_{h22} - \Omega_{h11} = \tfrac{\delta}{1-\delta(1-\pi)}\,[\theta_{f2}/2 + \theta_{h2}/2 + \rho_{h1}\beta_{h1} - \rho_{f2}\alpha_{f2}]. \tag{2.14}$$

More generally, the cost of deviating from the agreement in any period T_J is:

$$\Omega_{hJJ} = \tfrac{\delta}{1-\delta(1-\pi)}\,[\textstyle\sum_{j=1}^{J}\theta_{fj}/2+\theta_{hj}/2-\rho_{fj}\alpha_{fj}+\sum_{j=1}^{J-1}\rho_{hj}\beta_{hj}\,]. \tag{2.15}$$

The incremental gain is given as:

$$\Omega_{hJJ} - \Omega_{h(J\text{-}1)(J\text{-}1)} = \tfrac{\delta}{1-\delta(1-\pi)}\,[\theta_{fJ}/2 + \theta_{hJ}/2 + \rho_{h(J\text{-}1)}\beta_{h(J\text{-}1)} - \rho_{fJ}\alpha_{fJ}]. \tag{2.16}$$

In the appendix we demonstrate that the cost to deviating in the incremental case is greater than in the static case by the discounted value of the added irreversible sunk cost $\tfrac{\delta}{1-\delta(1-\pi)}\,\rho_{h(J\text{-}1)}\beta_{h(J\text{-}1)}$.

We are now ready to state our first important result which shows that that more groups can be added to the agreement over time. We proceed in two steps. First we show that past liberalizations introduce slack in the incentive constraint and that this slack allows other groups to be linked. Second, we show that it would have been impossible to link these goods in a static sense and that free trade would not have been enforceable for these goods by themselves. The key to all of these conditions being satisfied is that the production costs and their level of irreversibility are sufficiently high.

Proposition 2: *Incremental linking can add more groups of goods to the trade agreement than static linking. If there exist groups for which free trade cannot be enforced by themselves or if included in the initial trade agreement, then it may become possible to include these groups in later periods. These new additions in turn permit more groups to be added over time. The ability to incrementally add more groups is increasing in the previous groups measures of irreversibility and their sunk costs, the gains from trade of the current group, and the discount factor; it is decreasing in the speed of dispute resolution, and in the cost of the current group.*

Proposition 2 highlights the effect of the previously sunk irreversible costs on generating further tariff liberalization. The effect of the gains from trade is the same in both cases. It is the trade-partner specificity that uniquely distinguishes the static and incremental linking cases. In turn, the irreversible trade-partner specific costs magnify the effect of the discount factor and the speed of dispute resolution on permitting more incremental linking.

It is interesting to compare the contrasting effect of irreversibility as seen in proposition 2 versus that seen in result 1 and proposition 1. On the one hand, proposition 2 shows that these irreversibilities generate more incremental linking. On the other hand, result 1 and proposition 1 show that more irreversibility reduces the ability to initiate trade liberalization. We state these two conflicting effects of irreversibility together in corollary 1.

Corollary 1: *More irreversibility makes it harder to enforce free trade in any one group or any collection of linked groups, however, it makes it easier to link more groups over time.*

Proposition 2 shows that the scope of trade liberalization can increase over time. An alternative possibility is that an initially modest level of tariff liberalization (less than the lowest self-enforcing level) generates an initially broad agreement that encompasses many goods but that is shallow, with small tariff cuts. By result 2, non-zero tariffs could drop over time, and they may drop more if more goods are included in the agreement in the initial period It is of some interest to consider whether initially deep liberalization that is narrowly confined to a few goods, or initially broad but shallow liberalization will eventually generate the greatest level of overall trade liberalization. We leave this question for further research. Instead we add imperfect observability to our model in order to analyze why this incremental liberalization may stop growing and why countries may want to choose to make unlinked agreements.

3. Trade Disputes and Limited Incremental Linking.

Imperfectly Observable Trade Policies

We now include para-tariffs, indirect taxes and the tariff equivalent of these and other non-tariff barriers in our analysis. Although countries negotiate over these trade restrictions they are not perfectly observable and countries cannot be certain of their partner's compliance. We think of the trade agreement as being over the combined level of the observable and unobservable tariffs and in this way we can write τ_{ij} as the combined tariff and we note that this tariff is not perfectly observable. In addition to the imperfectly-observed tariffs, prices may be influenced by imperfectly-observed macroeconomic or preference fluctuations. These fluctuations are represented by the random variables $\{\varepsilon_{ijt}\}$, and reflect the noise inherent in observing a trade partner's policy. They are identically distributed mean zero random variables with cumulative distribution functions, *F,* that satisfy first-order stochastic dominance (FOSD) and densities that are defined over the full support of the distribution. The importer price for good *ij* is given by P_{-ij}. The producer price for good *ij* is then given by $P_{ijt} = P_{-ijt} - \tau_{ijt} - \varepsilon_{ijt}$.

In this uncertain environment low prices arise from unobserved tariff deviations or from macroeconomic or preference fluctuations. The imperfect tariff observability allows countries to deviate from the agreement and blame the stochastic element. For this reason, sufficiently large downturns need to be treated as potential deviations that trigger retaliation. Hence, we adapt our trade agreement strategies to also include a modification of the trigger strategies that were first introduced by Green and Porter (1984). In particular, the trigger is $\tilde{P}_{ij} > 0$ and the probability that the realization of the producer price P_{ijt} is greater than or equal to the trigger value is:

$$\Pr(P_{ijt} \geq \tilde{P}_{ij}) = \Pr(\varepsilon_{ijt} < P_{-ijt} - \tau_{ijt} - \tilde{P}_{ij}) = F(P_{-ijt} - \tau_{ijt} - \tilde{P}_{ij}) = \varphi_{ij}(\tau_{ijt}). \tag{3.1}$$

We use $\varphi_{ij}(\tau_{ijt})$ to denote the cumulative probability that the producer price is greater than the trigger price conditional on the chosen combined observable and unobservable tariff barriers. By the FOSD of *F* we have that the conditional distribution $\varphi_{ij}(\tau_{ijt})$ satisfies FOSD as well so that $\varphi_{ij}(\tau_{ijt})$ is decreasing in τ_{ijt}. We write the free trade cooperative case as $\varphi_{ij}(0) = \varphi_{ij}^c$. The joint probability that both the home and foreign producer prices are above their trigger value is written as:

$$\Phi_j = \Pr(P_{hjt} \geq \tilde{P}_{hj}, P_{fjt} \geq \tilde{P}_{fj}) = \Pr(P_{hjt} \geq \tilde{P}_{hj}) \cdot \Pr(P_{fjt} \geq \tilde{P}_{fj} \mid P_{hjt} \geq \tilde{P}_{hj}). \tag{3.2}$$

The conditional probability $\Pr(P_{fjt} \geq \tilde{P}_{fj} \mid P_{hjt} \geq \tilde{P}_{hj})$ is bounded below by $\varphi_{fj}(\tau_{fjt})$ if the fluctuations are independent and is bounded above by above by unity if they are perfectly correlated. Hence, $\Pr(P_{fjt} \geq \tilde{P}_{fj} \mid P_{hjt} \geq \tilde{P}_{hj}) \in [\varphi_{fj}(\tau_{fjt}), 1]$. Using this fact establishes that $\varphi_{ij}(\tau_{ijt}) \geq \Phi_j \geq \varphi_{fj}(\tau_{fjt}) \cdot \varphi_{hj}(\tau_{hjt})$, and the inequalities are strict unless the fluctuations are perfectly correlated.

In a similar manner we define the joint probability that the home and foreign producer prices are above their trigger values for groups 1 and 2 as:

$$\Phi_{12} = \Pr(P_{h1t} \geq \tilde{P}_{h1}, P_{f1t} \geq \tilde{P}_{f1}, P_{h2t} \geq \tilde{P}_{h2}, P_{f2t} \geq \tilde{P}_{f2}). \tag{3.3}$$

In a manner analogous to the paragraph after equation (3.2) it is straightforward to verify that:

$$\min\{\Phi_1, \Phi_2\} \geq \Phi_{12} \geq \Phi_1 \cdot \Phi_2 \geq \varphi_{f1}(\tau_{f1t}) \cdot \varphi_{h1}(\tau_{h1t}) \cdot \varphi_{f2}(\tau_{f2t}) \cdot \varphi_{h2}(\tau_{h2t}). \tag{3.4}$$

Note that the inequalities are strict unless the fluctuations are perfectly correlated across groups and countries. We write Φ_{1*J} as the joint probability that the home and foreign producer prices are above their values for goods 1 through J and we will write Φ_{1J} as the joint probability for groups 1 and J. When the countries adhere to the free trade agreement, and choose zero tariffs, the probabilities that the producer prices are greater than their trigger values are given by $\Phi^c_{\text{j}} = \Phi_{\text{j}}(0)$ for the good j case and $\Phi^c_{1*J} = \Phi_{1*J}(0)$ for the goods 1 through J case. On the other hand, a deviating tariff of τ^n_{ij} reduces Φ_j from Φ^c_j to $\Phi_j(\tau^d_{-ij}) = \Phi^{id}_j$, where Φ^{id}_j is the probability that neither producer price triggers a trade war, given that country i chose a deviating tariff. Similarly, Φ^c_{1*J} is reduced to Φ^d_{1*J}

If groups 1 through J are covered by the agreement, then a dispute state is signaled in period t (to start in $t+1$) with probability $1-\Phi^c_{1*J}$. If there is no uncertainty, so that the random variables $\varepsilon_{ijt} = 0$ for all t, then $\varphi^c_{ij} = \Phi^c_j = \Phi^c_{1*J} = 1$. Hence, we refer to Φ^c_j and Φ^c_{1*J} as measures of trade stability.

