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Abstract

This paper analyzes how uncertainty and the timing of its resolution influence the formation and design of regional trade agreements. Two sources of uncertainty – in demand and costs – are considered. We compare the case in which uncertainty is resolved "early" (before tariffs are chosen), with the case in which uncertainty is resolved "late" (after tariffs are chosen). These cases are, in turn, compared with the benchmark case of no uncertainty. We demonstrate that, as long as some decisions are made after uncertainty is resolved, trade agreements have option values. These option values differ across agreements, reflecting members' different degrees of (trade policy) freedom to respond to changes in the trading environment. Moreover, these option values may be sufficiently large as to lead prospective members to opt for a more flexible trading arrangement (such as a free trade area) over a less flexible agreement (such as a customs union). Indeed, countries may even prefer to stand alone than join a free trade area under some circumstances. Finally, we show that the timing of the resolution of uncertainty can significantly impact the type of trade agreement that countries wish to form.

KEYWORDS: Trade Agreement, Free Trade Area, Customs Union, Uncertainty, Resolution of Uncertainty.

JEL Classification: F12, F13, F15, D81.

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1 Introduction

Membership of a trade agreement (TA) usually requires a commitment to a restricted set of trade policies vis-à-vis trading partners who may be members or non-members. For example, members of the European Union commit to levying identical external tariff rates on imports from non-members while at the same time engaging in duty free trade among themselves. On the other hand, members of NAFTA set external tariff rates independently while committing to remove duties and quantitative restrictions on intra-bloc trade. To the extent that such policy commitments are difficult to reverse, TAs reduce a member country's ability to respond to changes in the trading environment; a potentially costly proposition in a trading world characterized by uncertainty. In this paper, we are primarily interested in two related questions. First, how does uncertainty influence the type of TA that countries choose to form? Second, how does the timing of the resolution of uncertainty affect this choice?

Since Viner (1950), the costs and benefits of different types of TAs have been extensively discussed in the literature.[1] More recently, particularly following the pioneering work of Riezman (1985), the choice of TA type has been analyzed as an application of the general problem of coalition formation. Nevertheless, comparatively little attention has been paid to the question of how countries choose between different TA designs under uncertainty.[2] A notable exception is the literature on the role of TA membership as an insurance mechanism.[3]

In this paper, we argue that the introduction of uncertainty has significant implications for TA member welfare that go beyond the insurance considerations already considered in the literature. In particular, we demonstrate that uncertainty alters the cost-benefit calculus associated with TA formation in several important ways.

First, consider the welfare implications of the internal trade liberalization implied by any TA. In the absence of uncertainty, this will benefit members provided that it is not too trade diverting. Under uncertainty, however, and assuming that the cost of TA renegotiation is prohibitive[4] (due to non-trivial reputation costs[5], for example), duty-free trade among member countries has an extra cost. Namely, an additional constraint that reduces a member country's degrees of (trade policy) freedom in responding to shocks to the trading environment. Alternatively put, the introduction of uncertainty necessitates the consideration of an additional source of welfare for member countries: TAs have an *option value*.

[1] For a comprehensive review of the TA literature see Freund and Ornelas (2010).

[2] There is, of course, a venerable literature on unilateral trade policy choice under uncertainty. See, for example, the work by Dasgupta and Stiglitz (1977) and Young (1979), among others, contrasting tariffs and quotas under uncertainty. More recently, Grant and Quiggin (1997) have looked at strategic trade policy under uncertainty.

[3] Under uncertainty, a trade bloc may have an insurance value for members by binding them more closely to a free trade future with each other. Ethier (2002) refers to the insurance motive for contingency measures (i.e. unilateralism) within a multilateral framework. Perroni and Whalley (2000) argue that small countries may seek to join regional trade agreements as insurance against future protection. Wu (2005) distinguishes between the self-insurance and self-protection motives for trade bloc membership.

[4] The possibility of trade bloc renegotiation is an important issue deserving of separate analysis.

[5] Schwartz and Sykes (2002) argue that the costs of reneging on trade agreements are twofold; the reneging country suffers reputation and credibility costs when dealing with the injured country in the future and also incurs costs when dealing with all other nations aware of the breach. Maggi (1999) suggests that the dissemination of information is a primary role of the WTO, informing third parties of trade agreement breaches and thus strengthening the enforcement mechanism of reputation costs.

Second, when trade blocs cannot be renegotiated, the impact of uncertainty varies according to the depth of trade integration - that is, by coalition type - and this must be taken into account at the time of the coalition formation decision. This is because, apart from the World Trade Organization's (WTO) "most favoured nation" (MFN) rule,[6] each TA type imposes a distinct set of trade policy restrictions on members. At one extreme, standing alone affords a country the luxury of choosing its external tariffs as it pleases. While a free trade area (FTA) permits members to choose their own external tariff rates, they must agree to: (i) free trade with their partner and (ii) a schedule of "rules-of-origin" that determine the duty-free status of goods originating in non-member nations but traded within the FTA. At the other extreme, a customs union (CU) requires members to commit to: (i) intra-union free trade, (ii) levy a 'common external tariff' (CET) on non-members and (iii) share the resulting CET revenue according to an agreed formula. In short, therefore, a country's ability to respond to changes in the trading environment is governed, in part at least, by the type of TA to which it belongs. Other things being equal, a TA characterized by shallower integration will tend to have a larger option value.

A third welfare consideration arising from uncertainty relates to the timing of its resolution. Intuitively, the option value of a TA can only be realized to the extent that TA members have the opportunity to respond (optimally) to changes in the trading environment *after they have occurred*. In other words, for the option value of a TA to be realized, member countries must have the opportunity to make at least some optimizing decisions after the uncertainty is resolved. Other things being equal, a TA's option value will be of greater welfare significance the more decisions member countries make after the resolution of uncertainty.

Reflecting the risks associated with trade policy commitment under uncertainty, the WTO provides a role for 'contingency measures' such as safeguards and anti-dumping measures. Such measures act as a 'safety valve' permitting TA members to temporarily, and in a WTO-compliant fashion, renege on their trade liberalization commitments in order to ameliorate any associated adjustment costs.[7] Note that contingency measures are a response to a particular type of uncertainty; that which arises from a *temporary* change in the trading environment. In contrast, this paper examines how countries make (irreversible) trade bloc membership decisions given that there is a potential for the trading environment to alter *permanently* in the future. Moreover, since all TAs must comply with WTO rules, contingency measures tend to be a standard feature of all types of TAs. As such they are unlikely to explain why countries prefer one type of TA over another - a FTA over a CU, for example.

In this paper, we examine the relationship between uncertainty and TA formation in the context of a partial

[6] The MFN rule require countries to levy identical tariffs on trading partners.

[7] See WTO (2009) for a comprehensive survey of this literature. The use of contingency measures can forestall more extreme protectionist tendencies (Bagwell and Staiger, 1990), help governments garner current domestic support for trade liberalization when future support is not guaranteed (Bagwell and Staiger, 2005), 'shelter' firms in member countries from world price fluctuations (Freund and Ozden, 2008) and solidify cooperation between members who wish to avoid being targeted by such measures (Martin and Vergote, 2008). While the inclusion of contingency measures tends to reduce the (terms-of-trade) benefits arising from cooperation, it allows countries to address the contractual incompleteness of trade agreements (Horn et al., 2010).

equilibrium, three-country world characterized by imperfect competition between firms. A three-stage game is considered in which countries form coalitions in stage one,[8] optimal tariffs are chosen in stage two and firms choose their profit maximizing outputs in stage three. In stage one, countries can join a FTA, a CU or choose to stand alone. Our model incorporates uncertainty in both demand and supply. In order to remove pure insurance considerations (which have already been addressed in the literature) we assume that all countries are risk neutral. We examine the role of the timing of the resolution of uncertainty by contrasting two cases: one in which uncertainty is resolved "early" (i.e., tariffs are chosen after its resolution), the other when uncertainty is resolved "late" (i.e., tariffs are chosen before its resolution).

We analyze both the "impact effect" of introducing uncertainty into our trading world, as well as the "marginal effect" of a change in the degree of uncertainty. We first demonstrate that, for all TA types, and provided that at least some optimizing decisions are made after uncertainty is resolved, the introduction of uncertainty makes the countries' welfare functions convex in the demand and supply random variables. This convexity is the source of a TA's option value and implies that a country's expected welfare increases with demand and supply uncertainty (variance) assuming a mean-preserving spread. Other things being equal, therefore, under uncertainty countries will opt for the TA design that permits them to best exploit this convexity. In other words, prospective member countries will balance the option value benefit against the "usual" costs/benefits of policy coordination and free trade that typically arise when FTAs or CUs form.

We show that when uncertainty is resolved early, a marginal change in uncertainty (second moments) can be decomposed into a *tariff-independent* and a *tariff-dependent* effect. The former is identical regardless which TA type forms. The latter, on the other hand, varies with TA type because the random variables influence the different (equilibrium) tariffs associated with each type of trade bloc in different ways and, in turn, the different tariffs affect country welfare differently. Therefore, it is only via tariffs that a change in uncertainty impacts on the (expected) welfare ranking of TAs by prospective members - our main concern. Specifically, we show that a marginal increase in demand or cost uncertainty of a particular TA member increases their own preference for a CU relative to a FTA, while reducing that of their TA partner. In the case of a marginal increase in demand uncertainty, the magnitude of the partner effect is greater while in the case of a marginal increase in cost uncertainty, the magnitude of the partner effect is smaller. Consequently, when uncertainty is resolved early, prospective member countries are (jointly) more likely to prefer a FTA to a CU, when their demand uncertainty is sufficiently high or production cost uncertainty is sufficiently low. This result stands in stark contrast to the welfare dominance of CUs predicted by most theoretical studies on TAs. Nevertheless, our prediction is

[8] Assuming no renegotiations.

consistent with the fact that the vast majority of observed trade blocs take the form of FTAs.

We show that when uncertainty is resolved late, equilibrium tariffs depend on means (of the random variables) only. Consequently, the tariff-dependent effect of uncertainty is zero: thus, only the tariff-independent effect is relevant. But, since the latter is identical for all TA types, the ranking of TA types by prospective members is invariant to the source or degree of uncertainty; a CU is always preferred most and standing alone least.

In the last part of the paper, we evaluate the preferred timing of tariff choice in TAs. We show that (assuming symmetric countries) in the presence of little or no uncertainty, member countries prefer a CU most and standing alone least, regardless of the timing of the resolution of uncertainty. As their demand uncertainty (variance) increases, however, prospective members are more likely to prefer *any* TA in which they can choose tariffs after the resolution of uncertainty. Indeed, when member demand variances are sufficiently high, member countries will even prefer standing alone to any TA in which tariffs are chosen before the resolution of uncertainty. On the other hand, as their cost variance increases, prospective members are more likely to prefer any TA in which they can choose tariffs before the resolution of uncertainty. These results reflect changes in the relative importance of the option value of TAs, as well as the usual cost/benefit calculations in standard TA models without uncertainty.

2 The General Framework - Introducing Uncertainty

Consider a world of three countries in which TAs can form. Assume that one country, Country 3 here, is "passive" in the sense that it does not sign TAs. Countries 1 and 2, on the other hand, are "active"; they may negotiate a bilateral TA if they wish. It is further assumed that countries 1 and 2 can choose between two alternative types of bilateral trade blocs - a FTA or a CU. Alternatively, countries 1 and 2 may prefer to stand alone (sa). Define the set of three possible coalition structures as $Y = (sa, fta, cu)$.[9] In what follows, all three elements in Y, including the sa case, are referred to as "types" of TAs. Consistent with WTO rules, this paper assumes that all TA types satisfy the MFN principle.

