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BILATERALISM AND FREE TRADE*

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We study a setting with many countries; in each country there are firms that can sell in the domestic as well as foreign markets. Countries can sign bilateral free-trade agreements that lower import tariffs and thereby facilitate trade. We allow a country to sign any number of bilateral free-trade agreements. A profile of free-trade agreements defines the trading regime. Our principal finding is that, in symmetric settings, bilateralism is consistent with global free trade. We also explore the effects of asymmetries across countries and political economy considerations on the incentives to form trade agreements.

1. INTRODUCTION

In recent years there has been a great deal of research on the relative merits of multilateralism and bilateralism, and their implications for the nature of the trading regime between countries.[2] Considerable attention has been given to the welfare effects of regional free-trade associations and customs unions. The importance of these issues motivates an examination of the incentives of nations to form such associations. Relatively little work has been done on this subject, specially concerning the strategic stability of different free-trade structures.[3] This article examines the incentives of countries to form bilateral free-trade agreements and the effects of these agreements on the welfare of third parties. In our work we use a model that is inspired by recent developments in the theory of strategic network formation.

We study a setting with many countries; in each country there are firms that can sell in the domestic market as well as in the foreign markets. The possibility of selling in foreign markets depends on the import tariffs faced by the firms. Countries can sign bilateral trade agreements that lower import tariffs and thereby facilitate

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[2] Please see, for example, Bhagwati and Panagariya (1996), Deardorff and Stern (1997), Krugman (1991), and Maggi (1999).

[3] There is a small literature on the stability of customs unions, for example, Bond et al. (2004) and Yi (1996). We elaborate on the differences between customs unions and free-trade agreements later in the Introduction.

trade. We allow a country to sign any number of bilateral trade agreements. The network of such trade agreements defines the trading regime.

There are three direct effects at work when a pair of countries sign a trade agreement that lowers import tariffs. First, the domestic firm is faced with greater competition from a foreign firm. Second, the domestic firm gets greater access to the foreign market. Third, domestic consumers benefit from greater competition, in terms of lower prices. In addition, there is an interesting indirect effect of such bilateral agreements: They make the markets of the countries signing the agreement less valuable to foreign firms that are already active in the market. Ethier (1998) has termed this effect *concession diversion*. He argues that the potential for concession diversion implies that bilateral trade agreements will be unable to support liberal trading regimes.

We find that concession diversion does arise when countries form additional bilateral trade agreements. We find, however, that given any profile of existing agreements, this concession diversion actually makes additional agreements more attractive because part of the costs of the new agreement are actually borne by the existing partners. This externality is central to our analysis. Our main finding is that in a *symmetric* setting, the latter two direct effects dominate and a complete network, i.e., one in which each pair of countries has a bilateral free-trade agreement, is a stable outcome. In our setting, bilateral trade agreements lower trade tariffs to zero. Thus we show that bilateralism is consistent with free trade.[4]

We then explore the role of the *symmetry* assumption. Specifically, we examine the effects of different market size and cost structures on the incentives of countries to form trade agreements. We find that smaller countries have greater incentives to form trade agreements than larger countries, and also that low-cost countries have greater incentives to form trade agreements than high-cost countries. Thus small low-cost countries have particularly strong incentives to form free-trade agreements with large high-cost economies.

In our basic model we assume that the government of each country maximizes social welfare, defined as the sum of consumer surplus and the total profits of the domestic firm. We then extend the basic model to allow for arbitrary weights on consumer surplus and firm profits. Our principal finding here is that a range of networks—which includes the empty network, the complete network, and networks where countries are divided into asymmetric mutually exclusive groups—are stable. Two special cases are worth noting: One, if the entire social weight is on consumer surplus, then the complete network is uniquely stable, and two, if the entire social weight is on firm profits, then a range of networks—which includes the empty network, the complete network and networks where countries are divided into asymmetric mutually exclusive groups—can be stable. The stability of networks with mutually exclusive groups of fully connected countries is consistent with the existence of NAFTA, EU, and ASEAN.

It is important to note that the complete network—and global free trade—is stable even if every country only cares about firm profits. This result is somewhat unexpected and we elaborate on this as it illustrates the role of the externality

[4] In Section B of the Appendix, we show that these results carry over in a setting with nontariff barriers.

reflected in concession diversion very nicely. When a country forms a trade agreement, the domestic firm is negatively affected in the home market because of increased competition. On the positive side, the domestic firm gains greater access to the foreign market. The negative effect of increased competition is shared by the domestic firm with the other currently active (foreign) firms in the home market. As a country forms more trade agreements and more foreign firms become active in its home market, this negative effect on the domestic firm's profits falls in magnitude and is more than offset by its profit gains in the foreign market. This makes free trade sustainable.

The provisions of GATT allow preferential trading arrangements—such as Customs Unions (CU) and Free-Trade Areas (FTA)—under certain circumstances. In particular, preferential trading agreements that are bilaterally negotiated between two countries should not lead to an increase in tariff duties on outside countries. This principle motivates us to endogenize the setting of tariffs by countries. We find that if a pair of countries signs a bilateral free-trade agreement, then this induces them to lower tariffs on third countries. This in turn leads to an increase in the welfare of such countries. Thus bilateral agreements are consistent with the spirit of GATT.[5]

The principal contribution of our paper is the introduction of network games to the study of trading regimes: the idea that a node can be viewed as a market and a link as an agreement to allow (or deter) entry into the market. Our model of network formation is inspired by recent work on strategic models of network formation; see, for instance, Bala and Goyal (2000), Jackson and Wolinsky (1996), and Kranton and Minehart (2001). This approach allows us to explicitly consider individual country incentives and the spillovers bilateral trade agreements generate for third parties. To the best of our knowledge, the present article is the first application of this approach to the study of the international trading system.[6]

We now elaborate on the network approach by comparing our article with the work on customs unions (see, e.g., Bond and Syropolous, 1996; Yi, 1996). In this work authors have applied the theory of coalition formation to study customs unions. This theory examines the strategic stability of different partitions of players into mutually exclusive groups. This is a natural way of thinking about CU, since a country cannot be a member of two customs unions. Our interest is in free-trade agreements, and in this context the restriction to partitions is unrealistic since it rules out intransitive relations between countries (in which 1 and 2 have an agreement and 2 and 3 have an agreement but there is no agreement between 1 and 3). This is a substantive restriction since, in practice, the trading

[5] Our result that the external tariff falls with the formation of an FTA has also been observed by other researchers, for example, Bond et al. (2004) and Yi (2000). In contrast, in a customs union (CU) where member countries coordinate their external tariff policies, external tariffs can rise after the formation of a CU. This was first shown by Krugman (1991), who divided the world into an equal number of CUs and then examined the consequences of simultaneously expanding the size of each.

[6] An earlier version of our article containing the results on stable and efficient networks (Propositions 1–3 below) and effects on endogenous tariffs (Proposition 8) was brought out by the Econometric Institute, Erasmus University, as Working Paper 9953/A, in 1999. Two recent papers, Belleflamme and Bloch (2004) and Furusawa and Konishi (2002), also use models of network formation to study closely related questions; we discuss these papers after presenting our results.

regime is characterized by such intransitive relationships. For instance, Israel has bilateral free-trade agreements with the United States and the European Community, respectively, but the latter two do not have such an agreement between them. Similarly, Mexico has bilateral free-trade agreements with Bolivia and Costa Rica, respectively, but the latter two do not have such a free-trade agreement (World Trade Organization, 1995). The theory of network games provides a natural way to think of such patterns. The difference in approach also has implications for predictions on trade regimes:[7] Yi (1996) shows that global free trade is generally not an equilibrium outcome, whereas we find that it is stable.

We now place our article in context by relating it to the existing literature in the theory of international trade. In an early paper, Krugman (1991) demonstrates in a model with differentiated products that world welfare is minimized when there are three equal size customs unions. Baldwin (1999), Bond et al. (2004), Bond and Syropoulos (1996), Kennan and Riezman (1990), and Spilimbergo and Stein (1998) have examined the effects of FTAs on welfare and incentives to set tariffs on third countries. These papers highlight the importance of trading agreements but they take as given a fixed trading structure. In this article, our interest is in the strategic stability of different bilateral free-trade arrangements. We, therefore, develop a model where any structure of free-trading agreements is in principle allowed and determined endogenously by strategic considerations.

The article is structured as follows. In Section 2 we introduce the basic model. Section 3 presents the main results on stable and efficient networks for the basic model with exogenous tariffs. Section 4 introduces endogenous tariffs into the analysis. Section 5 concludes.

2. THE BASIC MODEL

We consider a setting with N countries, each of which has one firm, which can sell in the domestic market as well as in each of the foreign markets. A country's ability to sell in foreign markets, however, depends on the level of import tariffs set by the different countries. If two countries have bilaterally negotiated an FTA, then each offers the other a tariff-free access to its domestic market; otherwise, each imposes a nonzero tariff on the imports from the other. Given a configuration of FTAs, firms then compete in different markets by choosing quantities. We are interested in the FTA network that emerges in this setting. We now develop the required terminology and provide some definitions.

2.1. *Network of Bilateral Trading Agreements*. Let $\mathbf{N} = \{1, 2, \ldots, N\}$ denote a finite set of identical countries. We shall assume that $N \geq 3$. For any $i, j \in \mathbf{N}$, the pairwise relationship between the two countries is captured by a binary variable, $g_{ij} \in$

[7] This difference in findings bears some resemblance to the results on stable coalitions and stable networks in the context of cost reducing alliances between firms. Stable coalitions consist of unequal size groups, whereas stable networks are complete (see, e.g., Bloch, 1995; Goyal and Joshi, 2003). The economic forces in the two contexts are different, since the free-trade network game exhibits local spillovers, whereas the cost reducing alliance game involves global spillovers (via the interaction of the firms in a single market).

$\{0, 1\}$; $g_{ij} = 1$ means that a free-trade agreement (or FTA) is established between countries i and j whereas $g_{ij} = 0$ means that no FTA is in effect. By definition, $g_{ii} = 1\ \forall i \in \mathbf{N}$ and $g_{ij} = g_{ji}\ \forall i, j \in \mathbf{N}$.