Adapting the trade agreement strategies to this uncertain environment is straightforward. If the trade agreement has been adhered to in the past and no external shock in the previous period triggers a withdrawal of concession stage or if the countries are in a withdrawal of concession stage and the dispute is settled, then each country sets its current tariff according to the trade agreement. After any other history they are in a withdrawal of concession stage awaiting a dispute settlement. Firms have similar strategies. If the countries are not in a dispute stage in period t and if there is no indication that either government intends to deviate from the treaty in the current period, then firms produce according to the expected tariff.

Payoff Functions

We start by describing the supergame payoff functions for group j when countries abide by the trade agreement strategies. The value of abiding by the agreement in some period t is given by:

$$G^c_{ij} = V^c_{ij} + \delta(\Phi^c_j G^c_{ij} + (1-\Phi^c_j)[V^n_{ij} + \delta(\pi G^c_{ij} + (1-\pi)\, G^w_{ij})]). \tag{3.5}$$

The withdrawal of concession stage is the same as in the noiseless case:

$$G^w_{ij} = V^n_{ij} + \delta(\pi G^c_{ij} + (1-\pi)\, G^w_{ij}) \tag{3.6}$$

Solving these two equations simultaneously yields:

$$G_{ij}^{c} = \frac{(1-\delta(1-\pi))V_{ij}^{c} + (1-\Phi_{j}^{c})\delta V_{ij}^{n}}{1-\delta(1+\Phi_{j}^{c}-\pi)+\delta^{2}(\Phi_{j}^{c}-\pi)}; \tag{3.7}$$

$$G_{ij}^{w} = \frac{\delta\pi V_{ij}^{c} + (1-\delta\Phi_{j}^{c})V_{ij}^{n}}{[1-\delta(1+\Phi_{j}^{c}-\pi)+\delta^{2}(\Phi_{j}^{c}-\pi)]}. \tag{3.8}$$

We write $\zeta = [1-\delta(1+\Phi_{j}^{c}-\pi)+\delta^{2}(\Phi_{j}^{c}-\pi)] = [1-\delta(\Phi_{j}^{c}-\pi)][1-\delta]$ and we note that $\zeta \in (0, 1)$. It is straightforward to verify that in the absence of uncertainty, so that $\Phi_{j}^{c} = 1$, equations (3.7) and (3.8) are the same as (2.4) and (2.6).

Given the trade agreement strategies, cooperating yields an expected current and continuation payoff of $V_{ij}^{c} + \delta[\Phi_{j}^{c}G_{ij}^{c} + (1-\Phi_{j}^{c})G_{ij}^{w}]$. A deviation yields expected current and continuation payoffs of $V_{ij}^{d} + \delta[\Phi_{j}^{id}G_{ij}^{c} + (1-\Phi_{j}^{id})G_{ij}^{w}]$. The one period gain from deviating on group j in period t is:

$$\Psi_{ijt} = V_{ij}^{d} - V_{ij}^{c} \tag{3.9}$$

This gain must be balanced against the cost of a future trade war:

$$\Omega_{ijt} = \delta(\Phi_{j}^{c}-\Phi_{j}^{id})(G_{ij}^{c}-G_{ij}^{w}) = \Delta(\Phi, \pi, \delta)(V_{ij}^{c}-V_{ij}^{n}) \tag{3.10}$$

where $\Delta(\Phi, \pi, \delta) = \dfrac{\delta(\Phi_{j}^{c}-\Phi_{j}^{id})}{1-\delta(\Phi_{j}^{c}-\pi)} > 0$. It is straightforward to verify that Δ is increasing in δ and in Φ_{j}^{c}, is decreasing in π, and that $\Phi_{j}^{c}-\Phi_{j}^{id}$ is non-negative and non-decreasing in τ_{-ij}^{d}.

We now consider how $\Delta(\Phi, \pi, \delta)$ changes as more groups are added to the agreement. First note that realized prices are bounded below by zero, therefore, the distributions, F, limit prices to be non-negative.[20] A simple example of a distribution function that satisfies the above assumptions is where $P_{ijt} = P_{-ijt} - \tau_{ijt}$ with probability χ and either 0 or $2P_{ijt}$ each with probability $(1-\chi)/2$. The expectation of P_{ijt} is unbiased and the distribution $\varphi_{ij}(\tau_{ijt})$ satisfies FOSD. Note that any tariff greater than the trade agreement tariff yields an observed price below the cooperative price so that any price lower than this cooperative expected price triggers a trade war phase. Note that in this case $\varphi_{ij}^{c} = (1+\chi)/2$. If we consider one group in each country and assume that the fluctuations are uncorrelated, then when countries adhere to the trade agreement strategies a trade war will start in the next period with probability $(3 - 2\chi - \chi^{2})/4$. If either

[20] If we do not make this assumption, then we could employ the exporting firm's ability to not sell their product at a negative price. In this case, their expected price would be conditional on the price being greater than zero. Although the inclusion of a truncated distribution clutters the analysis, it does not change the results.

country deviates a dispute is triggered with probability 1. For this distribution deviations are revealed with probability one and sometimes cooperation is indistinguishable from a deviation.

We now analyze how $\Phi^{c}_{1*J} - \Phi^{c}_{1*J-1} < \Phi^{id}_{1*J} - \Phi^{id}_{1*J-1}$ changes as more groups are added to the agreement. For the distribution considered in the above paragraph we have that $\Phi^{c}_{1} = (1+\chi)^2/4$ and that $\Phi^{id}_{1} = 0$. If J groups were linked, and if their fluctuations are uncorrelated, then $\Phi^{c}_{1*J} = [(1+\chi)^2/4]^J$ and $\Phi^{id}_{1*J} = 0$. In this case, $\Phi^{c}_{1*J} - \Phi^{c}_{1*J-1} < \Phi^{id}_{1*J} - \Phi^{id}_{1*J-1} = 0$. This inequality holds for any distribution, in the uncorrelated case, as long as $\Phi^{c}_{j} - \Phi^{id}_{j}$ is sufficiently large. More generally, as the following lemma shows, it must hold in the case of uncorrelated fluctuations as long as the number of linked groups is sufficiently large.

Lemma 1: *If the stochastic fluctuations are independently and identically distributed among the groups, then there exists a $\hat{J}$ such that for all $J \geq \hat{J}$ it is true that $\Phi^{c}_{1*J} - \Phi^{c}_{1*J-1} < \Phi^{id}_{1*J} - \Phi^{id}_{1*J-1}$. The critical number of groups, $\hat{J}$, is decreasing in the difference $\Phi^{c}_{j} - \Phi^{id}_{j}$ and in the magnitude of the deviating tariff. If deviations are revealed with probability one then as long as the fluctuations are not perfectly correlated $\hat{J} = 1$.*

Note that for the simple distribution described above, $\Phi^{id}_{j} = 0$ and that τ^{d}_{-ij} is maximal. From the second sentence of lemma 1, both of these push $\hat{J}$ to its minimal value, and as shown above, $\hat{J} = 1$. From lemma 1 we can derive sufficient conditions under which $\Delta(\Phi, \pi, \delta)$ is decreasing as more groups are added to the agreement and we do that in lemma 2.

Lemma 2: *(i.) If deviations are revealed with probability one and the stochastic fluctuations are not perfectly correlated, then $\Delta(\Phi, \pi, \delta)$ is declining in the number of groups, J, added to the agreement. (ii.) If the stochastic fluctuations are i.i.d., then there exists a $\tilde{J} \leq \hat{J}$ such that for all $J \geq \tilde{J}$, $\Delta(\Phi, \pi, \delta)$ is declining in J.*

Static Linking and Trade Disputes

As in the noiseless case we start by considering the incentive constraint for one group by itself. We then consider linking more groups at the same time and then over time. For group j, for the home country in period 1 this implies

$$\Psi_{hj1} = \alpha_{fj} - \theta_{fj}/2 - \theta_{hj}/2 \leq \Delta\, [\theta_{fj}/2 + \theta_{hj}/2 - \rho_{fj}\alpha_{fj}] = \Omega_{hj1} \qquad (3.11).$$

From equation (3.11) zero tariffs are self-enforcing if

$$\delta \geq \frac{2\alpha_{fj} - \theta_{fj} - \theta_{hj}}{(\Phi_j^c(1-\rho_{fj}) + \rho_{fj}\Phi_j^{id})2\alpha_{fj} + (\pi - \Phi_j^{id})(\theta_{fj} + \theta_{hj})} = \delta_{hj}. \qquad (3.12)$$

There are several interesting things to notice about equation (3.12). First, if $\Phi_j^c = 1$ and $\Phi_j^{id} = 0$, then $\delta_{hj} = [2\alpha_{fj} - \theta_{fj} - \theta_{hj}]/[2\alpha_{fj}(1 - \rho_f - \pi) + \pi(\theta_{fj} + \theta_{hj})]$ as in the noiseless case. Second, this critical discount factor is decreasing in Φ_j^c and increasing in ρ_{fj} (because $\Phi_j^c - \Phi_j^{id} > 0$). Furthermore, as long as θ_{hj} is not too much larger than θ_{fj} (or in the symmetric case where they are equal), then an increase in π generates an increase in the critical discount factor. These partial derivatives indicate that greater trade stability, more easily reversible export decisions, and longer expected trade disputes (or less forgiving dispute settlement) make it is easier to enforce free trade.

We now consider the possibility of static linking in this noisy environment where trade disputes occur with probability one. We first show that for two groups 1 and 2 taken separately it is possible that $\delta \geq \delta_{h2} > \delta_{h1}$, but taken together yield a discount factor $\delta_{h12} > \delta$. The key to this last part is that the probability of entering a trade dispute increases when the groups are linked. On the one hand, if the stochastic fluctuations are perfectly correlated, then linking more groups in the trade agreement does not increase the probability of entering a trade dispute and a result similar to that in proposition 2 obtains for the noisy case. On the other hand, as the correlation between the stochastic fluctuations drops, or the number of groups increases, the probability of entering a dispute increases and this in turn will decrease the benefit of linking the groups.

