Free Trade Networks*

Taiji Furusawa[†] Hideo Konishi[‡]

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Abstract

The paper examines the formation of free trade agreements (FTAs) as a network formation game. We consider an n-country model in which (possibly asymmetric) countries trade differentiated industrial commodities. We show that if all countries are symmetric, the complete FTA network is pairwise stable and it is the unique stable network if industrial commodities are not highly substitutable. We also compare FTAs and customs unions (CUs) as to which of these two regimes facilitates global trade liberalization, noticing that unlike CUs, each signatory of an FTA can have another FTA without consent of other member countries.

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[†]Corresponding author: Graduate School of Economics, Hitotsubashi University, 2-1 Naka, Kunitachi, Tokyo 186-8601 Japan, Tel/Fax +81-42-580-8866. (e-mail) furusawa@econ.hit-u.ac.jp

[‡]Department of Economics, Boston College, Chestnut Hill, MA 02467, USA. (e-mail) hideo.konishi@bc.edu

1 Introduction

The network of preferential trade agreements (PTAs) covers most countries in a complex way. The tendency towards "regionalism," a movement to form regional trade agreements, has been steadily growing especially since 1980s (Bhagwati, 1993). Since the Treaty of Rome established the European Economic Community (EEC) in 1957, the European Union (EU) has been growing with the accession of new members. The North American Free Trade Agreement (NAFTA) has started negotiations with Latin American countries to form the Free Trade Area of the Americas. Japan has recently signed free trade agreements (FTAs) with Singapore and Mexico. The website of the World Trade Organization (WTO) on regionalism provides us with an excellent introduction to this topic.

> The vast majority of WTO members are party to one or more regional trade agreements. The surge in RTAs has continued unabated since the early 1990s. Some 250 RTAs have been notified to the GATT/WTO up to December 2002, of which 130 were notified after January 1995. Over 170 RTAs are currently in force; an additional 70 are estimated to be operational although not yet notified. By the end of 2005, if RTAs reportedly planned or already under negotiation are concluded, the total number of RTAs in force might well approach 300.
>
> (http://www.wto.org/english/tratop/_e/region_e/region_e.htm, August 23, 2005)
>
> One of the most frequently asked questions is whether these regional groups help or hinder the WTO's multilateral trading system. A committee is keeping an eye on developments.
>
> (http://www.wto.org/english/thewto_e/whatis_e/tif_e/bey1_e.htm, August 23, 2005)

Whether PTAs serve as "building blocks" or "stumbling blocks" is a central question in this topic (Bhagwati, 1993). Of course, multilateral trade liberalization efforts and PTA formation interact with each other.[1] However, putting this feature aside for a while, another important question remains. Will successive PTA formation alone effectively achieve global free trade, or will the process stop prematurely so that the world is divided into several, mutually exclusive trading blocs? If PTA formation continues until the complete FTA network is achieved, we may conclude that PTAs are "building blocks." But otherwise, PTAs can be "stumbling blocks."[2]

Ohyama (1972) and Kemp and Wan (1976) demonstrate a positive result for this "dynamic" path problem. The so-called Kemp-Wan theorem states that member countries can appropriately adjust external tariffs and make internal transfers so that a newly formed customs union (CU) is Pareto-improving, not only to members themselves but also to all countries in the world.[3] Successive application of this Kemp-Wan process implies that the CU expansion continues until all countries in the world are covered.[4] Although the theorem looks promising, it should be taken as an existence theorem (of a Pareto-improving CU expansion). In reality, it is extraordinarily difficult to adjust external tariffs such that each nonmember country's welfare is not reduced by the CU formation. Indeed, as Viner (1950) taught us, adverse trade-diversion effects often prevent PTAs from being Pareto improving.[5] It is far from obvious that in reality, countries always have incentives to form PTAs so that we will eventually observe the complete free trade network (global free trade). Indeed, Yi (1996) shows that even if countries are symmetric, the world would be divided into two CUs

[1] Levy (1997), Krishna (1998), and Ornelas (2005c) show in their political economy models that PTA formation can hinder multilateral trade liberalization. Freund (2000b) demonstrates that countries have more incentive to form PTAs as multilateral trade negotiations lower tariffs imposed by every country. See also Bagwell and Staiger (1997a,b), Bond, Syropoulos, and Winters (2001), and Ethier (1998).