A *network*, $g = \{(g_{ij})_{i,j\in\mathbf{N}}\}$, is a formal description of the FTAs that exist between the countries in $\mathbf{N}$. Let $\mathbf{G}$ denote the set of all possible networks of FTAs between countries. Two special cases are the complete network, g^c in which $g_{ij} = 1\ \forall i, j \in \mathbf{N}$, and the empty network, g^e, in which $g_{ij} = 0\ \forall i, j \in \mathbf{N}, i \neq j$. Let $g + g_{ij}$ denote the network obtained by replacing $g_{ij} = 0$ in network g by $g_{ij} = 1$. Similarly, let $g - g_{ij}$ denote the network obtained by replacing $g_{ij} = 1$ in network g by $g_{ij} = 0$.

Let $N(g) = \{i \in \mathbf{N} : \exists j \neq i, g_{ij} = 1\}$. Each country in $N(g)$ is involved in an FTA with another distinct country in the network g. Therefore, $N(g^c) = \mathbf{N}$ and $N(g^e) = \emptyset$. There exists a *path* in g between countries i and j if either $g_{ij} = 1$ or there exists a distinct set of countries $\{i_1, i_2, \ldots, i_n\} \subset N(g)$ such that $g_{ii_1} = g_{i_1i_2} = \cdots = g_{i_nj} = 1$. A network is *connected* if there exists a path between any pair of countries; otherwise, it is *unconnected*.

A network $g' \subset g$ is a *component* of g if for all $i, j \in N(g')$, $i \neq j$, there exists a path in g' connecting i and j, and for all $i \in N(g')$ and $j \in N(g)$, $g_{ij} = 1$ implies $g_{ij} \in g'$. A component $g' \subset g$ is *complete* if $g_{ij} = 1$ for all $i, j \in N(g')$.

We will also let $N_i(g) = \{j \in \mathbf{N} : g_{ij} = 1\}$ denote the set of countries with whom i has an FTA in the trade network g. We define $i \in N_i(g)$. Let $\eta_i(g) = |N_i(g)|$.

2.2. *Demand and Cost Structure*. In each country there is a single firm producing a homogeneous good and competing as a Cournot oligopolist in all countries.[8] We let the output of firm j in country i be denoted by Q_i^j. The total output in country i is given by $Q_i = \sum_{j\in\mathbf{N}} Q_i^j$. In each country $i \in \mathbf{N}$, a firm faces an identical inverse linear demand given by

$$P_i = \alpha - Q_i, \quad \alpha > 0 \tag{1}$$

All firms have a constant and identical marginal cost of production, $\gamma > 0$. We assume that $\alpha > \gamma$. Thus the basic model has linear demand and costs of production. We explore the effects of general demand and asymmetries across countries after solving the basic model in Section 3. We examine the effects of nonlinear costs of production in Section B of the Appendix.

Let $T_j^i(g)$ be the tariff faced by firm i in country j in the network g. Note that $T_j^i(g) = T_i^j(g) = 0$ if $g_{ij} = 1$; however, in general, $T_j^i(g) \geq 0$ if $g_{ij} = 0$. The social welfare of country $i \in \mathbf{N}$ is given by the sum of consumer surplus, firm's profits, and tariff revenue:

(2)

$$S_i(g) = \frac{1}{2} Q_i^2(g) + \left[(P_i(g) - \gamma) Q_i^i(g) + \sum_{j\neq i} \left(P_j(g) - \gamma - T_j^i(g) \right) Q_j^i(g) \right] + \sum_{j\neq i} T_i^j(g) Q_i^j(g)$$

[8] In Section B of the Appendix, we show that our main results continue to hold if there are $m \geq 1$ firms in each country.

This formulation of social welfare places equal weight on consumer surplus and producer profits. We will assume that the government seeks to maximize this social welfare function when it makes decisions on whether or not to form free-trade agreements. In Section 3.1 we study the incentive effects of giving different weights to consumer surplus and producer surplus.

2.3. *Stable and Efficient Networks.* We employ a relatively weak notion of stability that is based on the idea that although FTAs are formed bilaterally, they can be severed unilaterally. We have borrowed this definition of stable networks from Jackson and Wolinsky (1996). Formally, the network g is stable if for all $i, j \in \mathbf{N}$

(i) $S_i(g) \geq S_i(g - g_{ij})$ and $S_j(g) \geq S_j(g - g_{ij})$

(ii) if $S_i(g + g_{ij}) > S_i(g)$, then $S_j(g + g_{ij}) < S_j(g)$

In words, in a stable network, each country has no incentive to sever an existing FTA with another, and any two countries that are not involved in an FTA have no incentive to form an agreement.

In order to study *efficient* networks, we need to consider world welfare. For any network, g, this is defined as the sum of social welfare of the N countries: $S(g) = \sum_{i \in \mathbf{N}} S_i(g)$. A network, $g^* \in \mathbf{G}$ is efficient if $S(g^*) \geq S(g)$ for all $g \in \mathbf{G}$.

3. EXOGENOUS TARIFFS

In this section we study a setting in which (positive) tariffs are exogenously given. Countries can reduce these tariffs to zero by entering into bilateral free-trade agreements. We have two principal findings: One, that a strategically stable network is either complete or almost complete (with all countries except one forming mutual free-trade agreements) and two, that the complete network maximizes global welfare.

We suppose that the initial pre-agreement import tariff in each country is $T > \alpha$, whereas if two countries sign a free-trade agreement, then they commit to zero tariffs on trade between themselves. The prohibitive tariffs assumption is made for expositional purposes; in Section B of the Appendix we show that our results continue to be valid even when the pre-agreement tariff is set at a level that permits trade between countries that have no free-trade agreement. From work in trade theory we know that, due to terms-of-trade effects, countries have an incentive to set tariffs at a positive level (see, e.g., Bagwell and Staiger, 1999).[9] The assumption that countries commit to zero tariffs in an FTA is made to rule out such deviations.

The assumption that $T > \alpha$ ensures that a firm i sells in country j if and only if there is a trade agreement between the two countries. Therefore, $\eta_i(g)$ is also the number of firms active in country i given the network g. If firm i is active in

[9] In our model, if we allowed countries to set tariffs noncooperatively, equilibrium tariffs would be positive. However, it can be shown that zero tariffs maximize the joint social welfare of countries in a bilateral trade agreement.

market j, then its output is given by $Q_j^i = (\alpha - \gamma)/(\eta_j(g) + 1)$. The social welfare of country i is given by

$$S_i(g) = \frac{1}{2}\left[\frac{(\alpha-\gamma)\eta_i(g)}{\eta_i(g)+1}\right]^2 + \sum_{j\in N_i(g)}\left[\frac{\alpha-\gamma}{\eta_j(g)+1}\right]^2 \tag{3}$$

An important concern in the literature has been the negative effects of (regional and bilateral) free-trade agreements on third parties. One aspect of this effect is "concession diversion." The above expression allows us to examine the nature of concession diversion explicitly. Fix a network g and a country i. Consider a country $j \in N_i(g)$. The firm from country j earns profits $(\alpha - \gamma)^2/(\eta_i(g) + 1)^2$ from its operations in country i. Now consider what happens when country i forms an additional bilateral trade agreement with, say, country k. This allows the firm of country k to enter the market of country i, thus raising the level of competition. In this new network $g + g_{ik}$, the profits of country j firm from its operations in country i are given by $(\alpha - \gamma)^2/(\eta_i(g) + 2)^2$. Suppose that $j \notin N_k(g)$. It follows that profits from all other operations remain the same. Thus the effect of this additional free-trade agreement between country i and country k on the profits of firm j is given by $(\alpha - \gamma)^2/(\eta_i(g) + 2)^2 - (\alpha - \gamma)^2/(\eta_i(g) + 1)^2$. This term is negative and is the measure of concession diversion created by the new bilateral free-trade agreement.

The above observations concerning concession diversion suggest that bilateral links generate negative spillovers for third countries. The following result builds on this insight and delimits the set of networks that can be stable.

PROPOSITION 1. *A stable trading network is either a complete network or consists of two components; one component has $N - 1$ countries and is complete, and the other component has a single country.*

PROOF. Consider a network g in which $g_{ij} = 0$. Note that an FTA between i and j leaves all other markets unaffected and raises the number of active firms in markets of country i and j by one each. Therefore,

$$\begin{aligned} S_i(g+g_{ij}) - S_i(g) = {} & \frac{1}{2}\left[\frac{(\alpha-\gamma)(\eta_i(g)+1)}{\eta_i(g)+2}\right]^2 - \frac{1}{2}\left[\frac{(\alpha-\gamma)\eta_i(g)}{\eta_i(g)+1}\right]^2 \\ & + \left[\frac{\alpha-\gamma}{\eta_i(g)+2}\right]^2 - \left[\frac{\alpha-\gamma}{\eta_i(g)+1}\right]^2 + \left[\frac{\alpha-\gamma}{\eta_j(g)+2}\right]^2 \end{aligned} \tag{4}$$

Simplifying the above expression, we find that $S_i(g + g_{ij}) \geq S_i(g)$ if

$$2\eta_i^2(g) - 5 + \frac{2(\eta_i(g)+2)^2(\eta_i(g)+1)^2}{(\eta_j(g)+2)^2} \;\geq\; 0 \tag{5}$$

This inequality is satisfied if $\eta_i(g) \geq 2$. Thus, if country i is involved in one or more FTAs, then it has an incentive to forge an additional FTA with j. This implies that in any network g, if i and j have one or more bilateral trade agreements, then stability demands that they have an agreement with each other as well. This means that any component in a stable trading network must be complete. Furthermore, in any stable network, there can be at most one nonsingleton component. Thus, if there are two or more components in a stable network, then at most one of them is a nonsingleton component.

We next show that any two countries in autarky have an incentive to form a trade agreement. Suppose that a network g is such that i and j are in singleton components. Then, the social welfare of these countries is identical and is given by $S_i(g) = \frac{1}{2}[\frac{(\alpha-\gamma)}{2}]^2 + [\frac{(\alpha-\gamma)}{2}]^2$. If i and j establish an FTA, then the social welfare of i (and j, by symmetry) is given by $S_i(g+g_{ij}) = \frac{1}{2}[\frac{2(\alpha-\gamma)}{3}]^2 + 2[\frac{(\alpha-\gamma)}{3}]^2$. It is easily verified that $S_i(g+g_{ij}) > S_i(g)$. Thus two singleton components are not sustainable in a stable trading network.