Proposition 3: *If the stochastic fluctuations are perfectly correlated, then linking groups of goods in a trade agreement, so that a deviation can be punished by retaliation in all linked groups, can permit tariff liberalization in a larger set of goods. If the stochastic fluctuations are not perfectly correlated, then there are groups of goods for which trade is self-enforcing separately but not when they are linked together in the trade agreement. If the deviating tariffs are revealed with probability one, then as the correlation in the stochastic fluctuations decreases, linking can enforce free trade in fewer groups. If the stochastic fluctuations are uncorrelated, then there exists a threshold number of groups (which may be as* *low as one) so that as the number of groups exceeds the threshold it becomes progressively harder to enforce free trade for all groups as more groups are added to the agreement.*

Proposition 3 is important because it shows how the inclusion of noise can change the results of BW. Whereas linking cannot be counterproductive in a deterministic environment, the possibility of entering a dispute even when no one deviated can limit the benefit of linking in a stochastic framework. Note that it is never disadvantageous for a noisy group when it is linked to a non-noisy group, however, the non-noisy group would suffer. A more subtle point is that linking is only disadvantageous when the stochastic fluctuations are not perfectly correlated. If they are perfectly correlated, then the same mistake would be made in both groups at the same time whether or not they are linked and, therefore, we are left only with the increased enforcement power of linking and do not suffer the increased dispute initiation effect. In addition, note that as the correlation decreases, the increased dispute initiation effect becomes stronger. In the deterministic BW model, linking becomes more productive as the groups are more different. Noise works in the opposite direction. As the correlations between the groups decreases, linking becomes more detrimental. We state this point below as a corollary of Proposition 3.

Corollary 2: *Noise operates in an opposite manner to all determinist differences which increase the benefit to linking as the difference between the groups increase. The presence of noise does not limit the benefit of linking groups when the stochastic fluctuations are perfectly correlated across groups. As the correlation decreases, so that the groups become more different in this respect, the benefit from linking decreases as well.*

Up until now we have considered that the probability of successful dispute resolution is the same across groups and also that it is the same when the groups are linked. We have no a priori expectation of how these may change, however, it is possible that for some reason that is external to the model $\pi_j \neq \pi_k$. For example, group 2 may require quicker dispute settlement than group 1 (perhaps because group 2 items are necessities and group 1 are luxury items). From equation (3.12) and its multi-group counterpart in the appendix it is evident that a higher probability of dispute settlement makes it harder to enforce free trade (or any cooperative tariff level). A potential problem, therefore, may arise if the probability of dispute settlement in the linked agreement has to correspond to the higher probability of group 2 so that $\pi_1 < \pi_2 = \pi_{12}$. In this case it is again possible that $\delta_{i1} < \delta_{i2} \leq \delta$ when taken separately, however, $\delta_{i12} > \delta$ when linked together.

Incremental Linking and Trade Disputes.

As shown in the previous section, the introduction of noise can limit the number of goods that can be linked in the agreement in the initial period. We now consider the effect of noise on incremental linking. As in the deterministic case analyzed in Proposition 2, we abstract from the horizontal linkage issue and only consider one group to be added to the agreement in each period. This assumption allows us to dispense with many summation symbols in the analysis and it is without loss of generality because we could consider each group as the composite of groups that are added in each period.[21]

The gains from deviating from the agreement are the same as in equations (2.9) through (2.12). The home country's period 1 cost to deviating from the period 1 agreement is:

$$\Omega_{h11} = \Delta(\Phi_1, \pi, \delta)(V_{h1}^c - V_{h1}^n) = \Delta(\Phi_1, \pi, \delta)[\theta_{f1}/2 + \theta_{h1}/2 - \rho_{f1}\alpha_{f1}]. \tag{3.14}$$

If a second group is to be added to the agreement in period T_2, then the cost of deviating is:

$$\Omega_{h22} = \Delta(\Phi_{12}, \pi, \delta)[\theta_{f1}/2 + \theta_{h1}/2 - \rho_{f1}\alpha_{f1} + \rho_{h1}\beta_{h1} + \theta_{f2}/2 + \theta_{h2}/2 - \rho_{f2}\alpha_{f2}]. \tag{3.15}$$

The incremental change in the cost of deviating is:

$$\begin{aligned}\Omega_{h22} - \Omega_{h11} = {} & [\Delta(\Phi_{12}, \pi, \delta) - \Delta(\Phi_1, \pi, \delta)][\theta_{f1}/2 + \theta_{h1}/2 - \rho_{f1}\alpha_{f1}] \\ & + \Delta(\Phi_{12}, \pi, \delta)[\theta_{f2}/2 + \theta_{h2}/2 + \rho_{h1}\beta_{h1} - \rho_{f2}\alpha_{f2}].\end{aligned} \tag{3.16}$$

More generally, the cost of deviating from the agreement in any period T_J where the group J goods would be added to the agreement is:

$$\Omega_{hJJ} = \Delta(\Phi_{1*J}, \pi, \delta)\, [\textstyle\sum_{j=1}^{J} \theta_{fj}/2 + \theta_{hj}/2 - \rho_{fj}\alpha_{fj} + \sum_{j=1}^{J-1} \rho_{hj}\beta_{hj}\,]. \tag{3.17}$$

The marginal change to the cost of deviating is:

$$\Omega_{hJJ} - \Omega_{h(J-1)(J-1)} = [\Delta(\Phi_{1*J}, \pi, \delta) - \Delta(\Phi_{1*J-1}, \pi, \delta)][\textstyle\sum_{j=1}^{J-1} \theta_{fj}/2 + \theta_{hj}/2 - \rho_{fj}\alpha_{fj} + \sum_{j=1}^{J-2} \rho_{hj}\beta_{hj}\,]$$

[21] Note that if we take this approach, then we can treat the αs, βs, and θs as averages, however, the ρs are not strictly averages because they need to be adjusted so that the composite product $\rho\beta$ is equivalent to the original sum of the individual products. As stressed above, and is the core of the paper, the joint probabilities Φ_{jk} are not averages.

$$+ \Delta(\Phi_{1*J}, \pi, \delta)[\theta_{fJ}/2 + \theta_{hJ}/2 + \rho_{h(J-1)}\beta_{h(J-1)} - \rho_{fJ}\alpha_{fJ}]. \tag{3.18}$$

The incremental cost to deviating has two additional terms as compared to the static linking case. First, there is the discounted value of the added irreversible sunk cost $\Delta(\Phi_{1*J}, \pi, \delta)\rho_{h(J-1)}\beta_{h(J-1)}$. This additional cost is comparable to the noiseless case, the difference is that the discount factor is $\Delta(\Phi_{1*J}, \pi, \delta)$ instead of $\frac{\delta}{1-\delta(1-\pi)}$. Second is the change in the discount factor multiplied by the irreversible sunk costs for each of the earlier added goods: $[\Delta(\Phi_{1*J}, \pi, \delta) - \Delta(\Phi_{1*J-1}, \pi, \delta)][\sum_{j=1}^{J-2}\rho_{hj}\beta_{hj}]$. If the fluctuations are perfectly correlated, then this second term is zero. If fluctuations are not perfectly correlated, then by lemma 2, this term is negative for J sufficiently high.

As in the noiseless case, the irreversible sunk costs can generate the ability to incrementally add more groups to the agreement over time that could not be linked in a static sense. The incremental decrease in the gain from deviating is the same in either case. The cost of deviating may be higher or lower, however, in the noisy case. If the fluctuations are perfectly correlated, then the cost is lower in the noisy incremental linking case because $\Delta(\Phi_{1*J}, \pi, \delta) < \frac{\delta}{1-\delta(1-\pi)}$. As the correlation between the fluctuations decrease, $\Delta(\Phi_{1*J}, \pi, \delta)$ is reduced. Furthermore, from lemma 2, if the deviations are revealed with probability one, or if the fluctuations are uncorrelated, then $[\Delta(\Phi_{1*J}, \pi, \delta) - \Delta(\Phi_{1*J-1}, \pi, \delta)]$ becomes negative as J increases. Hence, as the correlations decrease there is less potential for incremental linking. In addition, as more groups are added to the agreement, $\Delta(\Phi_{1*J}, \pi, \delta)$ is reduced so that incremental linking becomes progressively more difficult over time. These points are established formally in the following proposition.

Proposition 4: *If the stochastic fluctuations are perfectly correlated, incremental linking may enforce free trade in more groups than static linking, however, fewer additional groups will be added in the noisy than in the noiseless case. If the stochastic fluctuations are not perfectly correlated, and if the deviating tariffs are perfectly revealed, then free trade is enforced for fewer additional groups by incremental linking in the noisy case than in the noiseless case. If the deviating tariffs are revealed with probability one, then as the correlation between the stochastic fluctuations decreases the level of incremental linking in the noisy case will fall further below the noiseless case. If the deviations are revealed with probability* *one but the stochastic fluctuations are uncorrelated, then there exists a threshold number of groups, $\tilde{\tilde{J}} \leq \tilde{J} \leq \hat{J}$ (which may be as low as one), so that if the number of groups exceeds the threshold there is less incremental linking in the noisy case than in the noiseless case.*

Proposition 4 reinforces the idea that linking does not always enforce more cooperative outcomes when policies are observed with noise. As in the case of static linking, the benefit to incremental linking is increasing in the trade stability measure and in the correlation of the stochastic fluctuations. An unstable environment with uncorrelated shocks yields the smallest measure of incremental linking.