[2] Bhagwati and Panagariya (1996) raise this "PTA time-path" question. The complete FTA network may still be different from global free trade attained through multilateral trade negotiations, as Freund (2000a) demonstrates in a model where firms incur distribution network costs, for example. The complete FTA network may be more complex and inefficient ("spaghetti bowl" phenomenon) than global free trade attained through multilateral trade negotiations, as Bhagwati and Panagariya (1996) claim.

[3] See Panagariya and Krishna (2002) for an FTA version of the Kemp-Wan theorem.

[4] Baldwin (1995) demonstrates that as a regional trading bloc expands, outside countries have more incentive to join the bloc.

[5] Krugman (1991) claims that if a "natural" trading bloc, within which a large share of trade takes place even in the absence of a PTA, is formed, the gains from trade creation are likely to outweigh the losses from trade diversion.

of asymmetric size when the number of countries is a realistic number.

CUs are not the only form of PTA. A PTA can take a form of FTA, such as the NAFTA, in which member countries choose their individual external tariffs without consent of other member countries unlike in the case of CU where all member countries adopt the same external tariff schedule. An important consequence of this difference, which seems to be overlooked more or less in the literature, is that under an FTA, each member country (or a subset of member countries) can sign another FTA with outside countries without consent of other member countries. Whereas in the case of CUs, such as the EU, all member countries should be involved when an outside country forms a PTA with a member country of a CU. Thus, FTAs are more flexible than CUs: A hub-and-spoke system, for example, will not appear if only CUs are allowed as PTAs.[6] In practice, CUs and FTAs co-exist in a complex manner. The hub-and-spoke system is prevalent in the world. Mexico, which is a member of the NAFTA, has FTAs with the EU, Japan, and others. The traditional approach by coalition formation games such as Yi (1996, 2000) is not rich enough to capture this feature of the world PTA configuration. Coalition formation games cannot properly address the issues of the web of FTAs, nor can they analyze the situation where CUs and FTAs co-exist.

The network formation game developed by Jackson and Wolinsky (1996) provides an appropriate framework to analyze such complex formation of PTAs. The network formation game is suitable for the analysis of FTAs. We can predict whether or not an arbitrary FTA configuration is stable. As we show in Section 4, the situation in which CUs and FTAs co-exist can also be analyzed within the same framework. In this paper, given any FTA configuration in the world, we examine whether or not a pair of countries has an incentive to sign an FTA, and whether or not a country has an incentive to cut an existing FTA. A network that is immune to such deviations is called *(pairwise) stable network* (Jackson and Wolinsky, 1996). Then we ask if the complete FTA network is stable, and if it is, we further

[6]Kowalczyk and Wonnacott (1992) discuss the hub-and-spoke system in the argument about NAFTA. Mukunoki and Tachi (2006) investigate dynamic formation of bilateral FTAs in a three-country model.

ask if it is unique. If the complete FTA network is a unique stable network, the world is likely to attain global free trade, building many bilateral FTAs.[7] If the complete FTA network is not stable, on the other hand, FTA formation would stop prematurely. Investigating countries' incentives to sign FTAs and deriving conditions under which the complete FTA network is stable, we hope to gain an insight into how far the worldwide movement toward FTAs continues.[8]

First, we analyze each country's incentive to sign or abandon an FTA. As Krugman (1991) and Grossman and Helpman (1995) suggest, the asymmetry of countries is an important factor when we assess countries' incentives for FTAs. Viner (1950), on the other hand, suggests that substitutability of commodities traded internationally is also an important factor. The model of this paper is general enough to allow us to observe how these factors affect a country's decision to sign an FTA. We consider the model in which the world consists of n countries that trade a numeraire good and a continuum of non-numeraire, differentiated, industrial commodities. Consumers in all countries share a common quasi-linear utility function, in which substitutability of industrial commodities is parameterized. Countries may be different in the market size (population size) and the size of the industrial good industry (measure of firms). Each of the differentiated industrial commodities is produced by one firm that belongs to one of n countries. An FTA between countries i and j simply means that countries i and j simultaneously eliminate tariffs on industrial commodities