We have thus shown that the only candidates for stable trading networks are the complete trading network and the network with a complete component with $N-1$ countries and an isolated country. ■

Figure 1 provides examples of the networks that can be stable.

The crucial step in the above proof is the derivation of inequality (5). This expression suggests that the incentives of countries to have free-trade agreements increase as they enter into more agreements. This is a strong and interesting property: In particular, it shows how bilateral trade agreements can be a step toward a global free-trade regime.

The above result leaves open the question of whether the complete network, i.e., a global free-trade regime, is actually a stable network. Our next result responds to this concern.

PROPOSITION 2. *The complete trading network is stable.*

PROOF. Condition (ii) in the definition of stability is trivially satisfied since no further agreements are possible. The social welfare of country i in the complete network is given by

$$S_i(g^c) = \frac{1}{2}\left[\frac{N(\alpha-\gamma)}{N+1}\right]^2 + \frac{N(\alpha-\gamma)^2}{(N+1)^2} \tag{6}$$

In contrast, the social welfare of country i in the network $g^c - g_{ij}$ is given by

$$S_i(g^c - g_{ij}) = \frac{1}{2}\left[\frac{(N-1)(\alpha-\gamma)}{N}\right]^2 + \left[\frac{(\alpha-\gamma)}{N}\right]^2 + \frac{(N-2)(\alpha-\gamma)}{(N+1)^2} \tag{7}$$

It is easily established that if $N \geq 3$, then $S_i(g^c) > S_i(g^c - g_{ij})$. Thus, condition (i) of stability is also satisfied. ■

How can a network with $(N-1)$ countries in a complete network and one isolated country be stable? An FTA allows a foreign firm to enter the domestic

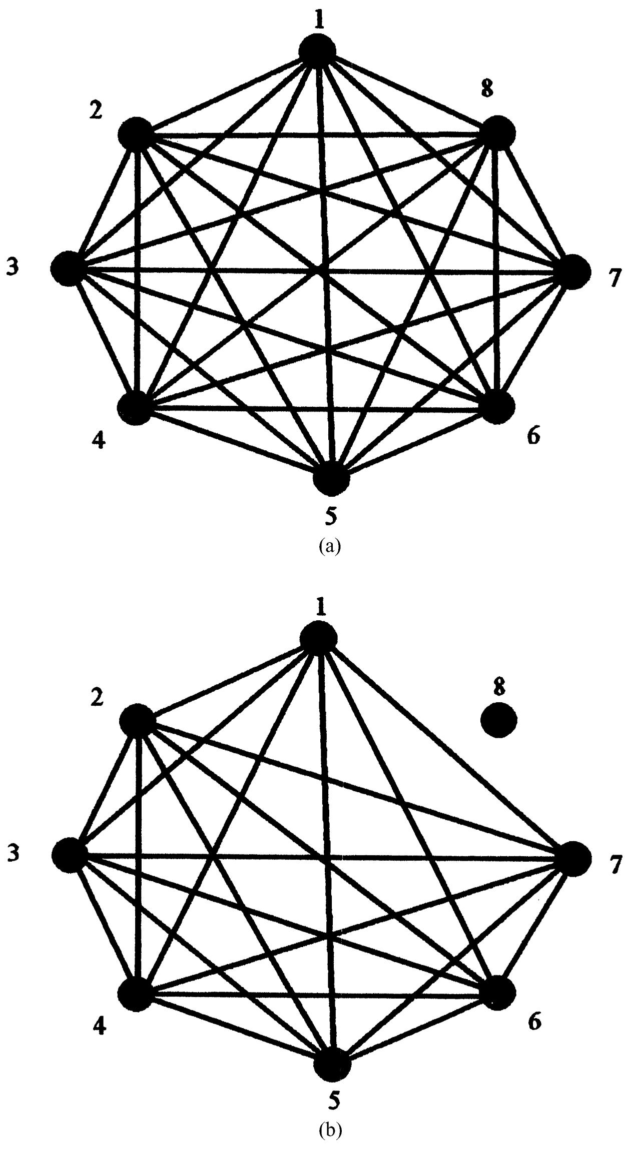

FIGURE 1

STABLE NETWORKS (N = 8): (A) COMPLETE NETWORK ($N = 8$) AND (B) ALMOST COMPLETE NETWORK ($N = 8$)

market more easily. This increases domestic competition and, therefore, increases consumer surplus and lowers profits of its own firm from domestic operations. The free-trade agreement also yields easier access to the foreign market for the domestic firm. This raises profits of the domestic firm from foreign operations. The last effect is positive. However, if the foreign country has a very competitive market, then this effect is relatively small compared to the large negative effect on profits of the (erstwhile monopoly) domestic firm. Thus, the overall effect of a bilateral free-trade agreement can be negative. This prevents the autarkic country from forming a bilateral free-trade agreement.

To make this intuition precise, let country 1 be the isolated country. Fix a network g in which this country is isolated and all the other $(N-1)$ countries are part of a complete component. Using (4) we can rewrite the marginal payoff to this country from a bilateral free-trade agreement as follows:

$$S_1(g+g_{i1}) - S_1(g) = -3 + \frac{72}{(N+1)^2} \tag{8}$$

This expression is negative if and only if $N \geq 4$. Thus we have shown that the unconnected network is stable if there are four or more countries.

We now examine the nature of efficient networks.

PROPOSITION 3. *The complete network is the unique efficient network.*

PROOF. World welfare is given by $S(g) = \sum_{i\in\mathbf{N}} S_i(g)$. Using (3) this can be expanded and written as

$$S(g) = \sum_{i\in\mathbf{N}} \frac{1}{2}\left[\frac{(\alpha-\gamma)\eta_i(g)}{\eta_i(g)+1}\right]^2 + \sum_{i\in\mathbf{N}} \sum_{j\in N_i(g)} \left[\frac{\alpha-\gamma}{\eta_j(g)+1}\right]^2 \tag{9}$$

World welfare is thus the sum of the consumer surplus in each country plus the producer surplus of every firm in the world. It is convenient to express the latter term a little differently in terms of the sum of producer surplus generated in each of the different markets. Thus we can write world welfare as

$$S(g) = \sum_{i\in\mathbf{N}} \frac{1}{2}\left[\frac{(\alpha-\gamma)\eta_i(g)}{\eta_i(g)+1}\right]^2 + \sum_{i\in\mathbf{N}} \eta_i(g) \left[\frac{\alpha-\gamma}{\eta_i(g)+1}\right]^2 \tag{10}$$

In the complete network, the welfare generated in every country is the same and is given by

$$\frac{1}{2}\left[\frac{(\alpha-\gamma)N}{N+1}\right]^2 + N\left[\frac{\alpha-\gamma}{N+1}\right]^2 \tag{11}$$

By comparison, in an arbitrary network g, the welfare generated in country i is given by

$$\frac{1}{2}\left[\frac{(\alpha-\gamma)\eta_i(g)}{\eta_i(g)+1}\right]^2 + \eta_i(g)\left[\frac{\alpha-\gamma}{\eta_i(g)+1}\right]^2 \tag{12}$$

We wish to show that (11) is larger than (12) for every i. It is easily seen that this is true, for all $\eta_i(g) < N$. Since the network g was arbitrary, the proof follows. ■

We now discuss the connections between our results—Propositions 1–3—and the findings of Furusawa and Konishi (2002). Furusawa and Konishi consider a setting with many countries and a continuum of differentiated goods. Every country produces a subset of the continuum of goods (the size of which determines its level of industrialization). Their principal result is that if countries are symmetric in terms of market size and level of industrialization, then the complete network is stable. Moreover, a network with one isolated country and all other countries forming free-trade agreements can also be stable under some circumstances. The proofs of these results exploit in a crucial way the negative spillovers—the concession diversion effects—of bilateral trade agreements on third countries, something which is central to our analysis. We therefore interpret their results as saying that our main findings and the intuition behind them are robust and carry over to settings with differentiated goods and price competition.

3.1. *Discussion of Assumptions*. The analysis of the basic model suggests that bilateralism is consistent, and should be seen as a building block, for global free trade. This is a clear-cut result and motivates a closer examination of the assumptions underlying the analysis. We examine the effects of general demand and different weights in the social welfare function, alternative market structure, and asymmetric costs and demands. This exploration of assumptions will reveal that if countries are symmetric, then our basic finding is robust and the complete network that supports global free trade is strategically stable. However, if governments place a lot of weight on firms' profits or if countries differ in cost structure/demand, then networks with distinct components—which can be interpreted as trading blocks—can also be stable.

3.1.1. *General demand and general social welfare function*. In this section we generalize our model along two dimensions: We allow for general demand functions and for arbitrary weights on consumer surplus and producer surplus in the social welfare function. In this general setting we find that the complete network is stable. In addition, networks with complete unequal sized components are also stable if governments assign relatively more weight to producers' surplus.

Let us assume that the inverse market demand $p(Q_i)$ is generated from maximizing the utility function $u(Q_i) + y_i$ of a representative consumer in country i, where y_i denotes income, $u'(Q_i) > 0$, and $u''(Q_i) < 0$. Therefore, $p(Q_i) = u'(Q_i)$ and satisfies $p'(Q_i) < 0$. We will also assume that $p''(Q_i) \leq 0$. Let $\pi^i_k(\eta_k(g))$ denote the profits of firm i in country k as a function of the number of firms active in k's market. Since all firms are ex ante symmetric, $\pi^i_k(\eta_k(g)) = \pi(\eta_k(g))$ for all k. We suppose that governments give weight $\beta \in [0, 1]$ to consumer surplus and $\delta \in [0, 1]$ to producer surplus. Then social welfare in country i, given a network g of FTAs, is

$$S_i(g) = \beta[u(Q_i(g)) - p(Q_i(g))Q_i(g)] + \delta \sum_{k \in N_i(g)} \pi(\eta_k(g)) \tag{13}$$

where the first term represents consumer surplus, $CS(g)$, and the second term the domestic firm's profits. We would like to look at incentives for FTAs in this general case. We start by considering two special cases, where governments care only about consumer surplus ($\beta = 1$, $\delta = 0$) and the case where governments care only about producer surplus ($\beta = 0$, $\delta = 1$). Finally, we will combine the analysis of the two cases and derive results for arbitrary weights on the two elements.