From the proof of proposition 4 it appears possible that noisy incremental linking could even enforce less cooperative outcomes than noisy static linking; however, this claim is not part of the proposition. What we show in the proof to proposition 4 is that the cost to deviating in the noisy incremental linking case is falling in the number of groups previously added to the agreement. We build on this idea in proposition 5 which is an immediate corollary of proposition 4.

Proposition 5: *If the stochastic fluctuations are uncorrelated, or if the stochastic fluctuations are not perfectly correlated and the deviating tariffs are revealed with probability one, then it becomes progressively more difficult to incrementally link groups in the noisy as compared to the noiseless case.*

Putting together propositions 3 through 5 it is evident that the process of incremental liberalization could stop even though there are groups of goods that would benefit from trade liberalization. These may be new groups that were not anticipated when the agreement was originated or they may be established groups for which no agreement was previously reached. Recognizing the benefit of liberalizing trade in these groups countries would want to include them in a trade agreement, however, they would prefer an agreement that is not linked to any previous agreement. Examples of unlinked agreements that are signed by contracting parties to the GATT/WTO are the zero-for-zero agreements covering information technology, financial services, and pharmaceuticals as well as sectors covered in PTAs that are not covered in the WTO. As we show in proposition 6 below these unlinked agreements should be more prevalent if there is more trade instability, if the agreement already contains many groups, or if the stochastic fluctuations are less correlated.

Proposition 6: *If the measure of trade stability is lower, the stochastic fluctuations are less correlated, and/or the number of already covered groups is greater, then countries will not link liberalization in new groups and these new groups will be covered by unlinked agreements.*

Proposition 6 predicts that we will see more zero-for-zero agreements as time progresses. It also yields the empirical prediction that they would be more common for groups whose price fluctuations are less correlated with overall macroeconomic fluctuations. It is interesting to note that both of these conditions would seem to be met for the information technology and pharmaceutical zero-for-zero agreements. An additional implication of proposition 6 is that countries may choose unlinked liberalization in certain groups by the use of selective preferential trading arrangements.

4. Anticipated Incremental Linking

Anticipatory Trade Agreement Strategies.

We now consider that future negotiations are anticipated by the participants in the trade agreement and we analyze the effects of disputes on the probability of adding other groups in subsequent periods. It would be straightforward to derive conditions in the anticipatory case so that our previous results hold, however, it is more interesting to analyze how anticipatory strategies would strengthen and weaken the previous results. The sufficient conditions that ensure that all of the previous results obtain are clear from this analysis. We then use the derivations behind this analysis to suggest further results.

We begin by noting that while they are engaged in a current dispute countries will never add additional groups by incremental linking that they could not add by static linking. The intuition is straightforward. The previously sunk irreversible trade partner specific costs are what permit incremental linking of groups for which static linking did not enforce free trade. During a dispute the revenues to cover these costs are already sacrificed and there is nothing further to lose, therefore, they do not enter the deviation decision calculus. Hence, countries need to wait for a trade dispute to end before they can consider incrementally adding additional groups. Note as well that if countries can choose when to add an additional group, then they will want to do so as soon as possible. After the irreversible investments have been made for group 1, countries will want to link group 2 in period 2 as long as they are not in a dispute in period 2. If they are in a dispute, then they need to wait until the dispute is finished before incrementally linking group 2.

To fix ideas, start by assuming that there are only two possible groups. If countries adhere to the cooperative path in period 1, and if it would be possible to add group 2 in the subsequent period, then the value of adhering to the agreement in period 1 is:

$$\Gamma_{i1} = G_{i1}^{c} + \delta[\,\Phi_{1}^{ic}\; G_{i2}^{c} + (1-\Phi_{1}^{ic})[0+\delta(\pi\, G_{i2}^{c} + (1-\pi)[0+\delta(\pi\, G_{i2}^{c} + (1-\pi)[0+\delta(\pi\, G_{i2}^{c} + (1-\pi)\cdots$$

$$= G_{i1}^{c} + \delta\, G_{i2}^{c}\,[\,\Phi_{1}^{ic} + (1-\Phi_{1}^{ic})[\delta\pi + (1-\pi)\delta^{2}\pi + (1-\pi)^{2}\delta^{3}\pi + (1-\pi)^{3}\delta^{4}\pi + \cdots$$

$$= G_{i1}^{c} + \delta\, G_{i2}^{c}\,[\,\Phi_{1}^{ic} + (1-\Phi_{1}^{ic})[\delta\pi \sum_{t=0}^{\infty} \delta^{t}(1-\pi)^{t}\;]$$

$$= G_{i1}^{c} + \delta\, G_{i2}^{c}\,[\,\Phi_{1}^{ic} + (1-\Phi_{1}^{ic})(\tfrac{\delta\pi}{1-\delta(1-\pi)})]. \tag{4.1}$$

More generally, when there are many possible incremental linkages, we use Γ_{ij} to denote the value of adhering to the agreement in the period when it is first possible to add group j. Hence, for group 1 in the many good case we have:

$$\Gamma_{i1}^{c} = G_{i1}^{c} + \delta\,\Gamma_{i2}^{c}\,[\,\Phi_{1}^{ic} + (1-\Phi_{1}^{ic})(\tfrac{\delta\pi}{1-\delta(1-\pi)})]. \tag{4.2}$$

Similarly, for group J we can write:

$$\Gamma_{iJ}^{c} = \sum\nolimits_{j=1}^{J} G_{ij}^{c} + \delta\,\Gamma_{i(J+1)}^{c}\,[\,\Phi_{1*J}^{ic} + (1-\Phi_{1*J}^{ic})(\tfrac{\delta\pi}{1-\delta(1-\pi)})]. \tag{4.3}$$

In the noiseless case $\Phi_{1*J}^{ic} = 1$ and $\Gamma_{iJ}^{cL} = \sum\nolimits_{j=1}^{J} G_{ij}^{c} + \delta\Gamma_{i(J+1)}^{cL}$, where we use L to differentiate the noiseless case. The value of the withdrawal of concession stage now can also be modified to include its effect on delaying liberalization in other groups. For group 1 it is written as:

$$\Gamma_{i1}^{w} = V_{i1}^{w} + \delta(\pi\,\Gamma_{i2}^{c} + (1-\pi)\,\Gamma_{i1}^{w}) \tag{4.4}$$

If dispute settlement is effective, then group 2 can be linked in the following period. In the noiseless case we would write Γ_{i2}^{cL} in place of Γ_{i2}^{c}. A withdrawal of concession stage triggered while there is free trade in groups 1 though J is written as $\Gamma_{iJ}^{w} = \sum\nolimits_{j=1}^{J} V_{ij}^{w} + \delta(\pi\,\Gamma_{i(J+1)}^{c} + (1-\pi)\,\Gamma_{iJ}^{w})$ or:

$$\Gamma_{iJ}^{w} = \tfrac{1}{1-\delta(1-\pi)}\,(\sum\nolimits_{j=1}^{J} V_{ij}^{w} + \delta\pi\Gamma_{i(J+1)}^{c}) \tag{4.5}$$

Given the anticipatory trade agreement strategies, cooperating in period T_J yields an expected current and continuation payoff of $\sum_{j=1}^{J} V_{ij}^{c} + \delta[\Phi_{1*J}^{c}\Gamma_{i(J+1)}^{c} + (1-\Phi_{1*J}^{c})\Gamma_{iJ}^{w}]$. A deviation yields expected current and continuation payoffs of $\sum_{j=1}^{J} V_{ij}^{d} + \delta[\Phi_{1*J}^{d}\Gamma_{i(J+1)}^{c} + (1-\Phi_{1*J}^{d})\Gamma_{iJ}^{w}]$. The one period gain from deviating in the anticipatory (with superscript *A*) agreement in period T_J is the same as in sections 2 and 3:

$$\Psi_{iJJ}^{A} = \sum_{j=1}^{J} V_{ij}^{d} - V_{ij}^{c} \tag{4.6}$$

Anticipatory strategies, therefore, only matter through their effect on the cost of the future trade war:

$$\Omega_{iJJ}^{A} = \delta(\Phi_{1*J}^{c} - \Phi_{1*J}^{d})(\Gamma_{i(J+1)}^{c} - \Gamma_{iJ}^{w}) = \tfrac{\delta}{1-\delta(1-\pi)}(\Phi_{1*J}^{c} - \Phi_{1*J}^{d})[(1-\delta)\Gamma_{i(J+1)}^{c} - \sum_{j=1}^{J} V_{ij}^{n}]. \tag{4.7}$$

It is straightforward to verify that equation (4.7) is identical to (3.17) if no future groups are anticipated to be linked to the agreement.

Anticipatory Trade Agreements Without Noise

In the absence of noise, equation (4.7) can be rewritten as:

$$\Omega_{iJJ}^{AL} = \tfrac{\delta}{1-\delta(1-\pi)}[(1-\delta)\Gamma_{i(J+1)}^{cL} - \sum_{j=1}^{J} V_{ij}^{n}]. \tag{4.8}$$

The incremental change in the noiseless case is:

$$\Omega_{iJJ}^{AL} - \Omega_{i(J-1)(J-1)}^{AL} = \tfrac{\delta}{1-\delta(1-\pi)}[(1-\delta)(\Gamma_{i(J+1)}^{cL} - \Gamma_{iJ}^{cL}) - V_{iJ}^{n}] =$$

$$\tfrac{\delta}{1-\delta(1-\pi)}[\theta_{fJ}/2 + \theta_{hJ}/2 + \rho_{h(J-1)}\beta_{h(J-1)} - \rho_{fJ}\alpha_{fJ}] + \tfrac{\delta}{1-\delta(1-\pi)}[(V_{i(J+1)}^{c} - V_{iJ}^{c}) + \delta(1-\delta)(\Gamma_{i(J+2)}^{cL} - \Gamma_{i(J+1)}^{cL})]. \tag{4.9}$$

The first expression in (4.9) is the same as (2.14) in the un-anticipatory case. The second term is the change in the cost of deviating that occurs only in the anticipatory case. The difference between incremental linking in the anticipatory and un-anticipatory cases depend on the signs of $V_{i(J+1)}^{c} - V_{iJ}^{c}$ and of $\delta(1-\delta)(\Gamma_{i(J+2)}^{cL} - \Gamma_{i(J+1)}^{cL})$. If each group has the same gains from trade, then $V_{i(J+1)}^{c} - V_{iJ}^{c} = 0$. Otherwise, it would generate more (less) incremental linking if $V_{i(J+1)}^{c} > (<) V_{iJ}^{c}$. This is reasonable: If countries anticipate incrementally adding groups with more gains from trade than the present group, then it would raise the cost of a current deviation and permit more linking in the current period.