[7]To derive a definite prediction regarding the time-path to global free trade, we may need to build a dynamic network formation model with farsightedness. Mukunoki and Tachi (2006) show in a dynamic, symmetric, three-country model that under certain parameter values, only one bilateral FTA is signed in equilibrium so that global free trade is not attained. As Kennan and Riezman (1990) suggest, countries in a bilateral FTA may in some cases prefer the current situation to global free trade. Then, each member country may not sign a new bilateral FTA with an outside country since it would induce an FTA between spoke countries, effectively attaining global free trade, in the future. However, extending Mukunoki and Tachi's (2006) analysis to the case of many countries is not an easy task.

[8]Driven by the same motivation, Freund (2000c) builds a model such that each country calls out the number of countries with which it wants to have FTAs, and shows that global free trade is effectively attained as a unique Nash equilibrium. However, she seems to assume implicitly that a bilateral FTA between two countries is made effective as long as one of the countries benefits from an agreement, even if the other strictly prefers not to sign the agreement. This "open membership" rule (see also Yi, 1996) does not seem to be appealing for discussions of FTAs. If FTAs require consent from both sides, then we will run into the multiplicity problem of Nash equilibria (see footnote 16).

imported from each other.

Furusawa and Konishi (2004) show that when consumers have quasi-linear utility functions and all countries share the same constant-returns-to-scale production technology for each commodity they commonly produce, social welfare of a country can be represented by the sum of consumers' gross utilities and trade surplus of non-numeraire goods. An FTA with another country is likely to raise the gross utility, although the second-best effect may sometimes outweigh the benefits from tariff reduction.[9] On the other hand, the impact on the (industrial) trade surplus is generally ambiguous, and is often crucial in determining whether or not an FTA is welfare improving.

The effect on a country's trade surplus of signing an FTA with another country can be further decomposed into two: one on the trade surplus between these two countries (the direct surplus effect) and the other on the trade surplus with third countries (the third country effect). The latter effect is always positive, since the country's exports to third countries are not affected by the FTA, whereas its imports from them decrease because their commodities become relatively more expensive after the FTA. Thus, the third country effect always serves to encourage countries to sign FTAs at the costs of third countries: all other countries including existing FTA partners are hurt by these new FTAs. In contrast, the sign of the direct surplus effect depends on the two countries' characteristics such as the market and industry size, and the characteristics of their current partners. Let us consider, for example, an FTA between a highly-industrialized small country and a less-industrialized large country. The FTA increases trade flows from the former to the latter disproportionately, dramatically increasing the trade surplus of the small highly-industrialized country and decreasing that of the large less-industrialized country. The direct surplus effect for the large less-industrialized country is likely to be negative, and it may outweigh the third country effect. Consequently,

[9] If tariffs have been imposed on a large portion of commodities, it may not be welfare improving to get rid of tariffs for a small portion of commodities since it enlarges distortions between these commodities and the ones with high tariffs.

the large less-industrialized country is likely to oppose to sign the FTA.[10] If two countries are similar in their characteristics, however, the direct surplus effects would be small, and the countries are likely to benefit from signing an FTA due to the third country effect.

The main results of this paper are as follows. When all countries are symmetric in the market size and the industry size, we show that the complete FTA network, the network in which any pair of countries has an FTA, is pairwise stable (Proposition 1). If commodities are highly substitutable among themselves, however, there may also be other pairwise stable networks. It is because the difference in the number of FTA partners can create a large differential in the impacts on the direct surplus, even though all countries are symmetric in the market size and industry size. We show that if predetermined external tariff rates are small or if commodities are not highly substitutable among themselves, the complete FTA network is a unique pairwise stable network (Proposition 2). If countries are asymmetric, on the other hand, the complete FTA network may not be attained. In a special case where all industrial commodities are independent from one another, a pair of countries signs an FTA if and only if their industrialization levels are close to each other (Proposition 3).[11] This proposition implies for example that developed countries and less developed countries respectively form mutually exclusive trading blocs. We also compare FTAs and CUs as to which of these two regimes facilitate global trade liberalization. We find that if all countries are symmetric, and if industrial commodities are not highly substitutable among themselves, a pair of countries has less incentive to form a new FTA if either of them is a member of a CU as opposed to an FTA (Proposition 4). If countries are asymmetric, on the other hand,