The three countries engage in a multi-stage trade policy game. In stage one, countries 1 and 2 choose a TA, $y \in Y$ and associated lump sum transfers, K_i^y, $i = 1, 2$. In stage two, given the TA that has formed, all three countries choose their tariffs, t_{ij}, $i, j = 1..3$, where t_{ij} denotes the tariff that Country i pays Country j, and where $t_{ii} = 0$. In stage three, given the previously chosen TA and tariffs, the firms in the three countries choose their outputs in each market. These outputs are denoted by q_{ij}, the quantity that firm i sells in Country j. For

[9] The assumption that Country 3 is passive means that we do not have to consider the case of global free trade. This simplifies the analysis significantly as, otherwise, we would have to consider all possible coalition structures among the three countries, not just those involving countries 1 and 2. It turns out that in this model, without uncertainty, global free trade dominates all other types of trade agreements. On the other hand, once uncertainty is introduced, the primacy of global free trade can no longer be guaranteed. Detailed analysis of the preference for global free trade under uncertainty is left for future research.

simplicity, we assume that there is one firm domiciled in each country.[10] Country i's firm is referred to as firm i.

We assume that the markets are segmented. Country $j's$ demand function is given by:

$$p_j = a_j - Q_j,\ j = 1..3,$$

where $a_j > 0$ is a demand parameter and $Q_j = \sum_{i=1}^{3} q_{ij}$ is the aggregate output sold in Country j. The technology of the firms in the three countries is captured by their marginal (and average) costs $c_i,\ i = 1..3$.

2.1 The Source of Uncertainty

We assume that countries face demand and cost uncertainty. Specifically, we assume that the demand parameter vector, $a = (a_1, a_2, a_3)$, is a vector of random variables, with means $E(a_i) = \mu_{ia}$, variances $Var(a_i) = \sigma_{ia}^2$ and covariances, $Cov(a_i, a_j) = \sigma_{ija}$. Furthermore, we assume that the cost parameter vector, $c = (c_1, c_2, c_3)$, is a vector of random variables with means $E(c_i) = \mu_{ic}$, variances $Var(c_i) = \sigma_{ic}^2$ and covariances $Cov(c_i, c_j) = \sigma_{ijc}$. For simplicity, we assume that there is no correlation between demand and cost conditions; that is, $Cov(a_i, c_i) = 0$. For the purpose of comparative statics, it is useful to write the random variables as:

$$a_i = \mu_{ia} + \sigma_{ia} e_{ia},\ c_i = \mu_{ic} + \sigma_{ic} e_{ic}, \quad i = 1..3, \tag{1}$$

where e_{ia} and e_{ic} are white noise random variables with zero mean and a variance of 1.

2.2 The Resolution of Uncertainty

In general, uncertainty may be resolved at any one of four different points of the multi-stage trade policy game. At one extreme, uncertainty may be resolved prior to the first stage. That is, TAs, tariffs and firm outputs are determined under complete certainty - this is referred to as the "base case" in what follows. Alternatively, uncertainty may be resolved "early"; that is, between stages one and two. This situation, in which TA choice is made in an environment of uncertainty, while tariffs and firm outputs are determined under certainty is, henceforth, referred to as "Case 1". Another possibility is that uncertainty is resolved "late"; that is, between stages two and three. This situation, in which TA and tariff choices are made under uncertainty while firm output choice occurs under certainty is, henceforth, referred to as "Case 2". A final possibility, not considered here, is that uncertainty is only resolved after all decisions have been made; that is, after stage three.[11] In this paper, it is assumed that once uncertainty is resolved, regardless of when that may be, the realizations of all random variables become common knowledge to all players.

[10] Assuming multiple firms yields little additional insight for our purposes while making the analysis more cumbersome.

[11] This last situation is not particularly interesting since, with risk neutrality, the countries' welfare functions become linear in random variables, so that only the means (and not higher moments) are important: uncertainty plays a limited role.

3 Case 1: Early Resolution of Uncertainty

In Case 1, TAs are chosen before the state of the world is known, but tariffs and firm output choices are made after uncertainty is resolved.

3.1 Stage 3: Output Choice

In stage 3, the three firms choose their outputs simultaneously in a Cournot game given the chosen tariffs and the TA. Given the demand functions defined in section 2 and the tariff rates chosen by each country, the profit firm i makes from selling in Country j is given by:

$$\pi_{ij} = [a_j - \sum_{h=1}^{3} q_{hj} - c_i - t_{ij}]q_{ij} \equiv \pi_{ij}(q^j, t_{ij}; a_j, c_i),\ i, j = 1..3, \tag{2}$$

where $q^j = (q_{1j}, q_{2j}, q_{3j})$ is the vector of quantities sold in Country j.

Since markets are segmented, the Nash equilibrium quantities in Country j are obtained by the simultaneous solution to the three countries' profit maximization problems given by:

$$\max_{q_{ij}} \pi_{ij}(q^j, t_{ij}; a_j, c_i),\ i = 1..3. \tag{3}$$

Let the Nash Equilibrium quantities in Country j, be denoted as q^*_{ij}. It easy to show that:

$$q^*_{ij} = q^*_{ij}(t^j; a_j, c) \equiv \frac{1}{4}[a_j + \sum_{k\neq i}(c_k + t_{kj}) - 3(c_i + t_{ij})],\ i = 1..3, \tag{4}$$

where $t^j = (t_{1j}, t_{2j}, t_{3j})$ is the vector of tariffs levied by Country j. Note that while q^*_{ij} depends on the *vectors* c and t^j, it only depends on Country j's demand parameter a_j (and not $a_{h\neq j}$). The Nash Equilibrium quantities in Country j can be written alternatively as the vector, $q^{*j} = q^{*j}(t^j; a_j, c)$.

Using equations (2) and (4), the corresponding Nash equilibrium profits, denoted as $\pi^*_{ij}[t^j; a_j, c]$, can be calculated to obtain:

$$\pi^*_{ij}[t^j; a_j, c] \equiv \pi_{ij}[q^{*j}(t^j; a_j, c), t_{ij}; a_j, c_i] = \frac{1}{16}[a_j + \sum_{h\neq i}(c_h + t_{hj}) - 3(c_i + t_{ij})]^2, i = 1..3. \tag{5}$$

Whereas (not surprisingly) $\pi^*_{ij}[t^j; a_j, c]$ is decreasing in c_i and t_{ij}, it is increasing in $c_{h\neq i}$, and $t_{h\neq i,j}$. Moreover, $\pi^*_{ij}[t^j; a_j, c]$ is convex in a_j, c.

3.2 Stage 2: Tariff Choice

In stage 2, the countries choose their tariffs given the TA in stage 1 and the known state of the world. We define the net welfare of Country i (welfare minus lump sum transfers) as the sum of consumer surplus, producer surplus and tariff revenue. Using the Nash equilibrium quantities derived above, we can explicitly write Country

$i's$ (net) welfare in stage 3 as:

$$w_i(t;a,c) \equiv \frac{1}{2}Q_i^{*2} + \sum_{j=1}^{3} \pi_{ij}^*[t^j;a_j,c] + \sum_{j\neq i} q_{ji}^*(t^i;a_i,c)t_{ji}, \tag{6}$$

where t is the vector of all tariffs, a is the vector of all the a_i terms and $Q_i^* = \sum_{j=1}^{3} q_{ji}^*$.

In order to be able to examine the choice of tariffs, we must consider the tariff restrictions implied by the three possible TAs, $y \in Y = (sa, fta, cu)$. In what follows, we define the set of tariff restrictions corresponding to each TA in y, as T_y.

3.2.1 Case 1 Tariff Choice: Stand Alone and Free Trade Area

When the countries stand alone in the first stage, the tariff restrictions are simply given by the MFN rules. Thus:

$$t \in T_{sa} \equiv \{t : t_{21} = t_{31} \equiv t_1^{sa},\ t_{12} = t_{32} \equiv t_2^{sa},\ t_{13} = t_{23} \equiv t_3^{sa},\ t_{ii} = 0\}, \quad i = 1..3. \tag{7}$$

That is, we only have three tariffs to solve for (one for each country).

If countries 1 and 2 form a FTA in the first stage, then $t_{12} = t_{21} = 0$. Moreover, the MFN rule requires that $t_{13} = t_{23}$. Thus, we have:

$$t \in T_{fta} \equiv \{t : t_{12} = t_{21} = 0,\ t_{31} \equiv t_1^{fta},\ t_{32} \equiv t_2^{fta},\ t_{13} = t_{23} \equiv t_3^{fta},\ t_{ii} = 0\}. \tag{8}$$

Notice that, as in the sa case above, with fta each country chooses only one tariff. Therefore, it is unclear whether, compared to sa, a FTA member has fewer (trade policy) degrees of freedom with which to respond to changes in the trading environment. This, however, is simply due to the MFN rule. Without the MFN rule, a country will clearly have greater flexibility to respond to changes in the trading environment under fta than sa.

We can satisfy the (7) and (8) restrictions, by substituting them directly into each country's welfare function. Define the resulting net welfare functions for sa and fta as:

$$w_i^y \equiv w_i(t_1^y,\ t_2^y,\ t_3^y; a, c) \equiv \{w_i(t;a,c):\ t \in T_y,\ y = sa, fta,\ i = 1..3,\}. \tag{9}$$

The three countries' net welfare maximization problems are, now, given by:

$$\max_{t_i^y}\{w_i(t_1^y,\ t_2^y,\ t_3^y; a,c),\ i = 1..3,\ y = sa, fta\}.$$

If we define the vector of tariffs as $t^y = (t_1^y, t_2^y, t_3^y)$, we can write the net welfare functions as, $w_i^y(t^y;a,c)$. It is quite straightforward to verify that for, each country, the net welfare function, $w_i^y(t^y;a,c)$, is strictly concave in its own tariff and additively separable in all tariffs. As an example, the explicit solutions for $w_1^y(t^y;a,c)$, $y = sa, fta$

are given in Appendix 8.1. The separability in tariffs, which follows from the (MFN) restrictions in equations (7) and (8), imply that tariffs are strategically neutral and, hence, we can solve for each t_i^y separately.[12]

Let the Nash equilibrium tariff in Country i be denoted as $t_i^{*y}(a,c)$, $i = 1..3$, $y = sa, fta$. The explicit solutions for $t_i^{*y}(a,c)$ are given by:

$$t_i^{*sa}(a,c) = \frac{1}{10}(3a_i - \sum_{i=1}^{3} c_i),\ i = 1..3 \tag{10}$$

$$\begin{aligned} t_i^{*fta}(a,c) &= \frac{1}{7}a_i - \frac{1}{21}c_i + \frac{1}{3}c_j - \frac{3}{7}c_3,\ i,j = 1,2, i \neq j \\ t_3^{*fta}(a,c) &= \frac{1}{10}(3a_3 - \sum_{i=1}^{3} c_i). \end{aligned} \tag{11}$$

First, note that, in both the sa and fta cases, the equilibrium tariff in Country i increases with its own demand curve, but is independent of demand conditions in the other countries. Second, the equilibrium tariff in Country 3 is the same in both cases, (decreasing with unit costs in any country). Third, in the sa case, the equilibrium tariffs in Countries 1 and 2 decrease with respect to all costs. On the other hand, in the fta case, for Countries 1 and 2, the equilibrium tariff decreases with respect to their own and Country 3's costs, but increases with respect to the cost of their FTA partner.