The second part of the second term $\delta(1-\delta)(\Gamma_{i(J+2)}^{cL} - \Gamma_{i(J+1)}^{cL})$ can be rewritten as $\delta(1-\delta)[\Gamma_{i(J+2)}^{cL}(1-\delta) - \sum_{j=1}^{J+1} G_{ij}^{c}]$. This second part depends on the number of groups already in the agreement and the potential number of groups to be added. If more groups are already covered by the agreement, then it pushes this second part towards being negative. More importantly, if there are fewer potential groups to be added to the agreement then it also pushes this part towards being negative. This second part is similar to the first part – if the agreement is expected to grow in value in the future, then it would increase the current benefit to incremental linking. Hence, there would be more or less incremental linking in the anticipatory case than in the un-anticipatory case depending on the expectation of the value of future linkages, the number of future linkages, and the number of current linkages.

The previous paragraph suggests a type of bicycle effect that could serve as an additional rationale for the rise of non-linked agreements. If countries do not anticipate many more groups to be added to the agreement (that is, pretty soon no one will be pedaling the bicycle forward), then it becomes less possible to incrementally link some currently available groups to the agreement and countries may choose to liberalize trade in these groups by the use of unlinked agreements.

Anticipatory Trade Agreements With Noise

We now return to the noisy case in anticipatory trade agreements. Using equation (4.7) we see that the incremental change in the cost of deviating is:

$$\Omega^A_{iJJ} - \Omega^A_{i(J-1)(J-1)} = [\Delta(\Phi_{1*J}, \pi, \delta) - \Delta(\Phi_{1*J-1}, \pi, \delta)][\sum_{j=1}^{J-1} \theta_{fj}/2 + \theta_{hj}/2 - \rho_{fj}\alpha_{fj} + \sum_{j=1}^{J-2} \rho_{hj}\beta_{hj}] +$$
$$\Delta(\Phi_{1*J}, \pi, \delta)[\theta_{fJ}/2 + \theta_{hJ}/2 + \rho_{h(J-1)}\beta_{h(J-1)} - \rho_{fJ}\alpha_{fJ}] +$$
$$\tfrac{\delta}{1-\delta(1-\pi)}(\Phi^c_{1*J} - \Phi^d_{1*J})[G^c_{i(J+1)}(1-\delta) + \tfrac{\delta}{1-\delta(1-\pi)}(\Phi^c_{1*(J+1)}[1-\delta] + \delta\pi)\Gamma^c_{i(J+2)}] -$$
$$\tfrac{\delta}{1-\delta(1-\pi)}(\Phi^c_{1*(J-1)} - \Phi^d_{1*(J-1)})[G^c_{iJ}(1-\delta) + \tfrac{\delta}{1-\delta(1-\pi)}(\Phi^c_{1*J}[1-\delta] + \delta\pi)\Gamma^c_{i(J+1)}]\,. \tag{4.10}$$

The first two terms in (4.10) are the same as in the un-anticipatory case. The final two terms are what distinguishes the anticipatory noisy case. Note that if there is no noise, then they are the same as the second term in (4.9). We begin our analysis of the noisy case by studying the case when the fluctuations are perfectly correlated so that (4.10) becomes:

$$\Omega^A_{iJJ} - \Omega^A_{i(J-1)(J-1)} = \Omega_{iJJ} - \Omega_{i(J-1)(J-1)} +$$
$$\tfrac{\delta}{1-\delta(1-\pi)}(\Phi^c - \Phi^d)[(G^c_{i(J+1)} - G^c_{iJ})(1-\delta) + \tfrac{\delta}{1-\delta(1-\pi)}(\Phi^c[1-\delta] + \delta\pi)(\Gamma^c_{i(J+2)} - \Gamma^c_{i(J+1)})]\,. \tag{4.11}$$

It is easy to compare (4.11) to the noiseless case as in (4.9). In particular, the second line in (4.11) has roughly the same two terms. The term $G^c_{i(J+1)} - G^c_{iJ}$ adds (subtracts) from the benefit of incremental linking if the next linked group is expected to have more (less) gains from trade than the current group.

Similarly, the sign of the expression $\Gamma^c_{i(J+2)} - \Gamma^c_{i(J+1)}$ depends on how many groups are currently covered by the agreement and how many could be linked in the future. Both of these terms are smaller than their noiseless case counterpart. If $\Phi^c - \Phi^d = 1$, then the second line of (4.11) is the same as the second term of (4.9). As the measure of trade stability, Φ^c, is reduced the second line falls below the second term in (4.9). Hence, we see that noise reduces the benefit of incremental linking in the anticipatory case as well.

When the fluctuations are not perfectly correlated we begin by noting that $\Phi^c_{1*(J-1)} > \Phi^c_{1*J} > \Phi^c_{1*(J+1)}$. If $\Phi^d_j = 0$, or (using lemma 1) if the fluctuations are uncorrelated and $J \geq \hat{J}$, then $\Phi^c_{1*J} - \Phi^d_{1*J} < \Phi^c_{1*(J-1)} - \Phi^d_{1*(J-1)}$ as well. Using these facts and examining the third and fourth line of (4.10) shows that their difference is less than the case of perfectly correlated fluctuations as seen in (4.11). Furthermore, as the correlation drops or as the number of groups increases the third minus the fourth line of (4.10) will also drop. Hence, in the anticipatory, as in the un-anticipatory, case, noise reduces the benefit of incremental over static linking. Furthermore, as the noise increases, the correlations between the fluctuations decreases, and/or the number of already linked groups increases, the potential for enforcing free trade in a group by an incremental link when it could not be enforced with a static link falls. We have already seen that in the presence of noise static links may enforce less free trade than unlinked agreements so in the anticipatory case countries may again choose unlinked zero-for-zero agreements. In the case of anticipatory strategies the number of groups becomes even more important and the number of remaining potential links turns out to be an important factor. Finally note that the anticipatory case with noise also yields the previously mentioned bicycle effect that further generates the formation of unlinked agreements.

5. Conclusion

We explain the broadened scope of the GATT/WTO through successive rounds of trade liberalization as a result of incremental linking. In more recent years, however, countries have pursued trade liberalization through sector specific zero-for-zero agreements and preferential trade agreements, both of which have a reduced chance of suffering cross retaliation. This increase in unlinked agreements is explained by imperfect observability of trade policies generating gratuitous trade disputes and unjustified cross retaliation. If the dispute generating noise is perfectly correlated across sectors, however, then it provides no reason not to link agreements in a static sense and in many cases incremental linking still generates more liberalization than static linking. It is only when the noise is imperfectly correlated that linking and cross retaliation are problematic so that some sectors can enforce more liberalization in an unlinked agreement. If the correlation drops, the noise increases, or the number of sectors already covered is large, then incremental linking of more sectors is inefficient and countries pursue unlinked agreements.

References:

Alessandria, George, Joseph Kaboski, and Virgiliu Midrigan, 2008. "Inventories, Lumpy Trade, and Large Devaluations," NBER Working Paper 13790. February, 2008.

Abreu, Dilip., David Pearce, and Ennio Stacchetti, 1990. "Toward a Theory of Discounted Repeated Games with Imperfect Monitoring," *Econometrica*, 58:5, pp. 1041-1063.

Bagwell, Kyle and Robert W. Staiger, 1990. "A Theory of Managed Trade," *American Economic Review*, vol. 80, September 1990, pp. 779-795 .

Bagwell, Kyle and Robert W. Staiger, 1999. "An Economic Theory of GATT," *American Economic Review* 89, pp. 215-248.

Bagwell, Kyle and Robert W. Staiger, 2002. *The Economics of the World Trading System.* Cambridge, MA: MIT Press.

Bagwell, Kyle and Robert W. Staiger, 2005. "Enforcement, Private Political Pressure and the GATT/WTO Escape Clause," *The Journal of Legal Studies*, 34:2, pp. 471-513.

Baldwin, Richard, 2006. "Multilateralising Regionalism: Spaghetti Bowls as Building Blocs on the Path to Global Free Trade," *The World Economy*, vol. 29(11), pages 1451-1518, November.

Baldwin, Robert and Paul Krugman, 1989. "Persistent Trade Effects of Large Exchange Rate Shocks," *Quarterly Journal of Economics,* 104:4, pp. 635-654.

Bernheim, B. Douglas, and Ray, Debraj, 1989. "Collective Dynamic Consistency in Repeated Games," *Games and Economic Behavior,* 1, pp. 295–326.

Bernheim, B. Douglas, and Whinston, Michael D, 1990. "Multimarket Contact and Collusive Behavior," *RAND Journal of Economics*, 21 (1), pp. 1–26.

Bond, Eric and Jee-Hyeong Park, 2002. "Gradualism in Trade Agreements with Asymmetric Countries," *The Review of Economic Studies*, Vol. 69, Issue 2, pp. 379-406, April 2002.

Chen, Maggie X. and Aaditya Mattoo, 2006. "Regionalism in Standards: Good or Bad for Trade?" World Bank working paper #3458

Chisik, Richard, 2003. "Gradualism in Free Trade Agreements: A Theoretical Justification," *Journal of International Economics,* 59:2, March 2003, pp. 367-397.