[10] It is interesting to note that countries in our model have a view that Krugman (1991) calls GATT-think: '(1) Exports are good, (2) Imports are bad, (3) and other things being equal, an equal increase in imports and exports is good.' Our model gives an economic reasoning to this "enlightened mercantilism" (see Furusawa and Konishi, 2004, for details). Bagwell and Staiger (1999a) argue that GATT's principle of reciprocity, which appears to reflect the "enlightened mercantilism," indeed has a sound economic role of enhancing efficiency.

[11] Furusawa and Konishi (2005) show that Propositions 1 and 2 in this paper can be generalized to the case of asymmetric countries if transfers between FTA signatories are allowed. With transfers, a pair of countries signs an FTA even if their industrialization levels are quite different (see the Concluding Remarks for more details).

the CU formation averages out member countries' industrialization levels, which may help further PTA formation. We illustrate this possibility in the case of mutually independent industrial commodities.

An independent work by Goyal and Joshi (2006) also investigates the FTA formation as a network formation game, and obtains the result that the complete FTA network is pairwise stable (the counterpart of our Proposition 1). Our model is richer in some important aspects, enabling us to obtain further insights on incentives to sign FTAs. In particular, their model assumes that firms produce a homogeneous good, whereas ours has an industry with differentiated commodities whose substitutability is parameterized. As briefly discussed above, substitutability among differentiated commodities plays an important role in determining the global FTA configuration. In addition, our model is more suitable for the analysis of asymmetric countries than theirs. The main part of their analysis assumes that all countries are symmetric with respect to the (Cournot-oligopolistic) market size and the number of domestic firms, whereas ours are more flexible so that we obtain such a result as Proposition 3 in the case of asymmetric countries. We also discuss the difference between FTAs and CUs as to which of them facilitates global trade liberalization in a higher degree.

2 The Model

2.1 Overview

Let $N = \{1, 2, \cdots, n\}$ be the set of n countries ($n \geq 3$), each of which is populated by a continuum of identical consumers who consume a numeraire good and a continuum of horizontally differentiated commodities that are indexed by $\omega \in [0, 1]$. A differentiated commodity can be considered as a variety of an industrial good. Each industrial commodity ω is produced by one firm, also indexed by the same ω, which engages in price competition with other firms in individual segmented countries. We assume that there is no entry of firms into this industry. Each firm is owned equally by all domestic consumers who receive equal shares of all firms' profits. The numeraire good is produced competitively, on the other hand. Each consumer is endowed with l units of labor, which is used for production of the industrial and numeraire goods. Each unit of labor produces one unit of the numeraire good, so that the wage rate equals 1. We also assume that industrial commodities are produced with a constant-returns-to-scale technology, and normalize the unit labor requirement to be equal to 0 for each industrial commodity, without loss of generality. Alternatively, we can interpret the model such that each consumer is endowed with l units of the numeraire good, which can be transformed by a linear technology into industrial commodities.

In country $i \in N$, measure μ^i of consumers and measure s^i of firms that produce industrial commodities are located. Thus, country i produces s^i industrial commodities, which are consumed in every country in the world. Since the markets are segmented, firms can perfectly price discriminate among different countries. We normalize the size of total population so that $\sum_{k=1}^{n} \mu^k = 1$ as well as $\sum_{k=1}^{n} s^k = 1$. The ratio $\theta^i \equiv s^i/\mu^i$ measures country i's industrialization level. The higher the ratio, the higher the country's industrialization level. This ratio plays an important role later in our analysis. Country i imposes a specific tariff at a rate of t_j^i on the imports of the industrial commodities that are produced in country j. Under the Most-Favored-Nation (MFN) principle, country i must impose the same tariff rate against all other countries unless they are FTA partners of country i. We assume that there is no commodity tax, so that $t_i^i = 0$, and that the countries do not impose tariffs on the numeraire good, which may be traded internationally to balance trade. Tariff revenue is redistributed equally to domestic consumers.