Now, define the corresponding Nash equilibrium net welfare in each country as:

$$w_i^{*y}(a,c) \equiv w_i(t^{*y}(a,c);a,c),\ i = 1..3,\ y = sa, fta, \tag{12}$$

where $t^{*y}(a,c) = [t_1^{*y}(a,c), t_2^{*y}(a,c), t_3^{*y}(a,c)]$ is the vector of equilibrium tariffs, for $y = sa, fta$. The Nash equilibrium welfare, for country i, can be calculated and is given by the following quadratic functions in the demand and cost parameters:

$$w_i^{*y} = \sum_{i=1}^{3}\sum_{j=1}^{3} \beta_{ij}^{iy} c_i c_j + \sum_{i=1}^{3}\sum_{j=1}^{3} \gamma_{ij}^{iy} c_i a_j + \sum_{i=1}^{3} \psi^{iy} a_i^2,\ y = sa, fta, \tag{13}$$

where the parameters β, γ and ψ are given in Appendix 8.2. It can be easily verified that the net welfare functions, w_i^{*y}, $i = 1..3$, are convex in all the random variables. As mentioned above, it is this convexity that is the source of a TA's option value.

3.2.2 Case 1 Tariff Choice: Customs Union

If countries 1 and 2 form a CU in the first stage, then $y = cu$ and $t_{12} = t_{21} = 0$. In addition, countries 1 and 2 levy a common external tariff on Country 3, $t_{31} = t_{32}$ and the MFN rule requires that $t_{13} = t_{23}$. Thus:

$$t \in T_{cu} \equiv \{t : t_{12} = t_{21} = 0,\ t_{13} = t_{23} \equiv t_3^{cu},\ t_{31} = t_{32} \equiv t_{cu}^{cu}, t_{ii} = 0\}. \tag{14}$$

[12] Note that since the MFN rules apply to all TAs, including the CU case, this separability arises in all three agreements, for both early and late resolution of uncertainty.

Note that now we have seven restrictions, which means that we only have two tariffs to solve: t_{cu}^{cu} and t_3^{cu}.

In this case, the two CU members choose only one tariff. Therefore, relative to both fta and sa, CU members have fewer (trade policy) degrees of freedom with which to respond to changes in the trading environment.

Substituting these restrictions directly into each $w_i(t; a, c)$ yields the net welfare function for Country i as:

$$w_i^{cu} \equiv w_i(t_{cu}^{cu}, t_3^{cu}; a, c) \equiv \{w_i(t; a, c) : \ t \in T_{cu}, \ i = 1..3\}. \tag{15}$$

We assume that countries 1 and 2 jointly choose their common tariff by maximizing (a social welfare function which is simply) the sum of their welfare:[13]

$$w^{cu}(t_{cu}^{cu}, \ t_3^{cu}; a, c) \equiv w_1(t_{cu}^{cu}, \ t_3^{cu}; a, c) + w_2(t_{cu}^{cu}, \ t_3^{cu}; a, c). \tag{16}$$

Country 3 maximizes its welfare function as before.

The problems of the CU and Country 3 are respectively given by:

$$\max_{t_{cu}^{cu}}\{w^{cu}(t_{cu}^{cu}, \ t_3^{cu}; a, c)\}, \quad \text{and} \quad \max_{t_3^{cu}}\{w_3(t_{cu}^{cu}, \ t_3^{cu}; a, c)\}.$$

Once again, the welfare functions of the CU and Country 3 are strictly concave in their respective tariffs and additively separable in all tariffs. As an example, the explicit solution for $w_1(t_{cu}^{cu}, \ t_3^{cu}; a, c)$ is given in Appendix 8.1.

Let the Nash equilibrium tariffs in the cu case be denoted as $t_{cu}^{*cu}(a, c), \ \ t_3^{*cu}(a, c)$. The explicit expressions for $t_{cu}^{*cu}(a, c)$,and $t_3^{*cu}(a, c)$ are given by:

$$\begin{aligned} t_{cu}^{*cu}(a, c) &= \frac{5}{38}(a_1 + a_2) + \frac{1}{19}(c_1 + c_2) - \frac{7}{19}c_3 \\ t_3^{*cu}(a, c) &= \frac{1}{10}(3a_3 - \sum_{i=1}^{3} c_i). \end{aligned} \tag{17}$$

Note that $t_3^{*cu}(a, c)$ is the same as in the SA and FTA cases. Moreover, the cu equilibrium tariff is decreasing with the unit cost of Country 3, but increasing with respect to the unit costs of countries 1 and 2. It also depends on both members' demand parameters.

Now, define the corresponding Nash equilibrium welfare in each country as

$$w_i^{*cu}(a, c) \equiv w_i^{cu}[t^{*cu}(a, c); a, c], \ i = 1..3, \tag{18}$$

where $t^{*cu}(a, c) = [t_{cu}^{*cu}(a, c), t_3^{*cu}(a, c)]$ is the vector of equilibrium tariffs. The Nash equilibrium welfare for Country i can now be easily calculated and is given by a quadratic equation that is similar to (13), with the superscript changed to cu instead of sa, except that now, unlike in the sa and fta cases, w_i^{*cu} will have an

[13] Since $K_1^{cu} + K_2^{cu} = 0$, it follows that the sum of the two countries' welfare is the same as the sum of their net welfare. See next section (and footnote 12) for a brief discussion of the choice of this particular welfare function.

additional term that involves the product of $a_1 a_2$.[14] The parameters of the quadratic welfare functions in the *cu* case, for Country 1, are given in Appendix 8.2. It can be easily verified that the net welfare functions, w_i^{*cu}, $i = 1..3$, are convex in all the random variables.

3.3 Stage 1: The Choice of Trade Agreement

In stage 1, before the state of the world is known, countries 1 and 2 choose a TA. Given the countries' risk neutrality, they simply consider their expected welfare. Note that risk neutrality does not necessarily imply that only the first moments matter. This would be the case only if all decisions were made before uncertainty is resolved. In Cases 1 and 2 some (but not all) decisions are made after uncertainty is resolved and, moreover, as was shown above, the objective functions are quadratic in the random variables. Hence, second moments do indeed play a role.[15]

In principle, we could use a general solution concept for the choice of an agreement; Nash Bargaining or the core, for example.[16] Since the specific solution concept is not the focus of the paper, we proceed (for consistency) by using the same social welfare function that was used above; namely, the sum of the two countries' expected welfare.

For any $y \in Y \equiv \{sa, fta, cu\}$, let the total expected welfare of countries 1 and 2 be given by:

$$\begin{aligned} W[y;m] &\equiv \{E[w_1^{*y}(a,c)] + K_1^y\} + \{E[w_2^{*y}(a,c)] + K_2^y\} \\ &= E[w_1^{*y}(a,c)] + E[w_2^{*y}(a,c)], \end{aligned}$$

where $K_1^y + K_2^y = 0$ and m denotes the first two moments of the distributions of the random variables a, c.[17] The countries select a TA by comparing the total welfare corresponding to the three elements of Y. Specifically, let y^* be the chosen (equilibrium) agreement, Then,

Proposition 1 *The agreement y^* is chosen if and only if for all $y \in Y$: $W[y^*;m] > W[y;m]$ for all $y \neq y^*$*

Proof. (i) If $W[y^*;m] > W[y;m]$ for all $y \neq y^*$, there must be corresponding transfers, given by $K_i^{y^*}$, where $K_1^{y^*} + K_2^{y^*} = 0$, such that $E[w_i^{*y^*}(a,c)] + K_i^{y^*} > E[w_i^{*y}(a,c)]$, thus y^* is preferred to any another agreement. (ii) If y^* is chosen, it must be better than any other agreement for both countries. In other words, we must have: $E[w_i^{*y^*}(a,c)] + K_i^{y^*} > E[w_i^{*y}(a,c)]$, $i = 1, 2$, for all $y \neq y^*$, where $K_1^{y^*} + K_2^{y^*} = 0$. Hence,

[14] Hence, $E(w_i^{*cu})$ will depend on the covariance between a_1 and a_2.

[15] In general, higher than second moments may also play a role, but given the linearity of demand and cost in the random variables, they do not paly a role in our model.

[16] In our context, both Nash Bargaining and the core are problematic. Specifically, the nature of the Nash bargaining "social welfare function" (non-linear and multiplicative) combined with the existence of uncertainty and a multi-stage, multi-party game, makes the solution intractable. The use of the core, on the other hand, does not always yield a unique equilibrium.

[17] Each country's expected welfare depends on the first two moments of the vectors a, c because, as demonstrated in Appendix 8.2, the welfare functions are quadratic in a, c.

$W[y^*; m] = E[w_1^{*y^*}(a,c)] + K_1^{y^*} + E[w_2^{*y^*}(a,c)] + K_2^{y^*} = E[w_1^{*y^*}(a,c)] + E[w_2^{*y^*}(a,c)] > E[w_1^{*y}(a,c)] + E[w_2^{*y}(a,c)]$
$= W[y; m]$, for all $y \neq y^*$.[18] ■

4 Case 2: Late Resolution of Uncertainty

In Case 2, demand and cost conditions are already known when outputs are chosen, but still unknown when tariffs and the TA are selected. Hence, Case 2 differs from Case 1 in that tariffs are now chosen when the state of the world is still unknown. Since the choice of outputs is the same as in Case 1, we can now go directly to the tariff-choice stage of the game under Case 2.

4.1 Case 2 Tariff Choice: Stand Alone and Free Trade Area

In the sa and fta cases, the countries' welfare functions are given by equation (9). The corresponding expected welfare functions are then:

$$E[w_i(t^y; a, c)] \equiv M_i^y(t^y, m),\ y = sa, fta,$$

so that the three countries' expected welfare maximization problems are given by:

$$\max_{t_i^y}\{M_i^y(t^y, m)\},\ i = 1..3,\ y = sa, fta\}.$$

It is quite simple to verify that each country's expected welfare function, $M_i^y(t^y, m)$, is strictly concave and quadratic in its own tariff and additively separable in all tariffs. As was the case in Case 1, this separability implies that tariffs are strategically neutral, so that we can solve for each t_i^y separately. In addition, the expected welfare functions are: (i) functions of the first and second moments only, (ii) quadratic in the first moments, but linear in the second moments and (iii) additively separable in all tariffs and all second moments.[19]

Let the (Case 2) Nash equilibrium tariff in Country $i = 1...3$, for TA $y = sa, fta$, be denoted as $t_i^{*y}(m)$. Because of the separability in second moments, the solutions become (linear) functions of the first moments only:

$$t_i^{*sa}(m) = \frac{1}{10}[3E(a_i) - \sum_{i=1}^{3} E(c_i)],\ i = 1..3 \tag{19}$$

$$\begin{aligned} t_i^{*fta}(m) &= \frac{1}{7}E(a_i) - \frac{1}{21}E(c_i) + \frac{1}{3}E(c_j) - \frac{3}{7}E(c_3),\ i, j = 1, 2, i \neq j, \\ t_3^{*fta}(m) &= \frac{1}{10}[3E(a_3) - \sum_{i=1}^{3} E(c_i)]. \end{aligned}$$

[18] It is useful to note that while the choice of agreement is always unique, the transfers are not uniquely determined. Since our objective is to identify the optimal trade agreement this is not a major problem here.

[19] That is, all the cross partial derivatives of tariffs and second moments are zero, implying that each country's t_i is unaffected by the second moments.

Note that, for each country, the solution is "similar" to the solution in Case 1 above, except for the fact that here it is with respect to the expected values, rather than the actual values, of the random variables.