We start with the case where the entire weight is on consumer surplus. The welfare function of country i is now given by

$$S_i(g) = CS(g) \equiv u(Q_i(g)) - p(Q_i(g))Q_i(g) \tag{14}$$

Suppose $g_{ij} = 0$ in g. Letting $\Delta CS(g) \equiv CS(g + g_{ij}) - CS(g)$, it follows that

$$\begin{aligned} S_i(g + g_{ij}) - S_i(g) &= \Delta CS(g) \\ &= [u(Q_i(g + g_{ij})) - u(Q_i(g))] \\ &\quad - [p(Q_i(g + g_{ij}))Q_i(g + g_{ij}) - p(Q_i(g))Q_i(g)] \end{aligned} \tag{15}$$

Let $\Delta Q_i(g) \equiv Q_i(g + g_{ij}) - Q_i(g)$. From the mean value theorem

$$\begin{aligned} &u(Q_i(g + g_{ij})) - u(Q_i(g)) = u'(\bar{Q}_i(g))\Delta Q_i(g) = p(\bar{Q}_i(g))\Delta Q_i(g) \\ &p(Q_i(g + g_{ij})) - p(Q_i(g)) = p'(\hat{Q}_i(g))\Delta Q_i(g) \end{aligned} \tag{16}$$

for some $\bar{Q}_i(g)$ and $\hat{Q}_i(g)$. We can rewrite (15) as

$$\begin{aligned} S_i(g + g_{ij}) - S_i(g) &= \Delta CS(g) \\ &= [p(\bar{Q}_i(g)) - p(Q_i(g + g_{ij}))]\Delta Q_i(g) \\ &\quad - p'(\hat{Q}_i(g))Q_i(g)\Delta Q_i(g) \end{aligned} \tag{17}$$

The following result provides a characterization of stable networks when governments care only about consumer surplus.

PROPOSITION 4. *Suppose inverse demands are downward-sloping and concave in each country and that each firm's cost function is linear in output. If social welfare in each country is equal to the consumer surplus, then the complete network is the unique stable network.*

The proof is given in Section A of the Appendix. The proof of this result proceeds by first noting that aggregate quantity sold in a market increases with an additional FTA. We then show that consumer surplus is strictly increasing in quantity sold in the market. This implies that in any network, a country has an incentive to form additional FTAs with every other country.

We next turn to the polar opposite case where firms control decision making in the government and $\beta = 0$ whereas $\delta = 1$. In this case the entire social weight is on the domestic firm's profits. The marginal returns to country i from forming a link with country j are now given by

$$S_i(g) - S_i(g - g_{ij}) = \pi(\eta_j(g)) - [\pi(\eta_i(g) - 1) - \pi(\eta_i(g)] \equiv \psi(\eta_i(g), \eta_j(g)) \tag{18}$$

In order to assess the marginal returns from links, we need to look at the curvature of firm profits as a function of the number of active firms. This requires stronger restrictions on demand than the analysis of consumer surplus. We define the elasticity of the slope of the inverse demand function as $e(Q) = Qp''(Q)/p'(Q)$. We will use the following assumption on demand.

ASSUMPTION D. *The inverse demand $p(Q)$ satisfies $e(Q) > -1$ and $e'(Q) \geq 0$ for $Q > 0$.*

The inverse demand, $p(Q) = \alpha - Q^a$, $0 < a \leq 1$ satisfies Assumption D. In particular, the linear model is a special case of this demand (with $a = 1$).

Belleflamme and Bloch (2004, Proposition 2.1) have shown that if demand satisfies Assumption D and the cost function is linear in output, then the profit function satisfies the following two properties. First, profits in any market are strictly declining in the number of firms active in that market

$$\pi(\eta_k(g) + 1) < \pi(\eta_k(g)), \quad \forall k \tag{19}$$

Second, profits in any market are strictly log-convex in the number of firms active on the market

$$\frac{\pi(\eta_k(g) - 1) - \pi(\eta_k(g))}{\pi(\eta_k(g))} > \frac{\pi(\eta_k(g)) - \pi(\eta_k(g) + 1)}{\pi(\eta_k(g) + 1)}, \quad \forall k \tag{20}$$

We use these two properties in proving the following result on stable networks if governments care only about firm profits.

PROPOSITION 5. *Suppose countries are symmetric, with inverse demand that satisfies Assumption D, and firms have a linear cost function. If social welfare in each country is equal to the domestic firm's profits, then*

1. *In the class of symmetric networks, only the empty and the complete networks can be stable.*
2. *In the class of asymmetric networks, stable networks have the exclusive group architecture consisting of a set of isolated countries and different sized complete components.*

The proof is given in Section A of the Appendix. We first note that in nonempty symmetric networks, producer surplus is strictly increasing in links. Thus every pair of countries with k links, where $0 < k < N - 1$, will want to form an FTA. We then turn to asymmetric networks and note that in any incomplete component there exist countries that can increase producer surplus by forming a link. This means that only complete components can be part of stable networks. The unequal size of components follows from the earlier observation that nonempty symmetric networks cannot be stable.[10]

We first note that if $2\pi(N) \geq \pi(N-1)$, then the complete network is stable even if governments place all weight on firm profits. This is somewhat surprising and it is worth elaborating on the reasons underlying this result. When two countries i and j form an FTA, the firm of country i gains free entry into the market of country j and vice versa. The firm from country i makes some profits in country j; this is only partly offset by the loss in profits of the local firm of country j. The profits of other firms operating in the market also go down. Similarly for the profits that firm from country j makes in market i. The profits that the firms from these two countries make come partly at the expense of other—foreign—firms operating in these markets. This externality is closely related to the concession diversion we noted above. It is also reflected in our second observation: If $\beta = 0$ and $\delta = 1$, then the empty network is stable. In the empty network there are no foreign firms active in any market and opening up markets makes them competitive, and the gains of the new foreign firm from j in market i must be fully borne by the local firm from country i. Combining the above arguments leads to our third observation: Networks with a complete component and several isolated countries can be stable. Thus there is an interesting threshold property in incentives for forming FTAs. An isolated country that puts high weight on firm profits may wish to remain autarkic, but once a country has a certain number of FTAs it has strict incentives to form FTAs with all other countries.

We can combine the results on the two special cases above to derive a result on stable networks under arbitrary weights on consumer surplus and producer surplus.

PROPOSITION 6. *Suppose countries are symmetric, with inverse demand that satisfies Assumption D, and firms have a linear cost function. If every country assigns weights* $\beta \in [0, 1]$ *to consumer surplus and* $\delta \in [0, 1]$ *to firm profits, then*

1. *In the class of symmetric networks, only the empty and the complete networks can be stable.*
2. *In the class of asymmetric networks, stable networks have the exclusive group architecture consisting of a set of isolated countries and different sized complete components.*

The proof follows from the arguments in Propositions 4–5 and is omitted.

In a recent paper, Belleflamme and Bloch (2004) consider a model in which each firm has a local market and firms form bilateral agreements to keep out of each other's local market. The model in the present article has a different motivation: In our article governments care about both consumer surplus and producer surplus and they form FTAs to enhance trade. Moreover, since this is

[10] For instance with linear demand and cost, $\beta = 0$, $\delta = 1$, and $N = 8$, the stable networks are complete, empty, the network in which there is one component with five nodes and one component with three nodes, and networks with a complete component (with three or more nodes), and isolated nodes.

a model of trade agreements between countries, there are additional strategic variables—such as tariff levels or quotas—which are not available in the case of networks of collusion.[11] However, it is possible to view their setting as a special case of our model, one in which all weight is placed on the profits of the local firm. Proposition 5 tells us that if the government puts sufficient weight on firm profits, then a stable network is either empty, complete, or consists of unequal size complete components. This corresponds to their finding on stable collusive networks.

3.1.2. *Market structure*. In the basic model we assume that there is only one firm in each market. The following result extends the analysis to the case with $k \geq 1$ firms in each country.

PROPOSITION 7. *Suppose there are $k \geq 1$ domestic firms in each market with inverse linear demand given by* (1). *A stable trading network is either a complete network or consists of two components, one component has $N - 1$ countries and is complete, and the other component has a single country*.

The proof of this result proceeds along the arguments of Proposition 1, and is given in Section A of the Appendix. Using computations analogous to those of Proposition 2, it can be shown that the complete network is stable.

We note now that the following two assumptions on market structure are critical in deriving our main results: (i) the market in each country is oligopolistic due to barriers to entry and (ii) the firms compete in quantities.[12] To see this, suppose that the market in each country is competitive with no barriers to entry. In this case, equilibrium price in each market is equal to marginal cost γ and all domestic firms earn zero (economic) profits in the home market. Since all countries are symmetric, there is no incentive to form trade agreements and the empty network is the unique stable network.

Now suppose that there are barriers to entry in each country but the firms compete in prices. If there is one firm in each country, then an additional FTA would reduce the equilibrium price to marginal cost γ and therefore increase social surplus to the maximum attainable. In a stable network each country would form at most one FTA. If each country had two or more firms, then the empty network would be the unique stable network.

3.1.3. *Asymmetries across firms and markets*. In the basic model, we assumed that all countries were symmetric: the size and the structure of the market is the same, and also the cost structure of the firms is identical. In this section we briefly examine the role of this symmetry assumption.

Differences in market size. We parameterize country size in terms of the value of $\alpha - \gamma$. The first observation concerns the impact of increasing demand size in a

[11] Our analysis of endogenous tariffs and nontariff barriers takes up these issues in Section 4 and Section B of the Appendix.

[12] We would like to thank an anonymous referee for drawing our attention to the role of these assumptions in our analysis.

world where all countries are of equal size. It follows from expression (4) that market size enters as a multiplicative term in the overall incentive to form links. Thus it enhances the overall effect of forming a link. For $\eta_i(g) \geq 2$, this effect is clearly positive. Our first observation is *increasing market size encourages countries to have more bilateral free-trade agreements.*

The other issue we wish to examine is the relative payoffs of large and small countries from forming a link with each other. Recall that in the basic model with the same country size, two countries with an equal number of links have the same returns from forming an extra agreement. However, in case the countries are of unequal size the benefits are unclear.