2.2 Consumer Demands

A representative consumer's utility is given by the following quasi-linear utility function:

$$U(q, q_0) = \int_0^1 q(\omega)d\omega - \frac{1-\sigma}{2}\int_0^1 q(\omega)^2 d\omega - \frac{\sigma}{2}\left[\int_0^1 q(\omega)d\omega\right]^2 + q_0, \tag{1}$$

where $q : [0,1] \rightarrow \Re_+$ is an integrable consumption function, and q_0 denotes the consumption level of the numeraire good.[12] The second last term represents the substitutability among differentiated commodities, which may become clearer if we notice $\left[\int_0^1 q(\omega)d\omega\right]^2 = \int_0^1 \int_0^1 q(\omega)q(\omega')d\omega' d\omega$. The higher the parameter σ, the higher the substitutability between industrial commodities. The industrial commodities are independent from one another if $\sigma = 0$, while they are perfect substitutes if $\sigma = 1$. Letting y denote the consumer's income, the budget constraint can be written as

$$y = \int_0^1 \tilde{p}(\omega)q(\omega)d\omega + q_0, \tag{2}$$

where $\tilde{p} : [0,1] \rightarrow \Re_+$ denotes the consumer price function. The first order condition for the consumer's maximization problem gives us the inverse demand function for each good ω:

$$\tilde{p}(\omega) = 1 - (1-\sigma)q(\omega) - \sigma \int_0^1 q(\omega')d\omega'.$$

Integrating over $[0,1]$, we obtain

$$\int_0^1 q(\omega)d\omega = 1 - \tilde{P},$$

where $\tilde{P} = \int_0^1 \tilde{p}(\omega)d\omega$. Substituting this equation back into the first order condition, we have

$$q(\omega) = \frac{1}{1-\sigma}\left[1 - \tilde{p}(\omega) - \sigma\left(1 - \tilde{P}\right)\right].$$

2.3 Equilibrium in Country i

Letting $p^i(\omega)$ and $\tilde{P}^i$ denote the producer price for commodity ω sold in country i, and the average consumer price in country i, respectively, a representative consumer's demands in

[12]This utility function is a continuous-goods version of the ones of Shubik (1984) and Yi (1996, 2000) who analyze the case where there are only finitely many differentiated commodities. Our setup of continuous commodities is based on the model developed by Ottaviano, Tabuchi, and Thisse (2002). This specification is more suitable, for example, than perfectly competitive models for the analysis of FTA formation among asymmetric countries with a differentiated good, in which substitutability among differentiated commodities plays an important role. Interestingly, price competition and quantity competition yield the same equilibrium outcomes in this setup of continuous commodities since a firm's choice of either price or production quantity has only a negligible impact on the demands for other firms' products. Therefore, the following analysis would not be affected by the choice of strategic variables, which is another appealing feature of the model.

country i for commodity ω produced in country k can be written as

$$q^i(\omega) = \frac{1}{1-\sigma}\left[1 - p^i(\omega) - t^i_k - \sigma\left(1 - \tilde{P}^i\right)\right]. \tag{3}$$

The firm ω in country k chooses $\{p^i(\omega)\}_{i=1}^n$ to maximize its profits $\pi(\omega) = \sum_{i=1}^n \mu^i p^i(\omega) q^i(\omega)$. The first order condition for this maximization gives us

$$p^i(\omega) = \frac{1}{2}\left[1 - t^i_k - \sigma\left(1 - \tilde{P}^i\right)\right], \tag{4}$$

for any i. Notice that $p^i(\omega)$ does not vary with ω. Prices charged by firms depend only on the importing country's tariff policies. We henceforth suppress the argument ω.