Now, define the corresponding Nash equilibrium expected welfare in each country, in Case 2, as:

$$M_i^{*y}(m) = M_i^y[t^{*y}(m), m],\ i = 1..3,\ y = sa, fta, \tag{20}$$

where $t^{*y}(m) = [t_1^{*y}(m), t_2^{*y}(m), t_3^{*y}(m)]$ is the vector of equilibrium tariffs. The Nash equilibrium expected welfare for country i can be easily calculated. It is given by:

$$\begin{aligned} M_i^{*y}(m) &= \sum_{n=1}^{3}(\beta_{nc}^{iy}\sigma_{nc}^2 + \phi_{nc}^{iy}\mu_{nc}^2) + \sum_{n=1}^{3}\left(\beta_{na}^{iy}\sigma_{na}^2 + \phi_{na}^{iy}\mu_{na}^2\right) + \\ & \sum_{n=1, n\neq k}^{3}\ \sum_{k=1, n\neq k}^{3}(\beta_{nk}^{iy}\sigma_{nkc} + \psi_{nk}^{iy}\mu_{nc}\mu_{kc}) + \sum_{n=1}^{3}\sum_{k=1}^{3}\gamma_{nk}^{iy}\mu_{na}\mu_{kc}, \end{aligned} \tag{21}$$

where the parameters β, ϕ, γ and ψ are given in Appendix 8.2. Thus, the Nash equilibrium expected welfare for Country i is a function of the first two moments. Moreover, it can be easily seen that it is (i) linear in all second moments and (ii) quadratic and convex in the first moments (from the convexity of the welfare functions in the random variables).

4.2 Case 2 Tariff Choice: Customs Union (cu)

When there is a CU between County 1 and Country 2 in the first stage, the countries' welfare functions are given by (15) and the corresponding expected welfare functions are

$$E[w_i(t^{cu}; a, c)] \equiv M_i^{cu}(t^{cu}, m),$$

where $t^{cu} = (t_{cu}^{cu},\ t_3^{cu})$.

Again, we assume that countries 1 and 2 choose their common tariff by maximizing (a social welfare function which is simply) the sum of their expected welfare:

$$M^{cu}(t_{cu}^{cu},\ t_3^{cu}; m) = M_1^{cu}(t_{cu}^{cu},\ t_3^{cu}; m) + M_2^{cu}(t_{cu}^{cu},\ t_3^{cu}; m).$$

The problems of the CU and Country 3 are, now, given by:

$$\underset{t_{cu}^{cu}}{\text{Max}}\{M^{cu}(t_{cu}^{cu},\ t_3^{cu}; m)\} \quad \text{and} \quad \underset{t_3^{cu}}{\text{Max}}\{M_3^{cu}(t_{cu}^{cu},\ t_3^{cu}; m)\}.$$

Ananlogously to the sa and fta cases, the $M^{cu}(t_{cu}^{cu},\ t_3^{cu}, m)$ and $M_3^{cu}(t_{cu}^{cu},\ t_3^{cu}, m)$ functions are strictly concave in their respective tariffs and each is quadratic in its "own" tariff while being additively separable in all tariffs. Again, the objective functions are linearly additively separable in tariffs and second moments, which implies that tariffs are unaffected by the second moments.

Let the Nash equilibrium tariffs be defined as $t_{cu}^{*cu}(m)$, $t_3^{*cu}(m)$. The explicit expressions for $t_{cu}^{*cu}(m)$,and $t_3^{*cu}(m)$ are given by:

$$
\begin{aligned}
t_{cu}^{*cu}(a,c) &= \frac{5}{38}\left[E(a_1)+E(a_2)\right]+\frac{1}{19}[E(c_1)+E(c_2)]-\frac{7}{19}E(c_3) \\
t_3^{*cu}(a,c) &= \frac{1}{10}[3E(a_3)-\sum_{i=1}^{3}E(c_i)].
\end{aligned}
\tag{22}
$$

These are the "same" as in Case 1, except that here we have the expected values of the random variables, instead of the random variables themselves. Consequently, the same properties hold with respect to the means.

The corresponding Nash equilibrium expected welfare in each country can be written as:

$$
M_i^{*cu}(m) \equiv M_i^{cu}[t_{cu}^{*cu}(m),\ t_3^{*cu}(m), m],\ i = 1...3. \tag{23}
$$

The Nash equilibrium expected welfare for Country i can now be easily calculated and is given by equations (21), with the superscript changed to cu instead of sa where the parameters are given in Appendix 8.2. Its properties are the same as in the sa case above.

4.3 Stage 1: The Choice of Trade Agreement

In stage 1, countries 1 and 2 choose a TA. Again, as in Case 1, we assume that they choose their TA by maximizing total expected welfare which, for any $y \in Y \equiv \{fta, cu, sa)$, is given by:

$$
M[y;m] \equiv \{M_1^{*y}(m)+K_1^y\}+\{M_2^{*y}(m)+K_2^y\} = M_1^{*y}(m)+M_2^{*y}(m),
$$

where $K_1^y + K_2^y = 0$. Thus, the countries select a TA, by comparing the total welfare corresponding to the three elements of Y. Specifically, let y^* be the chosen (equilibrium) agreement, Then,

Proposition 2 *The agreement y^* is chosen if and only if for all $y \in Y$: $M[y^*;m] > M[y;m]$ for all $y \neq y^*$*

Proof. (i) If $M[y^*;m] > M[y;m]$ for all $y \neq y^*$, there must be corresponding transfers, given by $K_i^{y^*}$, where $K_1^{y^*} + K_2^{y^*} = 0$, such that $M_i^{*y^*}(m) + K_i^{y^*} > M_i^{*y}(m) + K_i^y$, thus y^* is preferred to any another agreement. (ii) If y^* is chosen, it must be better than any other agreement for both countries. In other words, we must have: $M_i^{*y^*}(m) + K_i^{y^*} > M_i^{*y}(m) + K_i^y$, $i = 1,2$, for all $y \neq y^*$, where $K_1^{y^*} + K_2^{y^*} = 0$. Hence, $M[y^*;m] = M_1^{*y^*}(m) + K_1^{y^*} + M_2^{*y^*}(m) + K_2^{y^*} = M_1^{*y^*}(m) + M_2^{*y^*}(m) > M_1^{*y}(m) + M_2^{*y}(m) = M[y;m]$, for all $y \neq y^*$.[20] ■

5 Preferred Trade Agreements with Uncertainty

In this section we examine the effects of uncertainty on the choice of TAs in both the early and late resolution of uncertainty cases. To help illuminate the impact of uncertainty, we start with the benchmark case of no uncertainty.

[20] Again, it is useful to note that while the choice of agreement is always unique, the transfers are not uniquely determined.

5.1 Benchmark Case: No Uncertainty

First, note that with no uncertainty, all variances and covariances are zero. Thus, the timing of the resolution of uncertainty is irrelevant. Consequently, Cases 1 and 2 are identical. Second, to be able to compare the certainty and uncertainty cases, we need to assign values to the variables a_i and c_i in the no uncertainty case. We follow the standard practice and assume that the certain values are given by the means of the random variables.

In principle, given that we have closed form solutions for member country preferences over different TAs in a certain world, we can present these preferences in simple diagrams. But, since we have six parameters (the values of a_i and c_i, $i = 1...3$, taken as their means) there are twelve possible two-dimensional diagrams. Hence, for illustrative purposes, we provide two diagrams that show TA preferences for countries 1 and 2, drawn in their mean demands/costs space. The fixed values of the other four parameters are given in the Figures below.

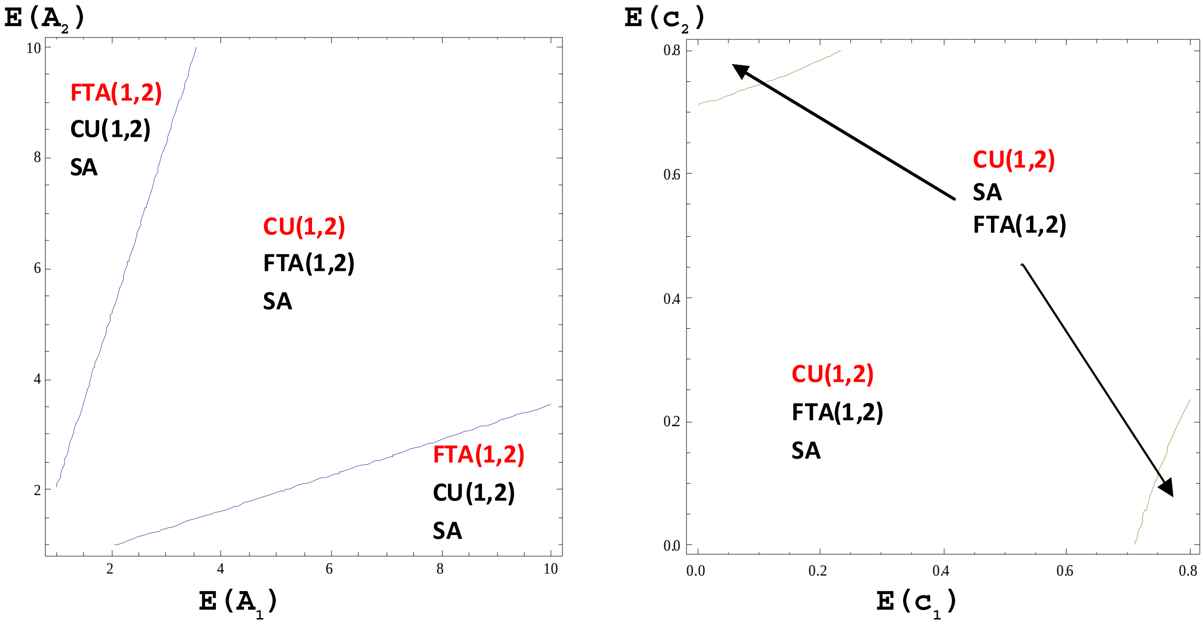

Figure 1: Member country preferences over trade agreement types when there is no uncertainty (all variances and covariances are zero). We assume: $\mu_{3a} = 1$ and $\mu_{1c} = \mu_{2c} = \mu_{3c} = \frac{1}{2}$ (left diagram); $\mu_{1a} = \mu_{2a} = \mu_{3a} = 1$ and $\mu_{3c} = \frac{1}{2}$ (right diagram).

When member countries have sufficiently similar demands (everything else being identical), they prefer *cu* to any other type of TA. When member demands diverge too much, however, fta is preferred. This can be seen in the left-hand panel of Figure 1. Note that member countries will continue to prefer *cu* when their demands are sufficiently similar even if their costs of production differ significantly. This can be seen in the right-hand panel of Figure 1. While members always prefer *cu* in this case, if production costs diverge sufficiently, members prefer *sa* to fta.

The intuition underlying the results in Figure 1 is as follows. When member countries are sufficiently similar, policy coordination in a CU is preferable since it allows members to extract additional rent from the excluded country compared to a FTA (or standing alone). This is because, under fta, a member country's optimal tariffs depend on both its own costs (negatively) and its partner's costs (positively). However, if countries are too dissimilar, then the common external tariff chosen under cu will be costly in the sense that it will most likely lie further away from each member country's preferred (unilateral) external tariff.

In our model, when there is no uncertainty, cu and fta are typically preferred by members to sa since they receive preferential treatment (zero tariff) under the former but not under the latter. Note, however, that the preference for sa over fta when member costs diverge arises from the fact that trade will expand as the (very) high-cost country imports more from the (very) low cost country. In this case, the zero tariffs associated with fta are very costly in terms of foregone tariff revenue and so sa is preferred.