Chisik, Richard, 2009. "Trade Disputes, Quality Choice, and Economic Integration," FIU Working Paper, 09-01.

Conconi, Paola and Perroni, Carlo, 2002. "Issue linkage and issue tie-in in multilateral negotiations," *Journal of International Economics*, 57(2), pp. 423-447.

Das, Sanghamitra, Mark Roberts, and James Tybout, 2007. "Market Entry Costs, Producer Heterogeneity and Export Dynamics," *Econometrica*, 75:3, pp. 837-873.

Devereux, Mick, 1997. "Growth, Specialization, and Trade Liberalization," *International Economic Review*, 38:3, pp. 565-585, August 1997.

Dixit, Avinash, 1987. "Strategic Aspects of Trade Policy." In Truman F. Bewley, ed., *Advances in Economic Theory: Fifth World Congress*. Cambridge: Cambridge University Press, 1987, pp. 329-62.

Dixit, Avinash, 1989. "Entry and Exit Decisions under Uncertainty," *Journal of Political Economy,* 97:3, pp. 620-638.

Eaton, Jonathan, Samuel Kortum, and Francis Kramarz, 2006. "An Anatomy of International Trade: Evidence from French Firms." University of Minnesota, mimeograph.

The Economist, 2006. "Least Favoured Nation," August 5-11, 2006.

Ederington, Josh, 2001. "International Coordination of Trade and Domestic Policies," *American Economic Review* 91, pp. 1580–1593.

Ederington, Josh, 2002. "Trade and Domestic Policy Linkage in International Agreements," *International Economic Review* 43, pp. 1347–1368.

Ederington, Josh, 2003. "Policy Linkage and Uncertainty in International Agreements," *Economic Inquiry* 41, pp. 305–317.

Eichengreen, Barry and Douglas A. Irwin, 1996. "The Role of history in Bilateral Trade Flows," NBER Working Paper 5565.

Farrell, Joseph and Maskin, Eric, 1989. "Renegotiation in Repeated Games," *Games and Economic Behavior,* 1, pp. 327–360.

Furusawa, Taiji and Edwin Lai, 1999. "Adjustment Costs and Gradual Trade Liberalization," *Journal of International Economics*, 49:2, pp. 333-361, December 1999.

Green, Edward and Robert Porter, 1984. "Noncooperative Collusion under Imperfect Price Information," *Econometrica,* 52:1, pp. 87-100.

Hoekman, Bernard M. & Michel M. Kostecki. 2001. *The Political Economy of the World Trading System*. 2nd ed. New York: Oxford University Press.

Hungerford, Thomas, 1991. "GATT: A Cooperative Equilibrium in a Noncooperative Trading Regime?" *Journal of International Economics*, 31:3-4, pp. 357- 369.

Klimenko, Mikhail, Garey Ramey and Joel Watson, 2008. "Recurrent Trade Agreements and the Value of External Enforcement," *Journal of International Economics* 74, pp. 475–499.

Lapan, Harvey, 1988. "The Optimal Tariff, Production Lags, and Time Consistency," *American Economic Review*, 78:3, pp. 395-401.

Lee, Gea M., 2007. "Trade Agreements with Domestic Policies As Disguised Protection," *Journal of International Economics*, 71:1, pp. 241-59.

Ludema, Rodney, 2001. "Optimal International Trade Agreements and Dispute Settlement Procedures," *European Journal of Political Economy*, 17, pp. 355-376.

Maggi, Giovanni and Andrés Rodríguez-Clare, 2007. "A Political-Economy Theory of Trade Agreements," *American Economic Review*, vol. 97(4), pages 1374-1406, September.

Martin, Alberto and Wouter Vergote, 2008. "On the Role of Retaliation in Trade Agreements," *Journal of International Economics*, vol. 76(1), pages 61-77, September.

Matsushima, Hitoshi, 2001. "Multimarket Contact, Imperfect Monitoring, and Implicit Collusion," *Journal of Economic Theory*, 98, pp. 158–178.

Mayer, Wolfgang, 1981. "Theoretical Considerations on Negotiated Tariff Adjustments," *Oxford Economics Papers*, 33:1, pp.135-153, March 1981.

McLaren, John, 1997. "Size, Sunk Costs, and Judge Bowker's Objection to Free Trade," *American Economic Review*, 87:3, pp. 400-420.

Nuno, Limao**,** 2005. "Trade Policy, Cross-border Externalities and Lobbies: Do Linked Agreements Enforce More Cooperative Outcomes?" *Journal of International Economics*, 67(1), pp. 175-199.

Nuno Limão, and Kamal Saggi, 2008. "Tariff Retaliation Versus Financial Compensation in the Enforcement of International Trade Agreements," *Journal of International Economics*, 76, pp. 48–60.

Onder, Harun, 2009. "Starting Small in Free Trade Agreements," FIU working paper 09-05.

Park, Jee-Hyeong, 2006. "Private Trigger Strategies in the Presence of Concealed Trade Barriers," Seoul National University, mimeograph.

Riezman, Raymond, 1991. "Dynamic Tariffs with Asymmetric Information." *Journal of International Economics*, 30:3-4, pp. 267-83.

Staiger, R., "A Theory of Gradual Trade Liberalization," in J. Levinsohn, A. Deardorff, and R. Stern (eds.) *New Directions in Trade Theory*, Ann Arbor, MI: University of Michigan Press; 1995, pp.249-284.

Thomas, Charles J and Robert D. Willig, 2006. "The Risk of Contagion from Multimarket Contact," *International Journal of Industrial Organization*, 24, pp. 1157–1184.

Van Damme, Eric, 1989. "Renegotiation-Proof Equilibria in Repeated Prisoners' Dilemma," *Journal of Economic Theory*, 47, pp. 206-217.

World Trade Organization, 2008. "WTO Dispute Settlement: Legal Text. Understanding on Rules and Procedures Governing the Settlement of Disputes," Annex 2 of the WTO Agreement, 2008.

Zissimos, Ben, 2007. "The GATT and Gradualism," *Journal of International Economics*, vol. 71(2), pages 410-433, April.

Appendix

Proof of Result 1: First consider the symmetric case so that $\alpha_{f1} = \alpha_{h1} = \alpha_1$, $\beta_{f1} = \beta_{h1} = \beta_1$, and $\rho_{f1} = \rho_{h1} = \rho_1$. In this case, the incentive constraints each require that $\frac{\delta}{1-\delta(1-\pi)}(\theta_1 - \rho_1\alpha_1) \geq \alpha_1 - \theta_1$. Noting that $\theta_{ij} \leq \alpha_{ij}$ for each good implies that this condition could not be satisfied when $\rho_1 = 1$. In the non-symmetric case, if country i's group 1 goods generate less gains from trade so that $\theta_{i1} < \theta_{-i1}$, then zero tariffs are not self enforcing for country i.□

Proof of Result 2: Consider, without loss of generality, the home country. From equations (2.6) and (2.7) we see that that Ψ_{h11} is continuous and strictly decreasing in its import tariff, τ_{f1t}, and that Ω_{h11} is continuous and strictly increasing in τ_{f1}. Hence, there exists a τ^c_{f1} such that $\Psi_{h11} = \Omega_{h11}$ at τ^c_{f1} and $\Psi_{h11} > \Omega_{h11}$ for all $\tau_{f1} > \tau^c_{f1}$. In period $t > 1$ the incentive constraint becomes:

$\Psi_{h1t} = \alpha_{f1} - \theta_{f1}/2 - \tau^c_{f1}/2 \leq \frac{\delta}{1-\delta(1-\pi)}[\theta_{f1}/2 + \theta_{h1}/2 + \tau^c_{f1}/2 - \tau^c_{h1}/2 - \rho_{f1}\alpha_{f1} + \rho_{h1}\beta_{h1}] = \Omega_{h1t}$. This change introduces slack in the constraint and permits τ^c_{f1} to drop at least once if

$\Psi_{h1t} - \Psi_{h11} = \theta_{h1}/2 - \tau^c_{h1}/2 < \frac{\delta}{1-\delta(1-\pi)}\rho_{h1}\beta_{h1} = \Omega_{h1t} - \Omega_{h11}$, or if $\delta > (\theta_{h1} - \tau^c_{h1})/[(1-\pi)(\theta_{h1} - \tau^c_{h1}) + 2\rho_{h1}\beta_{h1}]$.