It follows from (4) that country i's average consumer price is

$$\begin{aligned}\tilde{P}^i &= \sum_{k=1}^n s^k(p^i + t^i_k) \\ &= \frac{1}{2}\left[1 + \bar{t}^i - \sigma\left(1 - \tilde{P}^i\right)\right],\end{aligned}$$

where $\bar{t}^i \equiv \sum_{k=1}^n s^k t^i_k$. Thus, country i's average consumer price $\tilde{P}^i$ is given by

$$\tilde{P}^i = \frac{1 - \sigma + \bar{t}^i}{2-\sigma}. \tag{5}$$

Substituting (5) into (4) yields the equilibrium producer price p^i_k that each firm in country k charges for the market of country i, as a function of country i's tariff vector $\mathbf{t}^i = (t^i_1, ..., t^i_n)$:

$$p^i_k(\mathbf{t}^i) = \frac{1-\sigma}{2-\sigma} - \frac{1}{2}t^i_k + \frac{\sigma}{2(2-\sigma)}\bar{t}^i.$$

Then it follows from (3) that a representative consumer's demand in country i for a commodity produced in country k, denoted by q^i_k, is

$$q^i_k(\mathbf{t}^i) = \frac{1}{2-\sigma} - \frac{1}{2(1-\sigma)}t^i_k + \frac{\sigma}{2(1-\sigma)(2-\sigma)}\bar{t}^i. \tag{6}$$

Notice that $p^i_k(\mathbf{t}^i) = (1-\sigma)q^i_k(\mathbf{t}^i)$ for any tariff vector $\mathbf{t}^i$.

2.4 Social Welfare

Under the world tariff vector $\mathbf{t} = (\mathbf{t}^1, ..., \mathbf{t}^n)$, each firm in country i earns the profits:

$$\pi_i(\mathbf{t}) = \sum_{k=1}^{n} \mu^k p_i^k(\mathbf{t}^k) q_i^k(\mathbf{t}^k) = \sum_{k=1}^{n} \mu^k (1-\sigma) q_i^k(\mathbf{t}^k)^2. \tag{7}$$

Country i's *per capita* tariff revenue is

$$T^i(\mathbf{t}^i) = \sum_{k=1}^{n} t_k^i s^k q_k^i(\mathbf{t}^i). \tag{8}$$

A representative consumer's income in country i is the sum of labor income, redistributed tariff revenue, and the profit shares of the firms in country i:

$$y = l + T^i(\mathbf{t}^i) + \frac{s^i \pi_i(\mathbf{t})}{\mu^i}. \tag{9}$$

Then it follows from (2) that

$$\begin{aligned} q_0^i(\mathbf{t}) &= l + T^i(\mathbf{t}^i) + \frac{s^i \pi_i(\mathbf{t})}{\mu^i} - \sum_{k=1}^{n} s^k [p_k^i(\mathbf{t}^i) + t_k^i] q_k^i(\mathbf{t}_k^i) \\ &= l + \sum_{k=1}^{n} s^k t_k^i q_k^i(\mathbf{t}^i) + \frac{s^i}{\mu^i} \sum_{k=1}^{n} \mu^k p_i^k(\mathbf{t}^k) q_i^k(\mathbf{t}^k) - \sum_{k=1}^{n} s^k [p_k^i(\mathbf{t}^i) + t_k^i] q_k^i(\mathbf{t}^i) \\ &= l - \sum_{k \neq i} s^k p_k^i(\mathbf{t}^i) q_k^i(\mathbf{t}^i) + \frac{s^i}{\mu^i} \sum_{k \neq i} \mu^k p_i^k(\mathbf{t}^k) q_i^k(\mathbf{t}^k), \end{aligned} \tag{10}$$

where $q^i(\omega) = q_k^i(\mathbf{t}^i)$ if ω is produced in country k.

Substituting these equilibrium demands, (6) and (10), into (1), we obtain a representative consumer's utility in country i as a function of the world tariff vector, which can be considered as country i's *per capita* social welfare:

$$W^i(\mathbf{t}) \equiv U((q_k^i(\mathbf{t}^i))_{k \in N}, q_0^i(\mathbf{t})) = V^i(\mathbf{t}^i) + X^i(\mathbf{t}^{-i}) - M^i(\mathbf{t}^i), \tag{11}$$

where

$$V^i(\mathbf{t}^i) \equiv U((q_k^i(\mathbf{t}^i))_{k \in N}, l), \tag{12}$$

$$M^i(\mathbf{t}^i) \equiv \sum_{k \neq i} s^k p_k^i(\mathbf{t}^i) q_k^i(\mathbf{t}^i) = \sum_{k \neq i} (1-\sigma) s^k q_k^i(\mathbf{t}^i)^2, \tag{13}$$