5.2 The Effects of Uncertainty in Case 1

In this section we analyze how changes in the degree and nature of uncertainty (resolved early) influence member country preferences over different types of TAs. We examine both the impact and marginal effects of uncertainty. To investigate the impact effect, we compare preferences over TAs under uncertainty with the case when all second moments are zero, holding demand and cost parameters fixed at their *mean values.* To investigate the marginal effect we look at the consequences of small changes in variances and covariances. The marginal effects of uncertainty are obtained from comparative statics, using the explicit solutions given in Appendix 8.2. Given the complexity of the model (due to the: (i) multi-stage nature of the problem, (ii) number of countries (iii) number of random variables, (iv) existence of uncertainty), it is difficult to obtain global comparative statics results.[21] Nevertheless, we provide insights into the relationship between the nature of uncertainty and country welfare and consequently, the choice of TAs.

First, as an example, let us consider what happens when *demand* (but, for now, no cost) uncertainty is gradually introduced into the model, in a world of early uncertainty resolution. Figure 2 shows the cu/fta indifference loci for different $(\sigma_{1a}^2, \sigma_{2a}^2)$ pairs. For any $(\sigma_{1a}^2, \sigma_{2a}^2)$ pair, cu is preferred in the area "between" the two "arms" of the indifference locus, whereas fta is preferred outside of this area (sa is everywhere the least preferred). Note that the no-uncertainty case is captured by the (two arms of the) linear indifference locus corresponding to the pair: $\sigma_{1a}^2 = \sigma_{2a}^2 = 0$. As either demand variance increases, the indifference locus moves up (along the main diagonal), becoming curved. As Figure 2 shows, when either variance increases, countries 1 and 2 are more likely to prefer fta to cu (i.e. the former is preferred for a wider range of mean demand parameters).

[21] See Appendix 8.2 for a demonstration of this complexity.

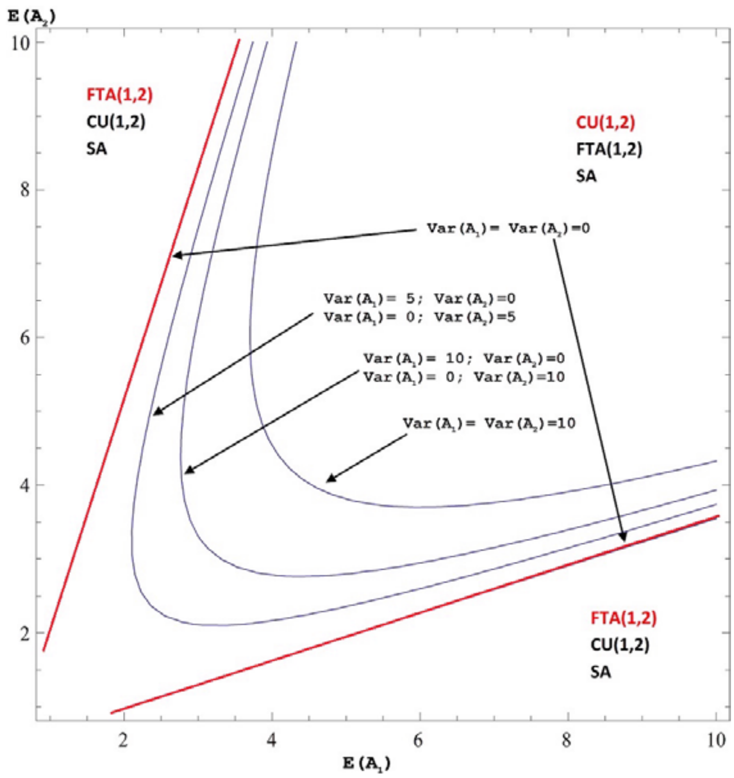

Figure 2: The impact of demand uncertainty on TA choice, in Case 1: $\sigma_{3a}^2 = \sigma_{ic}^2 = 0$, $\mu_{ic} = \frac{1}{2}$ $\forall i$; $\sigma_{ija} = \sigma_{ijc} = 0$ $\forall i, j$; $\mu_{3a} = 1$.

Figure 2 provides a simple example of the effects of uncertainty. But, even in the general model with uncertainty, we can still obtain closed form solutions for member country preferences over TAs. The presentation of our results, however, becomes much more complicated because we now have many more parameters (six first moments and 21 second moments from the symmetric $6X6$ variance/covariance matrix). Thus, for example, there are far too many possible two-dimensional diagrams. From an expositional view point it is, therefore, more *convenient* to present our results in propositions, where some of the parameters have been assigned fixed values. Specifically, in the remainder of this section, we assume that all countries are identical with respect to the mean values of their demand and cost parameters; that is, $\mu_{ia} = \mu_a$, $\mu_{ic} = \mu_c$, $i = 1...3$.[22] It is important to note that by taking the countries to be *symmetric*, our results are, *by construction*, biased in favour of *cu*. In other words, our conditions for preference for fta are too strict: we may be able to relax them for non-symmetric countries, so that fta may be preferred over an even larger set of parameter values.

We now derive two propositions that, for Case 1, relate the nature and degree of uncertainty to the preferred TAs of countries 1 and 2.[23]

Proposition 3 *Consider a world in which the only uncertainty relates to the demands of TA members and this*

[22] In addition to our assumtion in Section 2.1 that $Cov(a_i, c_i) = 0$.

[23] In the following propositions, we assume that lump sum transfers are possible between Countries 1 and 2.

uncertainty is resolved early (Case 1). Then, there exists a value v (which depends on $\mu_a, \mu_c, \sigma_{12a}$ and is defined in Appendix 8.3) such that: (i) the ranking of TAs is: cu $\succ$ fta $\succ$ sa if $\sigma_{1a}^2 + \sigma_{2a}^2 < v$, and fta $\succ$ cu $\succ$ sa if $\sigma_{1a}^2 + \sigma_{2a}^2 > v$, (ii) an increase in either σ_{1a}^2 or σ_{2a}^2 makes it more likely for fta to be preferred to cu, (iii) the attractiveness of fta relative to cu decreases with μ_a and σ_{12a}, but increases with μ_c.[24]

Proof. See Appendix 8.3. ■

Proposition 4 *Consider a world in which the only uncertainty relates the costs of TA members and this uncertainty is resolved early (Case 1). Then, there exists two values v_i, $i = 1, 2$, (which depend on $\mu_a, \mu_c, \sigma_{12c}$ and are defined in Appendix 8.4), such that: (i) the ranking of TAs is: (a) fta $\succ$ cu $\succ$ sa if $\sigma_{1c}^2 + \sigma_{2c}^2 < v_1$, (b) cu $\succ$ fta $\succ$ sa if $v_1 < \sigma_{1c}^2 + \sigma_{2c}^2 < v_2$, (c) cu $\succ$ sa $\succ$ fta if $\sigma_{1c}^2 + \sigma_{2c}^2 > v_2$, (ii) an increase in either σ_{1c}^2 or σ_{2c}^2 makes it less likely for fta to be preferred to either cu or sa, (iiia) ranking (a) becomes more likely when μ_c or σ_{12c}^2 increase, but it becomes less likely when μ_a increases, (iiib) ranking (b) becomes more likely when μ_a or σ_{12c}^2 increase, but less likely when μ_c increases, (iiic) ranking (c) becomes more likely when μ_c increases, but less likely when either μ_a or σ_{12c}^2 increase.*

Proof. See Appendix 8.4. ■

Propositions 3 and 4 imply that, when uncertainty is resolved early, TA members prefer:

(a) *fta* to a *cu* when either (i) demand uncertainty in member countries is sufficiently high or (ii) cost uncertainty in member countries is sufficiently low.

(b) *sa* to *fta* when cost uncertainty is sufficiently acute (the ranking of *fta* versus *sa* may be important because for reasons exogenous to the model, e.g., political, a customs union may not be feasible).

(c) *cu* to *sa* always.

To better appreciate the results above, it is useful to note that, in Case 1 (since optimal tariffs are functions of the random variables), a marginal change in any country's demand or cost variance has both tariff-independent and tariff-dependent effects on expected welfare (see Appendices 8.1 and 8.2 for the decomposition of the overall effect). It is easy to confirm that, for each country, the coefficients of the tariff-independent effects are identical (for all second moments) for each type of TA.[25] In other words, any change in the ranking of TA types (by member countries) arising from a marginal change in either $Var(a_i)$ or $Var(c_i)$ must be attributed to the tariff-dependent effect and hence, related to the different optimal tariffs chosen under each type of TA (which, in turn,

[24] Note that each strict preference becomes an indifference when we have an equality instead of an inequality (for the parameter range). The same is true in all the following propositions.

[25] See Appendix 8.1.

imply that changes in uncertainty affects these tariffs differently and furthermore, changes in the different tariffs affect welfare differently).[26]

Note that Propositions 3 and 4 explain both the rankings of different TAs and the effects of marginal changes in uncertainty on these rankings. Proposition 5 below further elaborates and helps us understand the effects of marginal changes in uncertainty. Specifically, calculating the magnitudes of the tariff-dependent effects of a marginal change in $Var(a_i)$ or $Var(c_i)$, $i = 1, 2$, on countries 1 and 2 (the TA members), reveals that:

Proposition 5 *In Case 1, a marginal increase in the demand or cost variance of a TA member: (i) increases their own preference for* cu *relative to* fta *while decreasing that of their partner, (ii) the magnitude of the latter (i.e. partner-country) effect is greater for marginal changes in demand uncertainty and smaller for marginal changes in cost uncertainty.*

Proof. See Appendix 8.5. ■

Given that TA members are assumed to maximize total joint expected welfare, and given our assumption that lump sum transfers are possible between members, Proposition 5 implies that a marginal increase in $Var(a_i)$, $i = 1, 2$ will make countries 1 and 2 jointly more likely to prefer fta over cu. On the other hand, a marginal increase in $Var(c_i)$, $i = 1, 2$ will make countries 1 and 2 jointly more likely to prefer cu over fta.

Of course, uncertainty can also change via a marginal change in (member) demand or cost covariances; that is, σ_{ija} or σ_{ijc}. Such changes also influence country welfare through both tariff-independent and tariff-dependent effects. Once again, for each country, the tariff-independent effects of a marginal change in covariance are identical across different TA types. In other words, any change in the welfare ranking of TAs by member countries must be due to the tariff-dependent effects and, hence, the related to the different optimal tariffs chosen under each agreement type.

Propositions 3 and 4 reflect the preceding discussion and confirm Proposition 5. In Proposition 3, as the variance of member demands increases, member countries increasingly prefer fta to cu. In Proposition 4, however, as member cost variances increase they are more likely to prefer a cu instead. Moreover, Propositions 3 and 4 demonstrate that, in Case 1, covariances play a crucial role in determining member preferences over TA types. In particular, fta is more likely to be preferred if either: (i) member demands are negatively correlated or (ii) member costs are positively correlated.

[26] This can be seen in Appendix 8.1 where differences in the $B_1^y s$ are due to differences in the $t^y s$, but also, differences in the B_1^y, functions themselves. In fact, it is straightforward to calculate the size of the tariff-dependent effect of a marginal change in uncertainty. First, the magnitude of the total effect of a marginal change in variance on any member country's welfare is given by the coefficient of the relevant a_i^2 or c_i^2 terms in the welfare functions derived in Appendix 8.2. For example, for a marginal increase in $Var(a_1)$, Country 1's welfare increases in total by $\frac{2}{5}$ in sa, $\frac{5}{14}$ in the case of fta and by $\frac{871}{2432}$ in the case of cu while Country 2's welfare increases in total by $\frac{1}{100}$ under sa, $\frac{4}{49}$ under fta and $\frac{167}{2432}$ under cu. The difference between these total effects and the tariff-independent effects yields the magnitudes of the tariff-dependent effects. For example, in the case of fta, a marginal increase in $Var(a_1)$ yields a tariff-dependent effect of $\frac{3}{224}$ (i.e., $\frac{5}{14} - \frac{11}{32}$) on Country 1 and $\frac{15}{784}$ (i.e., $\frac{4}{49} - \frac{1}{16}$) on Country 2.