We shall suppose that there are two types of countries, large and small. Large countries have a value of $\alpha - \gamma > 1$, whereas for small countries this value is exactly 1. Let country i be large and country j be small. It is then straightforward to show that

$$(21) \quad S_i(g + g_{ij}) - S_i(g) = (\alpha - \gamma)^2\big[2\eta_i^2(g) - 5\big] + \frac{2(\eta_i(g) + 2)^2(\eta_i(g) + 1)^2}{(\eta_j(g) + 2)^2}$$

Similarly, the benefits to the small country j are given by

$$(22) \quad S_j(g + g_{ij}) - S_j(g) = \big[2\eta_j^2(g) - 5\big] + (\alpha - \gamma)^2\frac{2(\eta_j(g) + 2)^2(\eta_j(g) + 1)^2}{(\eta_i(g) + 2)^2}$$

Simple calculations then show that $S_j(g + g_{ij}) - S_j(g) > S_i(g + g_{ij}) - S_i(g)$. Thus the small country gets relatively larger benefits when a large and a small country form a bilateral free-trade agreement. Our second observation is *when costs of forming link are significant, we should expect more bilateral free-trade agreements between large countries, and between small and large countries, and few such agreements between small countries.*

Differences in cost structure. We parameterize differences in costs of firms in terms of different values of γ. Our main interest is in the effect of different costs. To keep matters simple we shall suppose that there are two cost levels, high, γ_H, and low, γ_L. Our interest is in the incentives of low-cost countries to form links with high-cost countries and vice versa. We shall focus on the case where countries do not have any agreement, i.e., $\eta_i(g) = \eta_j(g) = 1$. Let country i have the high cost firm and country j the low-cost firm. We can show that

$$(23) \quad S_i(g + g_{ij}) - S_i(g) = \frac{1}{2}\frac{[2\alpha - \gamma_i - \gamma_j]^2}{9} - \frac{3}{2}\frac{[\alpha - \gamma_i]^2}{4} + 2\frac{[\alpha - 2\gamma_i + \gamma_j]^2}{9}$$

Similarly, the benefits to country j with the low cost firm are given by

$$(24) \quad S_j(g + g_{ij}) - S_j(g) = \frac{1}{2}\frac{[2\alpha - \gamma_i - \gamma_j]^2}{9} - \frac{3}{2}\frac{[\alpha - \gamma_j]^2}{4} + 2\frac{[\alpha - 2\gamma_j + \gamma_i]^2}{9}$$

Simple calculations then show that $S_j(g + g_{ij}) - S_j(g) > S_i(g + g_{ij}) - S_i(g)$. Thus the country with the lower-cost firm gets relatively larger benefits when it forms a free-trade agreement with a country that has a high-cost firm. This yields our third observation: *When costs of forming links are significant, we should expect to see relatively more bilateral free-trade agreements between low-cost countries, and few FTAs between high- and low-cost countries.* The eagerness of low-cost countries to link up with a high-cost country will be even greater if the latter also has a large market. This appears to be consistent with observed efforts of poorer low-cost countries to form reciprocal trade agreements with countries that have relatively large markets.

4. ENDOGENOUS TARIFFS

In the above section we considered the case where tariffs are either prohibitive or zero. In reality countries negotiate a range of trade agreements; moreover, the absence of an agreement is usually not the same as prohibitive tariffs. An important motivation for examining endogeneous tariff determination is the GATT clause that requires that the regional trade agreements do not lead to an increase in tariffs/barriers against third parties. We wish to examine if individual countries have an incentive to raise tariffs with third parties as they form additional trade agreements.

We consider the following generalized model: In the first stage, countries bilaterally negotiate FTAs with each other. If two countries sign such an agreement, then they commit to zero tariffs between them.[13] In the second stage, each country noncooperatively chooses an external tariff to levy on those countries with whom it does not have an FTA. In the third stage, firms in each country choose how much to produce for the domestic market and how much to export to the foreign countries.

Let g be an FTA network. Note that $T_i^j(g) = T_j^i(g) = 0$ if $g_{ij} = 1$. Furthermore, since all countries are ex ante symmetric, $Q_i^k(g) = Q_i^l(g)$ for all $k, l \in \backslash N_i(g)$. Therefore, $T_i^k = T_i$ for all $k \in \backslash N_i(g)$. The Cournot equilibrium outputs in country i are

$$Q_i^j(g) = \frac{(\alpha - \gamma) + (N - \eta_i(g))T_i(g)}{(N+1)}, \quad j \in N_i(g) \tag{25}$$

$$Q_i^k(g) = \frac{(\alpha - \gamma) - (\eta_i(g) + 1)T_i(g)}{(N+1)}, \quad k \in \backslash N_i(g) \tag{26}$$

[13] Bond et al. (2004) have noted that since the formation of an FTA between i and j leads to a fall in the external tariff on third countries $k \neq i, j$, it makes these non-FTA countries more aggressive in the markets of i and j. Therefore, countries forming an FTA may have an incentive not to reduce their tariffs on each other to zero. We show with a three-country example that this is true in our model as well. This means that our assumption that countries commit to a zero tariff level with FTA partners is required. The example is presented in Section B of the Appendix. We would like to thank an anonymous referee for drawing our attention to this possibility.

Substituting (25) and (26) in (2) yields social welfare in country i:

$$S_i(g) = \frac{1}{2}\left[\frac{N(\alpha-\gamma)-(N-\eta_i(g))T_i(g)}{(N+1)}\right]^2 + \sum_{j:g_{ij}=1}\left[\frac{(\alpha-\gamma)+(N-\eta_j(g))T_j(g)}{(N+1)}\right]^2 + \sum_{k:g_{ik}=0}\left[\frac{(\alpha-\gamma)-(\eta_k(g)+1)T_k(g)}{(N+1)}\right]^2 + (N-\eta_i(g))T_i(g)\left[\frac{(\alpha-\gamma)-(\eta_i(g)+1)T_i(g)}{(N+1)}\right] \tag{27}$$

Country i chooses its tariff noncooperatively to maximize (27). This yields

$$T_i^*(g) = \frac{3(\alpha-\gamma)}{\eta_i(g)(2N+5)-(N-2)} \tag{28}$$

Therefore, the optimal tariff is a *decreasing* function of the number of bilateral links of country i. This is an important finding and we provide some intuition for it now.

A rise in tariffs has three effects: The first effect is that it lowers competition in the domestic market, thus increasing the profits of the domestic firm. The second effect is that, by lowering competition, it lowers consumer surplus. The third effect is on the aggregate level of tariff revenue. Let us look at the impact of an additional FTA on each of these three effects. This impact is clearly reflected in the first derivative of the social welfare function with respect to the tariff level, which is produced below.

$$\frac{\partial S_i(g)}{\partial t_i(g)} = -\frac{N-\eta_i(g)}{N+1}\left[\frac{N(\alpha-\gamma)-(N-\eta_i(g))T_i(g)}{(N+1)}\right] + \frac{N-\eta_i(g)}{N+1}\left[\frac{2(\alpha-\gamma)+2(N-\eta_i(g))T_i(g)}{(N+1)}\right] + \frac{N-\eta_i(g)}{N+1}\left[(\alpha-\gamma)-2(\eta_i(g)+1)T_i(g)\right] \tag{29}$$

We note that a rise in the number of agreements from $\eta_i(g)$ to $\eta_i(g)+1$ has an impact on the marginal cost of tariffs (in terms of higher consumer surplus lost) and at the same time lowers the marginal benefit (in terms of lower profits of the domestic firm and lower tariff revenue) from higher tariffs. The sign of the first effect is unclear, but the latter two effects are straightforward. An additional free-trade agreement means that there are fewer countries on whom the tariff is effective. Hence there are fewer firms affected by such a tariff and this means that the positive effect on the profit of the domestic firm is less marked. Relatedly, fewer nonagreement countries means that the the pool from which the revenue is collected is smaller, and at the same time the quantity response to increases in tariff of the remaining firms (in the nonagreement countries) is more acute. Both these pressures work toward lowering the revenue-gathering effects of higher tariffs. These considerations account for the negative relationship between the number of bilateral free-trade agreements and the level of tariffs on goods from nonagreement countries.[14]

We next consider the impact of bilateral trade agreements on third country welfare. First consider the case of a country k that does not have a bilateral trade agreement with either country i or j in the network g. An FTA between i and j only affects the export profits of k in the markets of i and j. The impact on such a country can be stated as follows:

$$\begin{aligned} S_k(g+g_{ij}) - S_k(g) = 9(\alpha-\gamma)\big\{\big[Q_i^k(g) + Q_i^k(g+g_{ij})\big] \\ + \big[Q_j^k(g) + Q_j^k(g+g_{ij})\big]\big\} \end{aligned} \tag{30}$$

Thus bilateral trade agreements have positive externalities on such unconnected countries.

Consider next the welfare of a country k that has a bilateral free-trade agreement with both i and j. It can be seen that such a country is only affected via the impact on its firm's profits from export operations in i and j. There are two effects in these markets: First, more firms can compete without paying tariffs, and second, the tariffs on the remaining countries fall. Both these effects make the market more competitive and thus lower the export profits of firm k. This is the extent of concession diversion and it adversely affects the welfare of country k.

Countries that have an agreement with i but not j (or vice versa) fall in the intermediate category: There is some loss in welfare due to concession diversion (in country i with whom there is a free-trade agreement) but there is also an increase in profits due to lowering of tariffs in the other country j. Whether the net effect on k's welfare is positive or negative depends on the number of links of i and j. When the number of i's links increases, then the reduction in k's welfare due to concession diversion is smaller because it is shared among a larger number of active firms. Now note that T_j is decreasing and convex in η_j. When j's links increase, the increase in k's profits is smaller because the external tariff on k falls by a smaller amount. It follows that k's welfare increases when i has a large number of links and j has a small number of links, and it decreases when the opposite is true.[15]

[14] A similar result was first obtained by Joshi and Shivakumar (1997) within the coalition framework. It has subsequently also been reported by Bond et al. (2004), Furusawa and Konishi (2002), and Yi (2000). We note that these papers account for product differentiation and terms-of-trade effects, indicating that our result on falling tariffs is robust and not an artifact of our model.