$$X^i(\mathbf{t}^{-i}) \equiv \frac{s^i}{\mu^i} \sum_{k \neq i} \mu^k p_i^k(\mathbf{t}^k) q_i^k(\mathbf{t}^k) = \frac{s^i}{\mu^i} \sum_{k \neq i} (1-\sigma) \mu^k q_i^k(\mathbf{t}^k)^2, \tag{14}$$

with $\mathbf{t}^{-i} = (\mathbf{t}^1, \cdots, \mathbf{t}^{i-1}, \mathbf{t}^{i+1}, \cdots, \mathbf{t}^n)$. The functions $V^i(\mathbf{t}^i)$, $M^i(\mathbf{t}^i)$, and $X^i(\mathbf{t}^{-i})$ represent a consumer's gross utility, import payments, and the export value of industrial commodities, respectively.[13] Country i's social welfare consists of a consumer's gross utility $V^i(\mathbf{t}^i)$ and the per-capita industrial trade surplus $X^i(\mathbf{t}^{-i}) - M^i(\mathbf{t}^i)$.[14] Country i's tariffs affect social welfare through the effects on $V^i(\mathbf{t}^i)$ and $M^i(\mathbf{t}^i)$. Other countries' tariffs affect country i's social welfare through the effect on $X^i(\mathbf{t}^{-i})$.

Now, we examine the effects of tariff changes on the three components of social welfare: $V^i(\mathbf{t}^i)$, $X^i(\mathbf{t}^{-i})$, and $M^i(\mathbf{t}^i)$. We notice from (12)-(14) that an increase in a tariff rate affects these components only through the changes in the consumption of industrial commodities. We see from (6) that the consumption of an industrial commodity depends on the tariff rate imposed on that commodity and the average tariff rate, i.e., $q^i_k(\mathbf{t}^i) \equiv \tilde{q}^i_k(t^i_k, \bar{t}^i)$. Thus, we can write, for example, $V^i(\mathbf{t}^i) = \tilde{V}^i(\tilde{q}^i_1(t^i_1, \bar{t}^i), \cdots \tilde{q}^i_n(t^i_n, \bar{t}^i))$. An increase in t^i_j does not only affect q^i_j directly, but also affects q^i_k indirectly, for all $k = 1, 2, \cdots, n$. These changes in consumption affect $V^i(\mathbf{t}^i)$ and $M^i(\mathbf{t}^i)$, in turn. As for the effect on $V^i(\mathbf{t}^i)$, for example, we have

$$\frac{\partial V^i}{\partial t^i_j} = \sum_{k=1}^{n} \frac{\partial \tilde{V}^i}{\partial \tilde{q}^i_k} \left(\frac{\partial \tilde{q}^i_k}{\partial t^i_j} + \frac{\partial \tilde{q}^i_k}{\partial \bar{t}^i} \frac{\partial \bar{t}^i}{\partial t^i_j} \right).$$

An increase in another country's tariff rate on country i's commodity affects the export profits $X^i(\mathbf{t}^{-i})$ in a similar fashion. We can easily obtain the following lemma that shows the effects of raising a tariff rate on the three components of social welfare. The proof is straightforward and hence omitted.

Lemma 1 *The first order effects of raising t^i_j on V^i and M^i and the effect of raising t^j_i on*

[13]The gross utility $V^i(\mathbf{t}^i) = U((q^i_k(\mathbf{t}^i))_{k \in N}, l)$ includes the utility derived from the consumption of l units of the numeraire good. However, since l is a constant that does not necessarily represents the actual consumption level of the numeraire good, $V^i(\mathbf{t}^i)$ should be regarded as the function that represents the gross utility derived from the consumption of the industrial commodities.

[14]This decomposition of social welfare, developed by Furusawa and Konishi (2004), may appear to suggest that a rise in industrial trade surplus unambiguously enhances social welfare. It should be emphasized, however, that the decomposition would not support such mercantilism, since an increase in imports, for example, is not necessarily bad as it raises consumers' gross utilities as well as it lowers trade surplus.