Hence, a tariff reduction is more likely if δ, ρ_{h1}, and/or β_{h1} are higher or π is lower. □

Proof of Result 3: If the τ^c_{ij} are chosen so that $\Omega_{ij1} = \Psi_{ij1}$ for all i and j, then aggregating enforcement capacity and deviation incentives yields deviation costs and benefits of $\sum_j \Omega_{ij1} = \sum_j \Psi_{ij1}$.□

Proof of Proposition 1: Rewriting the home country's period 1 incentive constraints for the case when tariff liberalization means that tariffs drop to zero at the outset of the agreement yields:

$$\Psi_{hj1} = \alpha_{fj} - \theta_{fj}/2 - \theta_{hj}/2 \leq \frac{\delta}{1-\delta(1-\pi)}[\theta_{fj}/2 + \theta_{hj}/2 - \rho_{fj}\alpha_{fj}] = \Omega_{hj1}. \quad \text{(A.1)}$$

For each good j we can, therefore, solve for a critical discount factor δ_{hj}, such that zero tariffs are self-enforcing if $\delta \geq \dfrac{2\alpha_{fj} - \theta_{fj} - \theta_{hj}}{2\alpha_{fj}(1-\rho_{fj}-\pi)+\pi(\theta_{fj}+\theta_{hj})} = \delta_{hj}$. We now show that for two groups 1 and 2 taken separately it is possible that $\delta_{h2} > \delta > \delta_{h1}$, but taken together yields a discount factor $\delta_{h12} \leq \delta$. The critical discount factor, δ_{h12}, is given by the incentive constraint $\Psi_{h11} + \Psi_{h21} \leq \Omega_{h11} + \Omega_{h21}$. For these two groups together, zero tariffs are self-enforcing if $\delta \geq \dfrac{\sum_{j=1}^{2} 2\alpha_{fj} - \theta_{fj} - \theta_{hj}}{\sum_{j=1}^{2}(2\alpha_{fj}(1-\rho_{fj}-\pi)+\pi(\theta_{fj}+\theta_{hj}))} = \delta_{h12}$. Rewriting δ_{h2} as A/B and δ_{h1} as C/D, we have $\delta_{h12} = (A + C)/(B + D)$. It is then straightforward to verify that $\delta_{h2} > \delta_{h1}$ implies that $\delta_{h2} > \delta_{h12} > \delta_{h1}$. Hence, for all δ such that $\delta_{h2} > \delta \geq \delta_{h12} > \delta_{h1}$ the result obtains for zero tariffs in the two group case. Next consider a group of goods 1 through N such that zero tariffs are self enforcing for this group, but not for group $N + 1$. Writing the critical discount factor for N linked groups as δ_{h1*N} and proceeding in the same way as above it is immediate to see that $\delta_{hN+1} > \delta_{h1*N+1} > \delta_{h1*N}$ so that for all δ such that $\delta_{hN+1} > \delta \geq \delta_{h1*N+1}$ the result obtains. □

Proof of Proposition 2: Adapting the proof of result 2 to the case when J – 1 goods have been added to the agreement and evaluating the constraint at free trade we see that slack is introduced in the incentive constraint if $\Psi_{h(J\text{-}1)t} - \Psi_{h(J\text{-}1)(J\text{-}1)} = \theta_{hJ\text{-}1}/2 < \frac{\delta}{1-\delta(1-\pi)} \rho_{hJ}\beta_{hJ\text{-}1} = \Omega_{h(J\text{-}1)t} - \Omega_{h(J\text{-}1)(J\text{-}1)}$, or if

$\delta > \theta_{hJ\text{-}1}/[(1-\pi)\theta_{hJ\text{-}1} + 2\rho_{hJ\text{-}1}\beta_{hJ\text{-}1}]$ so that slack is more likely to be introduced if δ, $\rho_{hJ\text{-}1}$, and/or $\beta_{hJ\text{-}1}$ are higher, or if π is lower. Consider now the case of group j. From equation (A.1) we see that, by itself, free trade is enforceable for this group if $\Psi_{hjj} = \alpha_{fj} - \theta_{fj}/2 - \theta_{hj}/2 \leq \frac{\delta}{1-\delta(1-\pi)} [\theta_{fj}/2 + \theta_{hj}/2 - \rho_{fj}\alpha_{fj}] = \Omega_{hjj}$. From proposition 1 it is possible that this equation is not satisfied by itself, however, free trade can be enforced when statically linked with other groups. Note that $\Psi_{hj(j\text{-}1)} - \Psi_{h(j\text{-}1)(j\text{-}1)} = \Psi_{hjj}$ and $\Omega_{hj(j\text{-}1)} - \Omega_{h(j\text{-}1)(j\text{-}1)} = \Omega_{hjj}$ are also the marginal changes to the static case incentive constraint when adding group j in period $j - 1$ before the $j - 1$ investments are sunk. Hence, if the static constraint binds with equality for groups $j - 1$, then it would not be possible to add this group j in the period $j - 1$. The marginal changes in the incremental incentive constraint are given in equations (2.12) and (2.16) as $\Psi_{hJJ} - \Psi_{h(J\text{-}1)(J\text{-}1)} = \alpha_{fJ} - \theta_{fJ}/2 - \theta_{hJ}/2 - \rho_{f(J\text{-}1)}\beta_{f(J\text{-}1)}$ and $\Omega_{hJJ} - \Omega_{h(J\text{-}1)(J\text{-}1)} = \frac{\delta}{1-\delta(1-\pi)} [\theta_{fJ}/2 + \theta_{hJ}/2 + \rho_{h(J\text{-}1)}\beta_{h(J\text{-}1)} - \rho_{fJ}\alpha_{fJ}]$. The marginal gain to deviating in the incremental case is less than in static case by the increased irreversible sunk cost: $\rho_{f(J\text{-}1)}\beta_{f(J\text{-}1)}$. The incremental cost to deviating is more than in the static case by the discounted value of the added irreversible sunk cost $\frac{\delta}{1-\delta(1-\pi)} \rho_{h(J\text{-}1)}\beta_{h(J\text{-}1)}$. Incremental linking can, therefore, link more groups than static linking and its ability to link groups that static cannot link is increasing in ρ and β. Examination of equations (2.12) and (2.16) reveals the remainder of the comparative static predictions.□

Proof of Lemma 1: If $\Phi_j^{id} = 0$, then $\Phi_{1*J}^{c} - \Phi_{1*J}^{id} \leq \Phi_{1*J-1}^{c} - \Phi_{1*J-1}^{id}$ for all J, so $\hat{J} = 1$. If the fluctuations are i.i.d., then the condition $\Phi_{1*J}^{c} - \Phi_{1*J-1}^{c} < \Phi_{1*J}^{id} - \Phi_{1*J-1}^{id}$ can be written as $(\Phi_j^c)^J - (\Phi_j^c)^{J-1} < (\Phi_j^{id})^J - (\Phi_j^{id})^{J-1}$, or equivalently as $(\Phi_j^c)^{J-1}(1-\Phi_j^c) > (\Phi_j^{id})^{J-1}(1-\Phi_j^{id})$, or as J $> \dfrac{\ln[(1-\Phi_j^{id})/(1-\Phi_j^c)]}{\ln[\Phi_j^c/\Phi_j^{id}]} + 1 = \hat{J}$. From the FOSD of F we know that $\Phi_j^c - \Phi_j^{id} > 0$ and is non-decreasing in τ_{-ij}^d; therefore, $\hat{J} \geq 1$ and it is decreasing in $\Phi_j^c - \Phi_j^{id}$ and in τ_{-ij}^d.□

Proof of Lemma 2: If the deviations are revealed with probability one, then $\Phi_j^{id} = 0$ and $\Delta(\Phi, \pi, \delta) = \dfrac{\delta\Phi_{1*J}^c}{1-\delta(\Phi_{1*J}^c - \pi)}$. Note that Φ_{1*J}^c is weakly declining in J and it is strictly declining in J if the fluctuations are not perfectly correlated. If the deviations are not revealed with probability one, then $\Phi_j^{id} > 0$. In this case, $\Delta(\Phi_{1*J}, \pi, \delta) - \Delta(\Phi_{1*(J-1)}, \pi, \delta) = \dfrac{\delta(\Phi_{1*J}^c - \Phi_J^{id})}{1-\delta(\Phi_{1*J}^c - \pi)} - \dfrac{\delta(\Phi_{1*(J-1)}^c - \Phi_{J-1}^{id})}{1-\delta(\Phi_{1*(J-1)}^c - \pi)} =$ $\dfrac{\delta(\Phi_{1*J}^c - \Phi_J^{id})[1-\delta(\Phi_{1*(J-1)}^c - \pi)] - \delta(\Phi_{1*(J-1)}^c - \Phi_{J-1}^{id})[1-\delta(\Phi_{1*J}^c - \pi)]}{[1-\delta(\Phi_{1*J}^c - \pi)][1-\delta(\Phi_{1*(J-1)}^c - \pi)]}$. If the stochastic fluctuations are i.i.d., then by lemma for all $J \geq \hat{J}$, $(\Phi_{1*J}^c - \Phi_J^{id}) < (\Phi_{1*(J-1)}^c - \Phi_{J-1}^{id})$. Furthermore, $\Phi_{1*J}^c < \Phi_{1*(J-1)}^c$ so that $[1-\delta(\Phi_{1*(J-1)}^c - \pi)] > [1-\delta(\Phi_{1*J}^c - \pi)]$. Hence, there exists a $\tilde{J} \leq \hat{J}$ such that for all $J \geq \tilde{J}$, $\Delta(\Phi, \pi, \delta)$ is declining in J.□

Proof of Proposition 3: Rewriting the incentive constraint for the home country for the case of groups 1 and 2 yields: $\Psi_{h11} + \Psi_{h21} \leq \Omega_{h11} + \Omega_{h21}$. For these two groups together, zero tariffs are self-enforcing if:

$$\delta \geq \frac{\sum_{j=1}^{2} 2\alpha_{fj} - \theta_{fj} - \theta_{hj}}{\sum_{j=1}^{2}(\Phi_{12}^c(1-\rho_{fj}) + \rho_{fj}\Phi_{12}^{id})2\alpha_{fj} + \sum_{j=1}^{2}(\pi - \Phi_{12}^{id})(\theta_{fj} + \theta_{hj})} = \delta_{h12}. \tag{A.2}$$

Rewriting $2\alpha_{fj} \equiv A_j$, $\theta_{fj} + \theta_{hj} \equiv B_j$, $(\Phi_j^c(1-\rho_{fj}) + \rho_{fj}\Phi_j^{id}) \equiv X_j$, and $(\pi - \Phi_j^{id}) \equiv Y_j$, we have $\delta_{hj} = (A_j - B_j)/(X_jA_j + Y_jB_j)$ and $\delta_{h12} = [(A_1 + A_2) - (B_1 + B_2)]/[(X_{12}(A_1 + A_2) + Y_{12}(B_1 + B_2)]$. First, consider the case of perfectly correlated fluctuations so that $\Phi_{12}^c = \Phi_1^c = \Phi_2^c$ and $\Phi_{12}^{id} = \Phi_1^{id} = \Phi_2^{id}$. Hence, $X_1 = X_2 = X_{12} = X$ and

$Y_1 = Y_2 = Y_{12} = Y$. It is then straightforward to verify that $\delta_{h2} > \delta_{h1}$ implies that $X(A_1B_2 - B_1A_2) < Y(B_1A_2 - A_1B_2)$ which implies that $\delta_{h2} > \delta_{h12} > \delta_{h1}$. Hence, for all δ such that $\delta_{h2} > \delta \geq \delta_{h12} > \delta_{h1}$ the result obtains for zero tariffs in the two group case. Next consider a group of goods 1 through N such that zero tariffs are self enforcing for this group, but not for group $N + 1$. Writing the critical discount factor for N linked groups as δ_{h1*N} and proceeding in the same way as above it is immediate to see that $\delta_{hN+1} > \delta_{h1*N+1} > \delta_{h1*N}$ so that for all δ such that $\delta_{hN+1} > \delta \geq \delta_{h1*N+1}$ the result obtains.