[15] We can show this with an example. Let $N = 99$ and $\alpha - \gamma = 1$. If $\eta_i = 2$ and $\eta_j = 90$, then the net effect on k's welfare is $-1.35/(100)^2$ whereas if $\eta_i = 90$ and $\eta_j = 2$, then the net effect on k's welfare is $0.011/(100)^2$.

Given the complexity of the computations involved, we have been unable to completely characterize the nature of stable networks in this setting. We do have some interesting partial results.

PROPOSITION 8. *The complete network is the unique stable network within the class of symmetric networks.*

The proof of this result first shows that the complete network is stable. Here we compare the payoffs in the complete network with the payoffs from deleting a single link. We prove uniqueness by showing that any pair of countries with the same number of FTAs has a strict incentive to form an additional FTA. The details of the proof are presented in Section A of the Appendix.

What can we say about stable networks more generally? Our analysis of the exogenous tariffs case suggests that the sign of the expression $S_i(g + g_{ij}) - S_i(g)$ is crucial for an understanding of the nature of stable networks. Given the complexity of computations involved, we have been unable to pin down the sign of this term for networks in general. We therefore used simulations to get some idea of this expression. In our simulations we set $N = 100$, $\alpha = 200$, and $\gamma = 100$.

There are four different effects of an additional bilateral free-trade agreement, g_{ij}, on country i. The first effect is on the consumer surplus in country i. The second effect is on the profits of firm i in country j. The third effect is on the profits of firm i in its domestic market. The fourth effect is on the tariff revenue in country i. These effects are plotted, respectively, in Figures 2(a)–(d). We note that the signs of the effects correspond to our intuition. The first two effects are positive, whereas the latter two effects are negative.

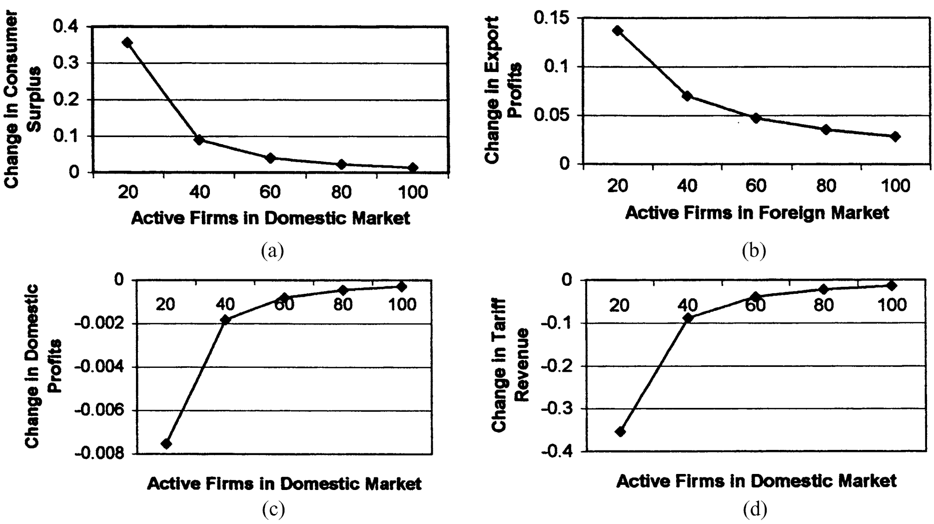

FIGURE 2

CHANGE IN THE COMPONENTS OF SOCIAL WELFARE DUE TO AN ADDITIONAL FTA: (A) CHANGE IN CONSUMER SURPLUS, (B) CHANGE IN PROFITS IN FOREIGN MARKET, (C) CHANGE IN PROFITS IN DOMESTIC MARKET, AND (D) CHANGE IN TARIFF REVENUE

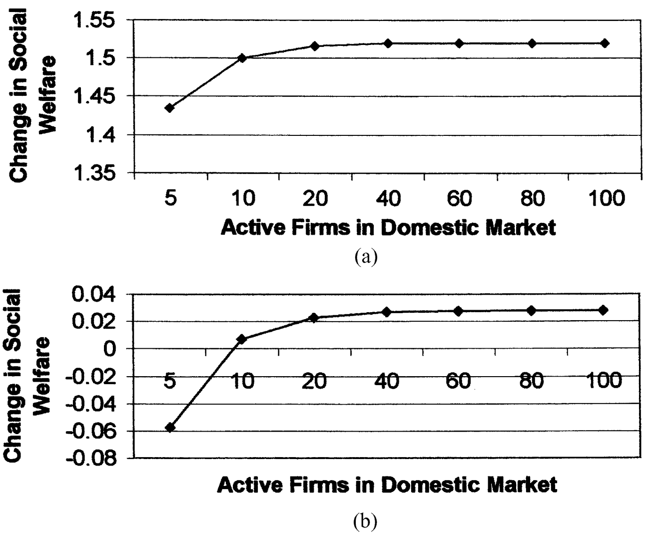

FIGURE 3

CHANGE IN SOCIAL WELFARE DUE TO AN ADDITIONAL FTA: (A) CHANGE IN DOMESTIC SOCIAL WELFARE (FTA PARTNER HAS 1 LINK) AND (B) CHANGE IN DOMESTIC SOCIAL WELFARE (FTA PARTNER HAS 100 LINKS)

We aggregate these effects in Figure 3. Figure 3(a) presents the results when we set $\eta_j(g) = 1$, and Figure 3(b) presents the results when we set $\eta_j(g) = 100$. These two numbers reflect the two extreme values for competitiveness in market j. Thus when $\eta_j(g) = 1$, the market is monopolized and hence very attractive for the firm from country i. When $\eta_j(g) = 100$, the market is very competitive and a free-trade agreement will not lead to any substantial increase in profits of firm i from its enhanced access of market j.

Our simulations suggest that $S_i(g + g_{ij}) - S_i(g)$ is positive at all levels of $\eta_i(g)$, if $\eta_j(g) = 1$. If $\eta_j(g) = 100$, then the sign is positive for all values of $\eta_i(g)$ above a small number. Overall, it seems that country i has an incentive to form bilateral free-trade agreements. Since this country was chosen arbitrarily, this suggests that bilateral free-trade agreements should lead to every pair of countries signing similar agreements, leading to the global free-trade regime. This result is broadly in conformity with the results in the case with exogenous tariffs.

5. CONCLUSION

Our interest has been in the following question: What structure of free-trade areas is consistent with the incentives of individual countries? We have developed a simple model of network formation to analyze this question. In this model, the nodes are the countries and the links between them represent bilateral free-trade agreements. We find that, if countries are *symmetric*, a complete network, i.e., one in which every pair of countries has a free-trade agreement (and thus global free trade obtains), is consistent with the incentives of individual countries. This result suggests that bilateralism can be seen as a useful building step toward a liberal world trading system. A related finding of policy relevance is that tariffs on third countries are a declining function of the number of free-trade agreements a country has: This suggests that bilateralism is consistent with one important element of GATT. We also explore the effects of asymmetric conditions across countries and political economy considerations on the incentives to form trade agreements.

There are a number of directions in which this framework can be extended. In the analysis we have assumed a linear cost function. Preliminary work suggests that the complete network and global free trade remain stable in the presence of increasing marginal costs. However, a systematic exploration of the impact of cost structure on trading networks is left for future work. We have assumed exogenous weights on consumer surplus and producer surplus in the social welfare function. In future work we hope to explore the effects of making these weights endogenous.

APPENDIX

A. *Proofs.*

PROOF OF PROPOSITION 4. Suppose $g \neq g^c$ and $g_{ij} = 0$ in g. We first note that aggregate output in country i increases when i forms an FTA with country j. This follows from standard results in Cournot oligopoly with concave demand and linear costs (see, e.g., Vives, 1999, Chapter 3). In an oligopoly, price exceeds marginal cost. Therefore, if i forms an FTA with j, then aggregate output is greater in country i. Let us now return to (17). We have shown that $\Delta Q_i(g) > 0$. Therefore, $Q_i(g) < \bar{Q}_i(g) < Q_i(g + g_{ij})$. Since $p' < 0$, it follows that $p(\bar{Q}_i(g)) > p(Q_i(g + g_{ij}))$. Therefore $S_i(g + g_{ij}) - S_i(g) > 0$ and i has an incentive to form as many links as possible. Since i is arbitrary, it follows that the complete network is the unique stable network. ■

We use the following lemma in the proof of Proposition 5.

LEMMA 1. *Suppose all firms are ex ante symmetric with homogeneous inverse demand satisfying assumption D and cost functions that are linear in output. For any network g, if $\psi(\eta_i(g), \eta_j(g)) \geq 0$, then $\psi(\eta_i(g) + 1, \eta_j(g) + 1) > 0$.*

PROOF. We can prove the lemma by considering the following three cases:

Case I. $\eta_i(g) = \eta_j(g) = \eta \geq 2$

In this case $\psi(\eta, \eta) = 2\pi(\eta) - \pi(\eta - 1) \geq 0$ is equivalent to $\pi(\eta)/\pi(\eta - 1) \geq 1/2$. From the strict log-convexity of profits, $\pi(\eta + 1)/\pi(\eta) > \pi(\eta)/\pi(\eta - 1) \geq 1/2$, and rearranging yields $\psi(\eta + 1, \eta + 1) = 2\pi(\eta + 1) - \pi(\eta) > 0$.

Case II. $\eta_i(g) < \eta_j(g)$

From strict log-convexity of profits:

$$\pi(\eta_i(g)) - \pi(\eta_i(g) + 1) < [\pi(\eta_i(g) - 1) - \pi(\eta_i(g))]\frac{\pi(\eta_i(g) + 1)}{\pi(\eta_i(g))} \tag{A.1}$$

Once again, since $\eta_i(g) < \eta_j(g)$, from the strict log-convexity of profits, $\pi(\eta_i(g)+1)/\pi(\eta_i(g)) < \pi(\eta_j(g)+1)/\pi(\eta_j(g))$. Substituting in (A.1) and rearranging:

$$\text{(A.2)} \qquad \frac{\pi(\eta_i(g)) - \pi(\eta_i(g)+1)}{\pi(\eta_j(g)+1)} < \frac{\pi(\eta_i(g)-1) - \pi(\eta_i(g))}{\pi(\eta_j(g))}$$

Now $\psi(\eta_i(g), \eta_j(g)) \geq 0$ is equivalent to $[\pi(\eta_i(g)-1) - \pi(\eta_i(g))]/\pi(\eta_j(g)) \leq 1$. Therefore, from (A.2), $[\pi(\eta_i(g)) - \pi(\eta_i(g)+1)]/\pi(\eta_j(g)+1) < 1$, and rearranging yields $\psi(\eta_i(g)+1, \eta_j(g)+1) > 0$.