Proposition 4 also shows that, in Case 1, sa will be preferred to fta (but not to cu) if member cost variances are sufficiently high and/or member costs are sufficiently negatively correlated. This result is analogous to the no-uncertainty case illustrated in Section 5.1. The more different are member costs, the greater the foregone tariff revenue implied by fta. In the case of cu, however, the welfare benefits of policy coordination still outweigh the welfare costs of this foregone tariff revenue.

5.3 The Effects of Uncertainty in Case 2

Since, in Case 2, tariffs depend only on the means, it is clear that, here, marginal changes in uncertainty only have a tariff-independent effect, but no tariff-dependent effects on (expected) country welfare. In Case 2 (unlike in Case 1), therefore, tariffs play no role when there is a marginal change in the degree or nature of uncertainty. As such, the comparative static (expected) welfare impacts of such changes are identical across all TA types. This is confirmed by inspecting the equilibrium welfare functions in Appendix 8.2 and noting that the relevant coefficients on the σ_{ia}^2, σ_{ia}^2 and σ_{ijc} terms are identical for all TA types. Proposition 6 summarizes these results.

Proposition 6 *Consider a world in which there is demand and/or cost uncertainty and this uncertainty is resolved late (Case 2). The ranking of TAs is, then,* $cu \succ fta \succ sa$, $\forall\ a$, c, *and for all* σ_{ia}^2, σ_{jc}^2, σ_{ija}, $\sigma_{ijc}, \forall i, j$.

Proof. See Appendix 8.6. ■

Proposition 6 shows that, in Case 2, the welfare ranking of different TA types by prospective member countries does not change with the nature of uncertainty. In particular, cu is always the most preferred TA type and sa is always the least preferred. Intuitively, any option value associated with TA flexibility is less prominent in Case 2 than in Case 1 since, in the former case, member countries do not have the opportunity to choose their tariffs optimally after the uncertainty has been resolved.

6 Preferred Timing of Tariff Choice in a Trade Agreement

In this section, we investigate the preferred *timing* of tariff decisions by TA members (rather than the preferred agreements themselves). As in Section 5, we take all countries to be identical with respect to the mean value of the demand and production cost parameters, i.e. $\mu_{ia} = \mu_a$ and $\mu_{ic} = \mu_c$. The second moments, however, can differ across countries.

We derive two propositions. Proposition 7 considers member-country preferences over the timing of tariff choice in a TA when there is only demand uncertainty. Proposition 8 relates to the timing of tariff choice in the presence of cost uncertainty only.[27] Let $y(j)$ denote an agreement of type $y = sa, fta, cu$ in case $j = 1, 2$ (early and late resolution of uncertainty).

[27] In this section, for simplicity we also assume that $\sigma_{12c} = 0$.

Proposition 7 *Consider a world in which the only uncertainty relates to the demands of TA members. Then, there exists values* $g_i,\ i = 1...4$ *(which depend on* μ_a, μ_c *and are defined in Appendix 8.7), such that the ranking of TAs is as follows:*

$$cu(1) \succ cu(2) \succ fta(1) \succ fta(2) \succ sa(1) \succ sa(2) \text{ if } \quad \sigma_{1a}^2 + \sigma_{2a}^2 < g_1$$
$$cu(1) \succ fta(1) \succ cu(2) \succ fta(2) \succ sa(1) \succ sa(2) \text{ if } \quad g_1 < \sigma_{1a}^2 + \sigma_{2a}^2 < g_2$$
$$fta(1) \succ cu(1) \succ cu(2) \succ fta(2) \succ sa(1) \succ sa(2) \text{ if } \quad g_2 < \sigma_{1a}^2 + \sigma_{2a}^2 < g_3$$
$$fta(1) \succ cu(1) \succ cu(2) \succ sa(1) \succ fta(2) \succ sa(2) \text{ if } \quad g_3 < \sigma_{1a}^2 + \sigma_{2a}^2 < g_4$$
$$fta(1) \succ cu(1) \succ sa(1) \succ cu(2) \succ fta(2) \succ sa(2) \text{ if } \quad \sigma_{1a}^2 + \sigma_{2a}^2 > g_4.$$

Proof. See Appendix 8.7. ■

Proposition 8 *Consider a world in which the only uncertainty relates to the costs of TA members. Then, there exists values* $b_i,\ i = 1...4$ *(which depend on* μ_a, μ_c *and are defined in Appendix 8.8), such that the ranking of TAs is as follows:*

$$cu(2) \succ cu(1) \succ fta(2) \succ fta(1) \succ sa(2) \succ sa(1) \text{ if } \ \sigma_{1c}^2 + \sigma_{2c}^2 < b_1$$
$$cu(2) \succ fta(2) \succ cu(1) \succ fta(1) \succ sa(2) \succ sa(1) \text{ if } \ b_1 < \sigma_{1c}^2 + \sigma_{2c}^2 < b_2$$
$$cu(2) \succ fta(2) \succ cu(1) \succ sa(2) \succ fta(1) \succ sa(1) \text{ if } \ b_2 < \sigma_{1c}^2 + \sigma_{2c}^2 < b_3$$
$$cu(2) \succ fta(2) \succ sa(2) \succ cu(1) \succ fta(1) \succ sa(1) \text{ if } \ b_3 < \sigma_{1c}^2 + \sigma_{2c}^2 < b_4$$
$$cu(2) \succ fta(2) \succ sa(2) \succ cu(1) \succ sa(1) \succ fta(1) \text{ if } \ \sigma_{1c}^2 + \sigma_{2c}^2 > b_4.$$

Proof. See Appendix 8.8. ■

Propositions 7 and 8 demonstrate that, in the presence of little (or no) uncertainty, member countries are predisposed to prefer *cu* most and *sa* least regardless of the timing of the resolution of uncertainty. The option value of TA flexibility is very low in such cases.

As uncertainty rises, these preference orderings alter. Proposition 7 shows that as demand uncertainty increases, TA members increasingly prefer *any* TA in which they can choose tariffs after the resolution of uncertainty. When demand uncertainty is sufficiently high, countries even prefer standing alone to any TA in which tariffs are chosen before the resolution of uncertainty. These results once again reflect the fact that the option value associated with TA flexibility is most valuable if member countries have the opportunity to choose their tariffs optimally after the uncertainty has been resolved (i.e. as in Case 1). On the other hand, as cost uncertainty rises, Proposition 8 shows that prospective TA members increasingly prefer *any* TA in which tariffs are chosen before the resolution of uncertainty.

7 Conclusion

This paper analyzes how the nature of uncertainty, as well as the timing of its resolution, influence the choice of TA's. Using a partial equilibrium, imperfect competition model of trade we demonstrate that, provided members can make some optimizing decisions after uncertainty is resolved, there is an option value associated with all types of TA. In deciding which type of TA to form, member countries balance the option value of the TA against all the other costs and benefits associated with policy coordination and free trade that typically arise when TAs form. Contrary to most of the existing theoretical literature on regional TAs, but consistent with observed behavior, we show that countries will often prefer shallower trade integration to deeper trade integration. In particular, when uncertainty is resolved early, a FTA will be chosen in preference to a CU when member demand uncertainty is sufficiently high or member cost uncertainty is sufficiently low. When uncertainty is resolved late, we find that prospective member preferences over different TA types are invariant to the nature of uncertainty; a CU is always preferred. Our results also have implications for the preferred timing of tariff choice by prospective TA members. As their demand uncertainty increases, prospective members are more likely to prefer any TA in which they can choose tariffs after the resolution of uncertainty. On the other hand, as their cost uncertainty rises, prospective members are more likely to prefer any TA in which they choose tariffs before the resolution of uncertainty.

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8 Appendix

8.1 Explicit solutions for Country 1 welfare, $w_1(t^y; a, c)$, Case 1

Let us define: $A_1(a,c) \equiv \frac{11}{32}{a_1}^2 + \frac{1}{16}\sum_{k\neq 1}{a_k}^2 + \frac{55}{32}{c_1}^2 - \frac{3}{8}\sum_{k\neq 1} c_1 a_k + \frac{1}{8}\sum_{h\neq 1}\sum_{k\neq 1} c_h a_k - \frac{17}{16}\sum_{k\neq 1} c_1 c_k + \frac{7}{32}\sum_{h\neq 1}\sum_{k\neq 1} c_h c_k - \frac{9}{16} a_1 c_1 - \frac{1}{16}\sum_{k\neq 1} c_k a_1,$

$$B_1^{sa}(t^{sa}; a, c) \equiv \tfrac{3}{8} a_1 t_1^{sa} - \tfrac{1}{8}\sum_{j=1}^{3} c_j t_1^{sa} - \tfrac{5}{8}\left(t_1^{sa}\right)^2 + \tfrac{1}{4}\sum_{k\neq 1}\left(t_k^{sa}\right)^2 - \tfrac{1}{4}\sum_{k\neq 1} a_k t_k^{sa} + \tfrac{3}{4}\sum_{k\neq 1} c_1 t_k^{sa} - \tfrac{1}{4}\sum_{h\neq 1}\sum_{k\neq 1} c_h t_k^{sa}$$

$B_1^{fta}(t^{fta};a,c) \equiv \frac{3}{16}a_1t_1^{fta} - \frac{1}{16}c_1t_1^{fta} + \frac{7}{16}c_2t_1^{fta} - \frac{9}{16}c_3t_1^{fta} - \frac{21}{32}t_1^{fta2} + \frac{1}{16}t_2^{fta2} + \frac{1}{4}t_3^{fta2} + \frac{1}{8}a_2t_2^{fta} - \frac{1}{4}a_3t_3^{fta} - \frac{3}{8}c_1t_2^{fta} + \frac{3}{4}c_1t_3^{fta} + \frac{1}{8}\sum_{h\neq i}c_ht_2^{fta} - \frac{1}{4}\sum_{h\neq 1}c_ht_3^{fta}$

$B_1^{cu}(t^{cu};a,c) \equiv \frac{3}{16}a_1t_{cu}^{cu} - \frac{7}{16}c_1t_{cu}^{cu} + \frac{9}{16}c_2t_{cu}^{cu} - \frac{7}{16}c_3t_{cu}^{cu} - \frac{19}{32}\left(t_{cu}^{cu}\right)^2 + \frac{1}{4}\left(t_3^{cu}\right)^2 + \frac{1}{8}a_2t_{cu}^{cu} - \frac{1}{4}a_3t_3^{cu} + \frac{3}{4}c_1t_3^{cu} - \frac{1}{4}\sum_{h\neq 1}c_ht_3^{cu}$

Then, the explicit expressions for Country $1's$ welfare as a function of tariffs, in Case 1, (equations (9), (16), with fta/cu between Countries 1 and 2), $w_1^y(t^y;a,c)$, $y = sa, fta, cu$, is given by: $w_1^{sa} = A_1(a,c) + B_1^{sa}(t^{sa};a,c)$, $w_1^{fta} = A_1(a,c) + B_1^{fta}(t^{fta};a,c)$ and $w_1^{cu} = A_1(a,c) + B_1^{cu}(t^{cu};a,c)$.

Note that the $B_1^y(t^y;a,c)$ functions are concave in Country 1's tariff, spareable in all tariffs and linear in all the random variables. But, in addition, the $B_1^y(t^y;a,c)$ functions themselves also differ for different $y's$ (TAs), namely: for equal values of $t^y = t$, we have: $B_1^z(t;a,c) \neq B_1^y(t;a,c)$, if $z \neq y$.