If the fluctuations are not perfectly correlated, then $\Phi_{12}^{c} < \min\{\Phi_1^c, \Phi_2^c\}$. Similarly, it must be the case that $\Phi_{12}^{id} \leq \min\{\Phi_1^{id}, \Phi_2^{id}\}$. This last inequality is weak because for any distribution whereby deviations are perfectly revealed it follows that $\Phi_{12}^{id} = \Phi_1^{id} = \Phi_2^{id} = 0$. We begin with the case of perfectly revealed deviations, so that $\Phi_{12}^{id} = \Phi_1^{id} = \Phi_2^{id} = 0$ and, therefore, $Y_1 = Y_2 = Y_{12} = \mathrm{Y}$. Because $\Phi_{12}^{c} < \min\{\Phi_1^c, \Phi_2^c\}$ we have that $X_{12} < \min\{X_1, X_2\}$. Hence, $\delta_{hj} = (A_j - B_j)/(X_jA_j + \mathrm{Y}B_j) < \delta < \delta_{h12} = [(A_1 + A_2) - (B_1 + B_2)]/[(X_{12}(A_1 + A_2) + Y(B_1 + B_2)]$ is possible. Note that as the correlation between the fluctuations decreases and/or as the number of groups increases, Φ_{1*J}^{c} decreases further below the minimum of $\{\Phi_1^c, ..., \Phi_J^c\}$. Hence, X_{1*J} drops further below $\min\{X_1, \ldots, X_\mathrm{J}\}$ and δ_{h1*J} increases further above the $\max\{\delta_{h1}, \ldots, \delta_{hJ}\}$ so that $\delta_{h1*J} > \delta \geq \max\{\delta_{h1}, \ldots, \delta_{hJ}\}$ becomes more likely.

If the deviations are not perfectly revealed and if the fluctuations are not perfectly correlations, then $\Phi_{12}^{id} < \min\{\Phi_1^{id}, \Phi_2^{id}\}$, so that $Y_{12} > \max\{Y_1, Y_2\}$. In this case, we first note that $\alpha_{fj} > \theta_{fj}$, and if the groups are reasonably symmetric, then $2\alpha_{fj} > \theta_{fj} + \theta_{hj}$. Hence, if they are reasonably symmetric, and if ρ_{fj} is reasonably large, then $X_{12}A_\mathrm{j} + Y_{12}B_\mathrm{j} < \min\{X_\mathrm{j}A_\mathrm{j} + Y_\mathrm{j}B_\mathrm{j}\}$ so that $\delta_{h12} > \delta \geq \delta_{h2} > \delta_{h1}$ is again possible in the noisy case when it was not in the deterministic case. If ρ_{fj} is small, then as long as the drop in Φ^{ic} is not too small in comparison to the drop in Φ^{id}, then $\delta_{h12} > \delta \geq \delta_{h2} > \delta_{h1}$ is possible. From lemma 1, we know that when the fluctuations are uncorrelated there exists a critical number of groups, $\hat{J}$, so that when adding more than $\hat{J}$ groups to the agreement Φ^{ic} is dropping faster than Φ^{id} as more groups are added. Hence, when the deviations are not perfectly revealed and the fluctuations are uncorrelated, then in the symmetric or un-symmetric case and for any value of ρ_{ij} it must be the case that as the number of groups exceeds $\hat{J}$ it becomes more likely that $\delta_{h1*J} > \delta \geq \max\{\delta_{h1}, \ldots, \delta_{hJ}\}$.□

Proof of Proposition 4: The gain to deviating and the marginal gain to deviating are the same in the noisy and noiseless case. From proposition 2 the marginal gain to deviating in the incremental case is less than in static case by the increased irreversible sunk cost: $\rho_{f(J-1)}\beta_{f(J-1)}$. Also from proposition 2 the marginal cost to deviating in the incremental noiseless case minus the marginal cost to deviating in the static noiseless case is:

$$\frac{\delta}{1-\delta(1-\pi)}\rho_{h(J-1)}\beta_{h(J-1)}. \tag{A.3}$$

The cost to deviating in the noisy case when $J-1$ groups are to be added to the agreement in period 1 is:

$$\Omega_{h(J-1)1} = \Delta(\Phi_{1*(J-1)}, \pi, \delta)\,[\textstyle\sum_{j=1}^{J-1}\theta_{fj}/2+\theta_{hj}/2-\rho_{fj}\alpha_{fj}\,].$$

If J groups are to be added in period 1 then the cost of deviating is:

$$\Omega_{hJ1} = \Delta(\Phi_{1*J}, \pi, \delta)\,[\textstyle\sum_{j=1}^{J}\theta_{fj}/2+\theta_{hj}/2-\rho_{fj}\alpha_{fj}\,].$$

The marginal change to the cost of deviating in the static noisy case is, therefore, given by:

$$\Omega_{hJ1} - \Omega_{h(J-1)1} = [\Delta(\Phi_{1*J}, \pi, \delta) - \Delta(\Phi_{1*J-1}, \pi, \delta)][\textstyle\sum_{j=1}^{J-1}\theta_{fj}/2+\theta_{hj}/2-\rho_{fj}\alpha_{fj}\,] +$$

$$\Delta(\Phi_{1*J}, \pi, \delta)[\theta_{fJ}/2 + \theta_{hJ}/2 - \rho_{fJ}\alpha_{fJ}]. \tag{A.4}$$

The marginal change to the cost of deviating in incremental noisy case is given by equation (3.18). Examination of equations (3.18) and (A.4) show that the cost to deviating in the incremental noisy case minus the cost to deviating in the static noisy case is given by:

$$[\Omega_{hJJ} - \Omega_{h(J-1)(J-1)}] - [\Omega_{hJ1} - \Omega_{h(J-1)1}] =$$

$$[\Delta(\Phi_{1*J}, \pi, \delta) - \Delta(\Phi_{1*J-1}, \pi, \delta)][\textstyle\sum_{j=1}^{J-2}\rho_{hj}\beta_{hj}\,] + \Delta(\Phi_{1*J}, \pi, \delta)[\rho_{h(J-1)}\beta_{h(J-1)}]. \tag{A.5}$$

If the stochastic fluctuations are perfectly correlated then $\Delta(\Phi_{1*J}, \pi, \delta) = \Delta(\Phi_{1*J-1}, \pi, \delta)$ so (A.5) is reduced to $\Delta(\Phi_{1*J}, \pi, \delta)[\rho_{h(J-1)}\beta_{h(J-1)}]$. This term is less than the comparable term in the noiseless case (A.3) because $\frac{\delta}{1-\delta(1-\pi)} > \frac{\delta(\Phi_1-\Phi_1^d)}{1-\delta(\Phi_1-\pi)} = \frac{\delta(\Phi_{1*J}-\Phi_{1*J}^d)}{1-\delta(\Phi_{1*J}-\pi)} = \Delta(\Phi_1, \pi, \delta)$. Hence, if the stochastic fluctuations are perfectly correlated, then there is additional incremental over static linking in the noisy than in the noiseless case.

If the stochastic fluctuations are not perfectly correlated, and if the deviating tariffs are always perfectly revealed, then by lemma 2, $\Delta(\Phi_{1*J}, \pi, \delta) - \Delta(\Phi_{1*J-1}, \pi, \delta) < 0$ and is decreasing in J. Also by lemma 2, $\Delta(\Phi_{1*J}, \pi, \delta)$ is decreasing in J. Hence, (A.5) falls further below (A.3) so that there is even less incremental linking in the noisy case when the fluctuations are not perfectly correlated.

If the stochastic fluctuations are uncorrelated, then by lemma 2 there exists a threshold number of groups, $\tilde{J}$, so that if $J \geq \tilde{J}$, then $\Delta(\Phi_{1*J}, \pi, \delta) - \Delta(\Phi_{1*J-1}, \pi, \delta) < 0$ and is decreasing in J. Furthermore, note that if the fluctuations are uncorrelated, then $\Delta(\Phi_{1*J}, \pi, \delta)$ is minimized and is decreasing in J, so that $\frac{\delta}{1-\delta(1-\pi)} - \frac{\delta(\Phi_{1*J} - \Phi_{1*J}^{d})}{1-\delta(\Phi_{1*J} - \pi)}$ is maximized. Hence, there exists a $\tilde{\tilde{J}} \leq \tilde{J} \leq \hat{J}$ such that for all $J \geq \tilde{\tilde{J}}$, there is less incremental linking in the noisy case than in the noiseless case.□

Proof of Proposition 5: Immediate from the last two paragraphs of the proof to proposition 4.□

Proof of Proposition 6: From lemma 2 and proposition 3, 4 and 5, if the measure of trade stability is lower, the stochastic fluctuations are less correlated, and/or the number of already covered groups is greater, then static and incremental linking will enforce free trade in fewer groups and some groups may only be able to enforce free trade if unlinked from other groups.□