Case III. $\eta_i(g) > \eta_j(g)$

Since $\eta_i(g) \geq \eta_j(g)+1$, it follows that $\pi(\eta_i(g)) \leq \pi(\eta_j(g)+1)$ since profits are decreasing in the number of active firms in the market. It now follows that

$$\text{(A.3)} \qquad \frac{\pi(\eta_i(g)) - \pi(\eta_i(g)+1)}{\pi(\eta_j(g)+1)} \leq \frac{\pi(\eta_i(g)) - \pi(\eta_i(g)+1)}{\pi(\eta_i(g))} < 1$$

and rearranging yields $\psi(\eta_i(g)+1, \eta_j(g)+1) > 0$. ■

PROOF OF PROPOSITION 5. We start with the case of symmetric networks. Assume by way of contradiction that some nonempty symmetric network $g \neq g^c$ is stable. Then there are countries i and j such that $g_{ij} = 0$ in g and $\eta_i(g) = \eta_j(g) = \eta \geq 2$. Since g is stable, $S_i(g) - S_i(g - g_{ik}) = \psi(\eta, \eta) \geq 0$ for some $k \neq i, j$ and similarly for j. Then, from Lemma 1, $S_i(g + g_{ij}) - S_i(g) = \psi(\eta+1, \eta+1) > 0$ and similarly for j. Therefore, i and j have an incentive to form a link contradicting the stability of g.

We now consider the case of asymmetric networks. Note that since profits are strictly log-convex and strictly decreasing in the number of active firms, they are also strictly convex in the number of active firms. Therefore $\psi(\eta_i(g), \eta_j(g))$ is strictly increasing in $\eta_i(g)$ and strictly decreasing in $\eta_j(g)$. We now use these properties of ψ along with Lemma 1 to derive the following property of asymmetric networks:

CLAIM. *Consider a stable network g. If $g_{ij} = 1$, $\eta_j(g) > \eta_i(g)$, then $g_{ik} = 1$ if $\eta_i(g) \leq \eta_k(g) \leq \eta_j(g)$ and $g_{kj} = 1$.*

Consider country i and note that

$$\text{(A.4)} \qquad \psi(\eta_i(g), \eta_k(g)) \geq \psi(\eta_i(g), \eta_j(g)) \geq 0$$

where the first inequality follows from the hypothesis that $\eta_k(g) \leq \eta_j(g)$ and ψ is decreasing in its second argument, whereas the second inequality follows from the stability of g. It now follows from Lemma 1 that

$$\text{(A.5)} \qquad S_i(g + g_{ik}) - S_i(g) = \psi(\eta_i(g)+1, \eta_k(g)+1) > 0$$

Next consider country k:

$$S_k(g+g_{ik}) - S_k(g) = \psi(\eta_k(g)+1, \eta_i(g)+1) > \psi(\eta_i(g), \eta_i(g)+1) \geq \psi(\eta_i(g), \eta_j(g)) \geq 0 \tag{A.6}$$

The first inequality follows from the fact that ψ is strictly increasing in its first argument, the second inequality from the property that ψ is decreasing in its second argument, whereas the final inequality follows from the stability hypothesis. Thus countries i and k have an incentive to form a link, proving the claim.

We now use the claim to show that every nonsingleton component $C(g)$ in g is complete. Since a component with two countries is trivially complete, let $|C(g)| > 2$ and suppose that it is incomplete. We already know that a symmetric incomplete component cannot be stable, so let $C(g)$ be asymmetric. Let country j be maximally connected in this component and be linked to a nonmaximally connected country i (such countries must exist in an asymmetric component), i.e., $g_{ij} = 1$ and $\eta_i(g) < \eta_j(g)$. Then there must exist some country k such that $g_{jk} = 1$ but $g_{ik} = 0$. There are two possibilities: $\eta_i(g) \leq \eta_k(g) \leq \eta_j(g)$ and $\eta_k(g) \leq \eta_i(g) \leq \eta_j(g)$. In both instances the above claim implies that $g_{ik} = 1$. Since k was arbitrary, this implies that $\eta_j(g) \leq \eta_i(g)$, a contradiction that proves the claim that $C(g)$ is complete. Finally we note that a stable network cannot have two nonsingleton components of equal size, for otherwise countries in the two components have an incentive to form a link by virtue of Lemma 1. ■

PROOF OF PROPOSITION 7. The crucial expression is $S_i(g+g_{ij}) - S_i(g)$. With $k \geq 1$ firms, expression (4) can be rewritten as follows:

$$\begin{aligned} S_i(g+g_{ij}) - S_i(g) = {} & \frac{1}{2}\left[\frac{(\alpha-\gamma)(\eta_i(g)+1)k}{(\eta_i(g)+1)k+1}\right]^2 - \frac{1}{2}\left[\frac{(\alpha-\gamma)\eta_i(g)k}{\eta_i(g)k+1}\right]^2 \\ & + k\left[\frac{\alpha-\gamma}{(\eta_i(g)+1)k+1}\right]^2 - k\left[\frac{\alpha-\gamma}{\eta_i(g)k+1}\right]^2 \\ & + k\left[\frac{\alpha-\gamma}{(\eta_j(g)+1)k+1}\right]^2 \end{aligned} \tag{A.7}$$

Simplifying the above term, we find that $S_i(g+g_{ij}) - S_i(g) > 0$, if

$$\left[2\eta_i^2(g)k^2 + 2\eta_i(g)k - 2\eta_i(g)k^2 - 2k^2 - 3k\right] + \frac{2((\eta_i(g)+1)k+1)^2(\eta_i(g)k+1)^2}{((\eta_j(g)+1)k+1)^2} > 0 \tag{A.8}$$

The second term is clearly positive. The first term is positive and increasing in value for all $\eta_i(g) \geq 2$. Thus any country that has a bilateral agreement, and has therefore $2k$ or more firms, has an incentive to form additional agreements. This implies that in any stable network, any two countries with agreements also have an agreement with each other. Finally, it is easily shown that if two countries are autarkic, then they have an incentive to form a bilateral free-trade agreement. This completes the proof. ■

PROOF OF PROPOSITION 8. Since $T_i^*(g^c) = 0$, social welfare of country i becomes

$$S_i(g^c) = \frac{1}{2}\left[\frac{N(\alpha-\gamma)}{(N+1)}\right]^2 + N\left[\frac{(\alpha-\gamma)}{(N+1)}\right]^2 \tag{A.9}$$

There are no links to add, so condition (ii) of stability is trivially satisfied. Now consider the network $g - g_{ij}$ and note that $T_i^*(g^c - g_{ij}) = T_j^*(g^c - g_{ij}) = T^*$.

(A.10)

$$\begin{aligned} S_i\left(g^c - g_{ij}\right) = \frac{1}{2}\left[\frac{N(\alpha-\gamma) - T^*}{(N+1)}\right]^2 + \left[\frac{(\alpha-\gamma) + T^*}{(N+1)}\right]^2 + \left[\frac{(\alpha-\gamma) - NT^*}{(N+1)}\right]^2 \\ + (N-2)\left[\frac{(\alpha-\gamma)}{(N+1)}\right]^2 + T^*\left[\frac{(\alpha-\gamma) - NT^*}{(N+1)}\right] \end{aligned}$$

It follows that

$$S_i(g^c) - S_i\left(g^c - g_{ij}\right) = \frac{T^*}{2}\left[2(\alpha-\gamma)(N-3) + T^*(2N-3)\right] > 0 \tag{A.11}$$

Therefore, condition (i) of stability is also satisfied. This completes the proof of stability of the complete network. We now show that the complete network is the only candidate for stability in the class of symmetric networks. We do this by proving that in any stable network g, if for some i and j, $\eta_i(g) = \eta_j(g)$ then $g_{ij} = 1$.

We first note that since $\eta_i(g) = \eta_j(g)$, then from the expression for optimal tariffs, it follows that $T_i^*(g) = T_j^*(g) = T$ and also that $T_i^*(g + g_{ij}) = T_j^*(g + g_{ij}) = T'$. Note also that we can let $\eta \leq N - 2$ since the proof for $\eta = N - 1$ is identical to the one demonstrating that the complete network is stable. The change in consumer surplus, $\Delta CS(g)$, is given by

$$\begin{aligned} \Delta CS(g) = \frac{1}{2}\left[\frac{(N-\eta)T - (N-\eta-1)T'}{N+1}\right] \\ \left[\frac{2N(\alpha-\gamma) - (N-\eta-1)T' - (N-\eta)T}{N+1}\right] \end{aligned} \tag{A.12}$$

The change in domestic profits, $\Delta\pi_i^i(g)$, is given by

(A.13)

$$\Delta\pi_i^i(g) = \left[\frac{(N-\eta-1)T' - (N-\eta)T}{N+1}\right]\left[\frac{2(\alpha-\gamma) + (N-\eta)T + (N-\eta-1)T'}{N+1}\right]$$

The change in tariff revenues, $\Delta\tau_i(g)$, is given by

$$\text{(A.14)} \qquad \Delta\tau_i(g) = \frac{1}{(N+1)}\,[(N-\eta-1)T'\{(\alpha-\gamma)-(\eta+2)T'\} \\ -(N-\eta)T\{(\alpha-\gamma)-(\eta+1)T\}]$$

The change in firm i's profit in country j's market, $\Delta\pi_j\; i\;(g)$, is given by

(A.15)
$$\Delta\pi_j^i(g) = \left[\frac{(N-\eta-1)T'+(\eta+1)T}{N+1}\right]\left[\frac{2(\alpha-\gamma)+(N-\eta-1)T'-(\eta+1)T}{N+1}\right]$$

To show that $S_i(g+g_{ij}) > S_i(g)$, we first show that $\Delta CS(g) + \Delta\pi_i^i\,(g) > 0$. From (A.12) and (A.13), this requires showing that $2N(\alpha-\gamma) > 4(\alpha-\gamma)+3(N-\eta)T + 3(N-\eta-1)T'$. Letting $\xi \equiv \eta(2N+5)-(N-2)$, this is equivalent to $2(N-2)\xi(\xi+2N+5) > 9(N-\eta)(\xi+2N+5)+9(N-\eta-1)\xi$. Noting that $\xi \geq N+7$, this is easily verified to be true. Next, we show that $\Delta\pi_j^i(g) + \Delta\tau_i(g) > 0$. For this, it suffices to show that $[(N-\eta-1)T' + (\eta+1)T][2(\alpha-\gamma)+(N-\eta-1)T' - (\eta+1)T] > (N+1)[(N-\eta)T\{(\alpha-\gamma)-(\eta+1)T\}]$. Simplifying, it requires showing that $6\xi(N-\eta-1) > (N+1)(N-\eta)$. This is easily verified to be true for $\eta \leq N-2$. ■

B.