8.2 Explicit solutions for equilibrium member-country welfare $(E(w_1^{*y}),\ M_1^{*y})$: Case 1 and 2

The solutions for equilibrium expected welfare of Country 1 for each TA, in Cases 1 and 2, are given below. These provide the parameter values in: equations(13), the corresponding equations for fta and cu in Case 1 and equations (21) in Case 2 (for the sa, fta and cu cases). The solutions are similar for Country 2.

Case 1:

$E(w_1^{*sa}) \equiv E[w_i(t^{*sa}(a,c);a,c)] = E[\frac{2}{5}{a_1}^2 + \frac{1}{100}{a_2}^2 + \frac{1}{100}{a_3}^2 - \frac{3}{5}c_1a_1 - \frac{7}{50}c_1a_2 - \frac{7}{50}c_1a_3 - \frac{1}{10}c_2a_1 + \frac{3}{50}c_2a_2 + \frac{3}{50}c_2a_3 - \frac{1}{10}c_3a_1 + \frac{3}{50}c_3a_2 + \frac{3}{50}c_3a_3 + \frac{79}{50}{c_1}^2 + \frac{7}{25}{c_2}^2 + \frac{7}{25}{c_3}^2 - \frac{57}{50}c_1c_2 - \frac{57}{50}c_1c_3 + \frac{14}{25}c_2c_3]$

$E(w_1^{*fta}) \equiv E[w_i(t^{*fta}(a,c);a,c)] = E[\frac{5}{14}{a_1}^2 + \frac{4}{49}{a_2}^2 + \frac{1}{100}{a_3}^2 - \frac{4}{7}c_1a_1 - \frac{8}{21}c_1a_2 - \frac{7}{50}c_1a_3 + \frac{20}{147}c_2a_2 + \frac{3}{50}c_2a_3 - \frac{1}{7}c_3a_1 + \frac{4}{49}c_3a_2 + \frac{3}{50}c_3a_3 + \frac{9637}{6300}{c_1}^2 + \frac{13819}{44100}{c_2}^2 + \frac{1591}{4900}{c_3}^2 - \frac{3373}{3150}c_1c_2 - \frac{941}{1050}c_1c_3 + \frac{1823}{7350}c_2c_3]$

$E(w_1^{*cu}) \equiv E[w_i(t^{*cu}(a,c);a,c)] = E[\frac{871}{2432}{a_1}^2 + \frac{167}{2432}{a_2}^2 + \frac{1}{100}{a_3}^2 + \frac{25}{1216}a_1a_2 - \frac{47}{76}c_1a_1 - \frac{33}{76}c_1a_2 - \frac{7}{50}c_1a_3 - \frac{1}{76}c_2a_1 + \frac{15}{76}c_2a_2 + \frac{3}{50}c_2a_3 - \frac{5}{38}c_3a_1 + \frac{3}{38}c_3a_2 + \frac{3}{50}c_3a_3 + \frac{3081}{1900}{c_1}^2 + \frac{521}{1900}{c_2}^2 + \frac{621}{1900}{c_3}^2 - \frac{1049}{950}c_1c_2 - \frac{899}{950}c_1c_3 + \frac{271}{950}c_2c_3]$

Tariff-independent and Tariff-dependent Effects of Uncertainty:

For example, consider the effect of σ_{1c} on $E[w_1^{*y}]$, $y = sa, fta, cu$. First note that $E[w_1^{*y}]$ is given by (using the expressions for w_1^y, in the previous Appendix): $E[w_i(t^{*y}(a,c);a,c)] = E(A_1) + E[B_1^y(t^{*y};a,c)]$, where the random variables are given by equation (1) above. Thus (using equation (1)), a change in σ_{1c} has both tariff-independent and tariff-dependent effects on expected welfare. This is can be seen as follows: $\frac{dE[w_1(t^{*y}(a,c);a,c)]}{d\sigma_{1c}} = \frac{\partial E[w_1(t^{*y}(a,c);a,c)]}{\partial\sigma_{1c}} + \frac{\partial E[w_1(t^{*y}(a,c);a,c)]}{\partial t^{*sa}(a,c)}\frac{\partial t^{*y}(a,c)}{\partial c_1}\frac{dc_1}{d\sigma_{1c}} = \frac{\partial E[A_1]}{\partial\sigma_{1c}} + [\frac{\partial E[B_1^y(t^{*y};a,c)]}{\partial c_1} + \frac{\partial E[B_1^y(t^{*y};a,c)]}{\partial t^{*y}(a,c)}\frac{\partial t^{*y}(a,c)}{\partial c_1}]\frac{dc_1}{d\sigma_{1c}} \equiv$ *tariff-independent effect+ tariff-dependent effect.*[28] Note that since every t_i^{*y} includes all $c_i's$, but not all $a_i's$ (sa and fta cases include only the "own" demand parameter, whereas cu includes both members' demand parameters), cost uncertainty effects are more complex than demand uncertainty effects.[29]

[28] Note that $dE[w_1(t^{*sa}(a,c);a,c)]/d\sigma_{1c} = dconsmer\ surplus/d\sigma_{1c} + dtotal\ profits/d\sigma_{1c} + dtariff\ revenues/d\sigma_{1c}$.

[29] For example, in Appendix 8.1, $E[B_1^{sa}(t^{sa};a,c)]$, contains two terms $(E(\frac{3}{8}a_1t_1^{sa}), -E[\frac{5}{8}\left(t_1^{sa}\right)^2])$ involving σ_{1a}, but σ_{1c} is included

Case 2:

$M_1^{*sa} = \frac{55}{32}\left(\sigma_{1c}^2 + \mu_{1c}^2\right) + \frac{7}{32}\left(\sigma_{2c}^2 + \mu_{2c}^2\right) + \frac{7}{32}\left(\sigma_{3c}^2 + \mu_{3c}^2\right) + \frac{11}{32}\left(\sigma_{1a}^2 + \mu_{1a}^2\right) + \frac{1}{16}\left(\sigma_{2a}^2 + \mu_{2a}^2\right) + \frac{1}{16}\left(\sigma_{3a}^2 + \mu_{3a}^2\right) - \frac{17}{16}\left(\sigma_{12c} + \mu_{1c}\mu_{2c}\right) - \frac{17}{16}\left(\sigma_{13c} + \mu_{1c}\mu_{3c}\right) + \frac{7}{16}\left(\sigma_{23c} + \mu_{2c}\mu_{3c}\right) + \frac{9}{160}\mu_{1a}^2 - \frac{21}{400}\mu_{2a}^2 - \frac{21}{400}\mu_{3a}^2 - \frac{3}{5}\mu_{1a}\mu_{1c} - \frac{7}{50}\mu_{2a}\mu_{1c} - \frac{7}{50}\mu_{3a}\mu_{1c} - \frac{111}{800}\mu_{1c}^2 - \frac{1}{10}\mu_{1a}\mu_{2c} + \frac{3}{50}\mu_{2a}\mu_{2c} + \frac{3}{50}\mu_{3a}\mu_{2c} - \frac{31}{400}\mu_{1c}\mu_{2c} + \frac{49}{800}\mu_{2c}^2 - \frac{1}{10}\mu_{1a}\mu_{3c} + \frac{3}{50}\mu_{2a}\mu_{3c} + \frac{3}{50}\mu_{3a}\mu_{3c} - \frac{31}{400}\mu_{1c}\mu_{3c} + \frac{49}{400}\mu_{2c}\mu_{3c} + \frac{49}{800}\mu_{3c}^2$

$M_1^{*fta} = \frac{55}{32}\left(\sigma_{1c}^2 + \mu_{1c}^2\right) + \frac{7}{32}\left(\sigma_{2c}^2 + \mu_{2c}^2\right) + \frac{7}{32}\left(\sigma_{3c}^2 + \mu_{3c}^2\right) + \frac{11}{32}\left(\sigma_{1a}^2 + \mu_{1a}^2\right) + \frac{1}{16}\left(\sigma_{2a}^2 + \mu_{2a}^2\right) + \frac{1}{16}\left(\sigma_{3a}^2 + \mu_{3a}^2\right) - \frac{17}{16}\left(\sigma_{12c} + \mu_{1c}\mu_{2c}\right) - \frac{17}{16}\left(\sigma_{13c} + \mu_{1c}\mu_{3c}\right) + \frac{7}{16}\left(\sigma_{23c} + \mu_{2c}\mu_{3c}\right) + \frac{3}{224}\mu_{1a}^2 + \frac{15}{784}\mu_{2a}^2 - \frac{21}{400}\mu_{3a}^2 - \frac{4}{7}\mu_{1a}\mu_{1c} - \frac{8}{21}\mu_{2a}\mu_{1c} - \frac{7}{50}\mu_{3a}\mu_{1c} - \frac{9529}{50400}\mu_{1c}^2 + \frac{20}{147}\mu_{2a}\mu_{2c} + \frac{3}{50}\mu_{3a}\mu_{2c} - \frac{209}{25200}\mu_{1c}\mu_{2c} + \frac{33377}{352800}\mu_{2c}^2 - \frac{1}{7}\mu_{1a}\mu_{3c} + \frac{4}{49}\mu_{2a}\mu_{3c} + \frac{3}{50}\mu_{3a}\mu_{3c} + \frac{1397}{8400}\mu_{1c}\mu_{3c} - \frac{11141}{58800}\mu_{2c}\mu_{3c} + \frac{4153}{39200}\mu_{3c}^2$

$M_1^{*cu} = \frac{55}{32}\left(\sigma_{1c}^2 + \mu_{1c}^2\right) + \frac{7}{32}\left(\sigma_{2c}^2 + \mu_{2c}^2\right) + \frac{7}{32}\left(\sigma_{3c}^2 + \mu_{3c}^2\right) + \frac{11}{32}\left(\sigma_{1a}^2 + \mu_{1a}^2\right) + \frac{1}{16}\left(\sigma_{2a}^2 + \mu_{2a}^2\right) + \frac{1}{16}\left(\sigma_{3a}^2 + \mu_{3a}^2\right) - \frac{17}{16}\left(\sigma_{12c} + \mu_{1c}\mu_{2c}\right) - \frac{17}{16}\left(\sigma_{13c} + \mu_{1c}\mu_{3c}\right) + \frac{7}{16}\left(\sigma_{23c} + \mu_{2c}\mu_{3c}\right) + \frac{35}{2432}\mu_{1a}^2 + \frac{15}{2432}\mu_{2a}^2 - \frac{21}{400}\mu_{3a}^2 - \frac{47}{76}\mu_{1a}\mu_{1c} + \frac{25}{1216}\mu_{1a}\mu_{2a} - + \frac{7}{16}\left(\sigma_{23c} + \mu_{2c}\mu_{3c}\right) + \frac{35}{2432}\mu_{1a}^2 + \frac{15}{2432}\mu_{2a}^2 - \frac{21}{400}\mu_{3a}^2 - \frac{47}{76}\mu_{1a}\mu_{1c} + \frac{25}{1216}\mu_{1a}\mu_{2a} - \frac{33}{76}\mu_{2a}\mu_{1c} - \frac{7}{50}\mu_{3a}\mu_{1c} - \frac{1477}{15200}\mu_{1c}^2 + \frac{1}{76}\mu_{1a}\mu_{2c} + \frac{15}{76}\mu_{2a}\mu_{2c} + \frac{3}{50}\mu_{3a}\mu_{2c} - \frac{317}{7600}\mu_{1c}\mu_{2c} + \frac{843}{15200}\mu_{2c}^2 - \frac{5}{38}\mu_{1a}\mu_{3c} + \frac{3}{38}\mu_{2a}\mu_{3c} + \frac{3}{50}\mu_{3a}\mu_{3c} + \frac{883}{7600}\mu_{1c}\mu_{3c} - \frac{1157}{7600}\mu_{2c}\mu_{3c} + \frac{1643}{15200}\mu_{3c}^2.$