B.1. *Effects of nonlinear costs of production.* We study a three-country example with exogenous tariffs. We assume that every firm has the following cost function: $C(Q) = Q^2/2$ and normalize $\alpha-\gamma = 1$. The other aspects of the model remain as in Section 2. We first derive the equilibrium quantities, profits, and social welfare for each of the four networks: the empty network, g^e, the network with one link, g^L, the star network, g^s, and the complete network g^c.

In g^e, every firm sells only in its local market. The payoffs to each firm are $(1-Q_i^i)Q_i^i - (Q_i^i)^2/2$. It follows that optimal quantity is $Q_i^i = 1/3$ and profits are $\pi_i(g^e) = 3/18$. The consumers surplus is given by $1/18$ and so the total social welfare, $S_i(g^e) = 4/18$ for every country.

In g^L, let countries 1 and 2 have a link. The payoff of the firm in country 1 is given by $(1-Q_1^1+Q_1^2)Q_1^1 + (1-Q_2^1-Q_2^2)Q_2^1 - (Q_1^1+Q_2^1)^2/2$. Using symmetry, it is easy to show that $Q_1^1 = Q_2^1 = Q_1^2 = Q_2^2 = 1/5$. It then follows that firm profits in countries 1 and 2 are $8/50$, the consumers surplus is $4/50$, and social welfare $S_1(g^L) = S_2(g^L) = 12/50$. The social welfare in country 3 is as in the empty network $S_3(g^L) = 4/18$.

In g^s, let country 1 be the hub and countries 2 and 3 be at the spokes. The optimal quantities are as follows: $Q_1^1 = 1/9$, $Q_2^1 = Q_3^1 = 1/6$, $Q_1^2 = Q_1^3 = 1/6$, $Q_2^2 = Q_3^3 = 2/9$. The payoff of firm in country 1 is $\pi_i(g^s) = 19/81$, whereas payoff of firm in country 2 and 3 is $\pi_2(g^s) = \pi_3(g^s) = 11/72$. The social surplus in country 1 is $S_1(g^s) = 1/3$ and in countries 2 and 3 is $S_2(g^s) = S_3(g^s) = 37/162$.

In g^c, the optimal quantity for every firm l in a market k is $Q_k^l = 1/7$. So profits for firm are $\pi_i(g^c) = 15/98$, consumers surplus is 9/98, and social welfare $S_i(g^c) = 24/98$ in every country.

A comparison of social welfare reveals that the complete network is the unique stable network.

B.2. *Level of initial tariffs*. We now revert to the original model with one firm in each country but assume that the initial pre-agreement tariffs are at a nonprohibitive level, t, so that all firms are operative in each country. In particular, we will let $\alpha - \gamma > 2(N-1)t$. It is easily verified that all tariff levels satisfying this condition are nonautarkic. We now show that our choice of the initial tariff level in Proposition 1 did not bias our results in favor of free trade.

PROPOSITION 9. *Suppose that the initial tariff level t in each country satisfies $\alpha - \gamma > 2(N-1)t$. A stable trading network is either a complete network or consists of two components; one component has $N-1$ countries and is complete, and the other component has a single country.*

PROOF. We can write $S_i(g)$ as follows:

(B.1)
$$S_i(g) = \frac{1}{2}\left[\frac{N(\alpha-\gamma) - t(N-\eta_i(g))}{N+1}\right]^2 + \sum_{j\in N_i(g)}\left[\frac{(\alpha-\gamma)+t(N-\eta_j(g))}{N+1}\right]^2 + \sum_{j\notin N_i(g)}\left[\frac{(\alpha-\gamma)-t(\eta_j(g)+1)}{N+1}\right]^2 + t(N-\eta_i(g))\left[\frac{(\alpha-\gamma)-t(\eta_i(g)+1)}{N+1}\right]$$

The proof follows by examining $S_i(g+g_{ij}) - S_i(g)$ and noting that any two unlinked countries have an incentive to form a link if they both have at least one link in g. Furthermore, if two countries are autarkic, then they have an incentive to form a bilateral free-trade agreement. This completes the proof. ■

Once again, using computations analogous to those of Propositions 2 and 9, a stable network always exists; in particular, the complete trading network is stable.

B.3. *The case of nontariff barriers*. We now briefly examine the case of nontariff barriers.[16]

Consider next the case where quotas are endogenous. In stage 1, countries choose FTA partners. In stage 2 they choose quota levels on those countries with whom they have no trade agreement. Let $s_i = \{(s_{ij})_{j\notin N_i(g)}\}$ be the quota level

[16] We would like to thank Francis Bloch for discussions on the subject of nontariff barriers. Consider first the case where quotas are set equal to zero for all countries and an FTA lifts the quota completely. In this case, the analysis is identical to what we have done in the basic model with prohibitive tariffs. So the result is also the same: *A stable network is either complete or a complete component with $N-1$ countries and one isolated country.*

set by country i for each of the countries with whom it does not have free-trade agreements. (Note that we omit dependence of quota strategy on network g for expositional simplicity.) Define $s = \{s_1, s_2 \ldots, s_N\}$ to be the strategy profile of quotas, in stage 2, given the network g. In stage 3 firms compete in different markets depending on the quotas. Suppose that every country i has two possibilities with respect to every country $j \notin N_i(g)$: Set a quota of zero or remove quotas altogether. Let $\pi^i_j(g, s_{ji})$ be the payoffs of country i in a country j when i and j do not have a free-trade agreement and country j sets a quota s_{ji} on country i. Let $S_i(s_i, s_{-i} \mid g)$ denote the payoffs to country i in network g with quota strategy on non-FTA countries given by s. The payoffs to i from a strategy of zero quotas for all non-FTA countries are given by

(B.2)
$$S_i(s_i = 0; s_{-i} \mid g) = \frac{1}{2}\left[\frac{(\alpha-\gamma)(\eta_i(g))}{\eta_i(g)+1}\right]^2 + \left[\frac{\alpha-\gamma}{\eta_i(g)+1}\right]^2 + \sum_{j \in N_i(g)} \left[\frac{\alpha-\gamma}{\eta_j(g)+1}\right]^2 + \sum_{j \notin N_i(g)} \pi^i_j(g, s_{ji})$$

Now consider the strategy in which country i removes quotas on one of the non-FTA countries. The payoffs are given by

$$S_i(s'_i, s_{-i} \mid g) = \frac{1}{2}\left[\frac{(\alpha-\gamma)(\eta_i(g)+1)}{\eta_i(g)+2}\right]^2 + \left[\frac{(\alpha-\gamma)}{\eta_i(g)+2}\right]^2 + \sum_{j \in N_i(g)} \left[\frac{1}{\eta_j(g)+1}\right]^2 + \sum_{j \notin N_i(g)} \pi^i_j(g, s_{ji}) \tag{B.3}$$

It can be checked that removing quotas on country $k \notin N_i(g)$ dominates not removing quotas so long as $\eta_i(g) \geq 2$. We can now repeat the argument and conclude that if a country has one FTA in g, then it would be better off with no quotas on any country. Finally, we observe that payoff from no trade is $3(\alpha-\gamma)^2/8$, which is strictly less than the payoff from unilateral free trade (i.e., imposing no quotas on any non-FTA country):

$$\frac{1}{2}\left[\frac{(\alpha-\gamma)N}{N+1}\right]^2 + \left[\frac{(\alpha-\gamma)}{N+1}\right]^2 + \sum_{j \in N_i(g)} \left[\frac{1}{\eta_j(g)+1}\right]^2 \tag{B.4}$$

so long as $N > 2$. It follows then that free trade is the unique outcome in a game with quotas under our assumption that $N \geq 3$.

B.4. *Example of noncooperative tariffs among FTA partners*. Consider three countries i, j, k where i and j have an FTA with each other and k does not have any agreement with either i or j. Each country first sets the tariff on its FTA partners, then it chooses the tariff on the non-FTA countries, and finally it competes in output in all three markets. Consider country i and let t_i denote the tariff imposed on its FTA partner j and t_i the tariff on k. Then country i's welfare is given by

$$
\text{(B.5)} \qquad \begin{aligned} S_i(g) = \frac{1}{2}\left[\frac{3(\alpha-\gamma)-t_i-T_i}{4}\right]^2 + \left[\frac{(\alpha-\gamma)+t_i+T_i}{4}\right]^2 \\ + \left[\frac{(\alpha-\gamma)-3t_j+T_j}{4}\right]^2 + \left[\frac{(\alpha-\gamma)-2T_k}{4}\right]^2 \\ + t_i\left[\frac{(\alpha-\gamma)-3t_i+T_i}{4}\right] + T_i\left[\frac{(\alpha-\gamma)+t_i-3T_i}{4}\right] \end{aligned}
$$

Country i's tariff on k is $T_i = [3(\alpha-\gamma)+11t_i]/21$. Substituting T_i in $S_i(g)$, it can be verified that $\frac{\partial S_i(g)}{\partial t_i}|_{t_i=0} > 0$. Therefore i has an incentive to impose a nonzero internal tariff on its FTA partner. It can also be verified that the optimal internal tariff is equal to zero if i and j choose the internal tariff to maximize their joint welfare.

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