8.3 Proof of Proposition 3

Given the sums of expected welfare of Countries 1 and 2, in Cases 1 and 2 (defined by $W[y;m]$, and $M[y;m]$ in Sections 3.3 sand 4.3), we define the differences in Countries' 1 and 2 total expected welfare, for $y = sa, fta, cu$, as follows.[30] In case 1, let: $D^1_{cu\_fta} = W[cu,m] - W\,[fta,m]\,,\ D^1_{cu\_sa} = W[cu,m] - W\,[sa,m]$ and $D^1_{fta\_sa} = W[fta,m] - W\,[sa,m]\,.$ Similarly, in case 2, let: $D^2_{cu\_fta} = M[cu,m] - M\,[fta,m]\,,\ D^2_{cu\_sa} = M[cu,m] - M\,[sa,m]$ and $D^2_{fta\_sa} = M[fta,m] - M\,[sa,m]\,.$

Assume that there is only demand uncertainty. Define $v = \frac{2450}{713}\sigma_{12a} + \frac{1024}{713}\left[\mu_a - \mu_c\right]^2$. Therefore, for Case 1 and assuming that $\mu_{ia} = \mu_a$ and $\mu_{ic} = \mu_c\ \forall i$, it is straightforward to show that $\forall a, c$: $D^1_{cu\_fta} > 0$ if $\sigma_{1a}^2 + \sigma_{2a}^2 < v$, $D^1_{cu\_sa} > 0$ if $\sigma_{1a}^2 + \sigma_{2a}^2 > -\frac{1250}{511}\sigma_{12a} - \frac{2272}{511}\left[\mu_a - \mu_c\right]^2$ and $D^1_{fta\_sa} > 0$ since $\sigma_{1a}^2 + \sigma_{2a}^2 > -2\left[\mu_a - \mu_c\right]^2$. From the definition of v it is clear that $\partial v / \partial \mu_a > 0,\ \partial v / \partial \mu_c < 0,\ \partial v / \partial \sigma_{12a} > 0$, which proves part (iii). ■

8.4 Proof of Proposition 4

Consider Case 1, where there is only cost uncertainty. Define $v_1 = \frac{280}{221}\sigma_{12c} - \frac{72}{221}\left[\mu_a - \mu_c\right]^2$, $v_2 = \frac{3052}{374}\sigma_{12c} + \frac{1269}{374}\left[\mu_a - \mu_c\right]^2$. It is straightforward to show that $\forall a, c$: $D^1_{cu\_fta} > 0$ if $\sigma_{1c}^2 + \sigma_{2c}^2 > v_1$. $D^1_{cu\_sa} > 0$ if $\sigma_{1c}^2 + \sigma_{2c}^2 > -2\sigma_{12c} - \frac{71}{34}\left[\mu_a - \mu_c\right]^2$. $D^1_{fta\_sa} > 0$ if $\sigma_{1c}^2 + \sigma_{2c}^2 < v_2$. The effects of changes in μ_a. μ_c, σ_{12a} on v_1 and v_2 (thus,

in six terms $(-\frac{1}{8}E[c_1 t_1^{sa}], -\frac{5}{8}\left(t_1^{sa}\right)^2, \frac{1}{4}\sum_{k\neq 1}\left(t_k^{sa}\right)^2, \frac{3}{4}\sum_{k\neq 1} c_1 t_k^{sa})$.

[30] Note that fta and cu can only be formed by Countries 1 and 2.

the range of the three regions) follow directly from the definitions of v_1 and v_2.■

8.5 Proof of Proposition 5

Consider Case 1. Let $D^{i1}_{cu\_fta} = E[w_1^{*cu}(a,c)] - E[w_1^{*fta}(a,c)]$. It can be shown that for $i,j=1,2$: $\frac{\partial D^{i1}_{cu\_fta}}{\partial \sigma^2_{ia}} > 0$, $\frac{\partial D^{i1}_{cu\_fta}}{\partial \sigma^2_{ic}} > 0$, $\frac{\partial D^{j\neq i1}_{cu\_fta}}{\partial \sigma^2_{ia}} < 0$ and $\frac{\partial D^{j\neq i1}_{cu\_fta}}{\partial \sigma^2_{ic}} < 0$. Moreover, it can also be shown that for $i,j=1,2$: $\frac{\partial D^{i1}_{cu\_fta}}{\partial \sigma^2_{ia}} < \frac{\partial D^{j\neq i1}_{cu\_fta}}{\partial \sigma^2_{ia}}$ and $\frac{\partial D^{i1}_{cu\_fta}}{\partial \sigma^2_{ic}} > \frac{\partial D^{j\neq i1}_{cu\_fta}}{\partial \sigma^2_{ic}}$.■

8.6 Proof of Proposition 6

For Case 2 we have: (i) $D^2_{cu\_fta} = \frac{16}{931}\left[\mu_a - \mu_c\right]^2 \geq 0$, $\forall\ a,c$ and for all σ^2_{ia}, σ^2_{jc}, σ_{ija}, $\sigma_{ijc}, \forall i,j$. (ii) $D^2_{cu\_sa} = \frac{71}{950}\left[\mu_a - \mu_c\right]^2 \geq 0$, $\forall\ a,c$ and for all σ^2_{ia}, σ^2_{jc}, σ_{ija}, $\sigma_{ijc}, \forall i,j$. (iii) $D^2_{fta\_sa} = \frac{141}{2450}\left[\mu_a - \mu_c\right]^2 \geq 0$, $\forall\ a,c$ and for all σ^2_{ia}, σ^2_{jc}, σ_{ija}, $\sigma_{ijc}, \forall i,j$.■

8.7 Proof of Proposition 7

Define $g_1 \equiv \frac{512}{969}\left[\mu_a - \mu_c\right]^2$, $g_2 \equiv v$, $g_3 \equiv \frac{752}{49}\left[\mu_a - \mu_c\right]^2$, $g_4 \equiv \frac{1136}{57}\left[\mu_a - \mu_c\right]^2$. With demand uncertainty:

(1) $W[cu,m] - M[cu;m] = \frac{25}{1216}\left[\sigma^2_{1a} + \sigma^2_{2a} + 2\sigma_{12a}\right] \geq 0$, (2) $W[cu,m] - M[fta;m] = \frac{1024[\mu_a-\mu_c]^2+1225\left[\sigma^2_{1a}+\sigma^2_{2a}\right]+24502\sigma_{12a}}{59584} \geq 0$, (3) $W[cu,m] - M[sa;m] = \frac{2272[\mu_a-\mu_c]^2+625\left[\sigma^2_{1a}+\sigma^2_{2a}\right]+1250\sigma_{12a}}{30400} \geq 0$, (4) $W[fta,m] - M[cu;m] = \frac{-512[\mu_a-\mu_c]^2+969\left[\sigma^2_{1a}+\sigma^2_{2a}\right]}{29792}\begin{pmatrix}\geq\\<\end{pmatrix}0$, if $\sigma^2_{1a}+\sigma^2_{2a}\begin{pmatrix}\geq\\<\end{pmatrix}g_1$, (5) $W[fta,m] - M[fta;m] = \frac{51}{1568}\left[\sigma^2_{1a} + \sigma^2_{2a}\right] \geq 0$, (6) $W[fta,m] - M[sa;m] = \frac{3\left\{752[\mu_a-\mu_c]^2+425\left[\sigma^2_{1a}+\sigma^2_{2a}\right]\right\}}{39200} \geq 0$, (7) $W[sa,m] - M[cu;m] = \frac{-1136[\mu_a-\mu_c]^2+57\left[\sigma^2_{1a}+\sigma^2_{2a}\right]}{15200}\begin{pmatrix}\geq\\<\end{pmatrix}0$, if $\sigma^2_{1a}+\sigma^2_{2a}\begin{pmatrix}\geq\\<\end{pmatrix}g_4$, (8) $W[sa,m] - M[fta;m] = \frac{3\left\{-752[\mu_a-\mu_c]^2+49\left[\sigma^2_{1a}+\sigma^2_{2a}\right]\right\}}{39200}\begin{pmatrix}\geq\\<\end{pmatrix}0$, if $\sigma^2_{1a}+\sigma^2_{2a}\begin{pmatrix}\geq\\<\end{pmatrix}g_3$, (9) $W[sa,m] - M[sa;m] = \frac{3}{800}\left[\sigma^2_{1a} + \sigma^2_{2a}\right] \geq 0$. The proposition follows directly from these conditions and from those in Propositions 3 and 6.■

8.8 Proof of Proposition 8

Define $b_1 \equiv \frac{6400}{15533}\left[\mu_a - \mu_c\right]^2$, $b_2 \equiv \frac{10152}{16633}\left[\mu_a - \mu_c\right]^2$, $b_3 \equiv \frac{568}{317}\left[\mu_a - \mu_c\right]^2$, $b_4 \equiv v_2 - \frac{3052}{374}\sigma_{12c}$.With only cost uncertainty: (1) $W[cu,m] - M[cu;m] = -\frac{317}{7600}\left[\sigma^2_{1c} + \sigma^2_{2c}\right] \leq 0$, (2) $W[cu,m] - M[fta;m] = \frac{6400[\mu_a-\mu_c]^2-15533\left[\sigma^2_{1c}+\sigma^2_{2c}\right]}{372400}\begin{pmatrix}\geq\\<\end{pmatrix}0$ if $\sigma^2_{1c}+\sigma^2_{2c}\begin{pmatrix}\leq\\>\end{pmatrix}b_1$, (3) $W[cu,m] - M[sa;m] = \frac{568[\mu_a-\mu_c]^2-317\left[\sigma^2_{1c}+\sigma^2_{2c}\right]}{7600}\begin{pmatrix}\geq\\<\end{pmatrix}0$ if $\sigma^2_{1c}+\sigma^2_{2c}\begin{pmatrix}\leq\\>\end{pmatrix}b_3$, (4) $W[fta,m] - M[cu;m] = \frac{-57600[\mu_a-\mu_c]^2-316597\left[\sigma^2_{1c}+\sigma^2_{2c}\right]}{3351600} \leq 0$, (5) $W[fta,m] - M[fta;m] = -\frac{16633\left[\sigma^2_{1c}+\sigma^2_{2c}\right]}{176400} \leq 0$, (6) $W[fta,m] - M[sa;m] = \frac{10152[\mu_a-\mu_c]^2-16633\left[\sigma^2_{1c}+\sigma^2_{2c}\right]}{176400}\begin{pmatrix}\geq\\<\end{pmatrix}0$ if $\sigma^2_{1c}+\sigma^2_{2c}\begin{pmatrix}\leq\\>\end{pmatrix}b_2$, (7) $W[sa,m] - M[cu;m] = \frac{-568[\mu_a-\mu_c]^2-589\left[\sigma^2_{1c}+\sigma^2_{2c}\right]}{7600} \leq 0$, (8) $W[sa,m] - M[fta;m] = \frac{-1128[\mu_a-\mu_c]^2-1519\left[\sigma^2_{1c}+\sigma^2_{2c}\right]}{19600} \leq 0$, (9) $W[sa,m] - M[sa;m] = -\frac{31}{400}\left[\sigma^2_{1c} + \sigma^2_{2c}\right] \leq 0$. The proposition follows directly from these conditions and from those in Propositions 4 and 6.■