X^i *are:*

$$\frac{\partial V^i}{\partial t^i_j} = s^j \left[-\frac{1}{2-\sigma} + \frac{\sigma}{2(2-\sigma)} \sum_{k=1}^{n} s^k q^i_k(\mathbf{t}^i) + \frac{1}{2} q^i_j(\mathbf{t}^i) \right],$$

$$\frac{\partial X^i}{\partial t^j_i} = -\frac{\mu^j s^i q^j_i(\mathbf{t}^j)}{\mu^i} \left(1 - \frac{\sigma s^i}{2-\sigma}\right),$$

$$\frac{\partial M^i}{\partial t^i_j} = s^j \left[-q^i_j(\mathbf{t}^i) \left(1 - \frac{\sigma s^j}{2-\sigma}\right) + \sum_{k \neq i,j} q^i_k(\mathbf{t}^i) \frac{\sigma s^k}{2-\sigma} \right].$$

It may appear that an increase in a tariff rate of country i, say t^i_j, necessarily decreases the domestic consumer's gross utility V^i. Each consumer in country i reduces the consumption of country j's commodities as a consequence, which is detrimental. However, each agent consumes other commodities more than before, which tends to increase the consumer's gross utility. The latter indirect effect may outweigh the former so that an increase in a tariff rate may increase the domestic consumer's gross utility, if the industrial commodities are highly substitutable among themselves. Similarly, an increase in a tariff rate may not always decrease the import payments. If the industrial commodities are highly substitutable, the resulting decrease in q^i_j may be outweighed by increases in q^i_k for $k \neq i, j$. However, it is easy to see from Lemma 1 that an increase in another country's tariff unambiguously decreases the domestic profits obtained from the export to that country.

3 Free Trade Agreements

3.1 Incentives to sign an FTA

We examine incentives for country i to sign an FTA with country j. If countries i and j sign an FTA, they eliminate all tariffs imposed on commodities imported from each other, while keeping all other tariffs at their original levels. Letting $\mathbf{t}$ and $\mathbf{t}'$ denote the world tariff vectors before and after the FTA, respectively, $\mathbf{t}'$ is different from $\mathbf{t}$ only in the respect that $t^{i\prime}_j = t^{j\prime}_i = 0$. Country i has an incentive to sign an FTA with country j if and only if

$W^i(\mathbf{t}') \geq W^i(\mathbf{t})$, which can be written as

$$\Delta V^i(\mathbf{t}^i) + \left[\Delta X^i(\mathbf{t}^{-i}) - \Delta M^i(\mathbf{t}^i)\right] \geq 0, \tag{15}$$

where Δ represents a change in the respective function values caused by an FTA between countries i and j such that $\Delta V^i(\mathbf{t}^i) \equiv V^i(\mathbf{t}^{i\prime}) - V^i(\mathbf{t}^i)$, for example. As we will see shortly, a tariff reduction is likely to increase a consumer's gross utility, unless the industrial commodities are highly substitutable from one another. Since the FTA increases country i's export profits and is also likely to increase the import payments, on the other hand, the FTA has an ambiguous impact on country i's industrial trade surplus. Under the MFN principle, each country i imposes the same external tariff rate, denoted by t^i, on all commodities imported from countries that have no FTAs with country i. We define $C_i = \{k \in N | t^i_k = 0\}$ as the set of countries that produce commodities on which country i does not impose tariffs. (Notice that C_i includes country i itself since $t^i_i = 0$.)

First, we investigate the sign of $\Delta V^i(\mathbf{t}^i)$. The next lemma shows that an FTA increases a consumer's gross utility of a country that has liberalized trade with the majority of countries, i.e., the majority of commodities are exempt from tariffs.

Lemma 2 *A bilateral FTA with country j increases a consumer's gross utility for country i, i.e., $\Delta V^i(\mathbf{t}^i) > 0$, if $s^{C_i} + (s^j/2) \geq 1/2$.*

Remark 1 *The condition reflects the second best effect: In an economy with distortions, the partial removal of tax distortions may reduce efficiency. When a tariff on a commodity is eliminated, distortions between this commodity and untaxed commodities shrink, whereas distortions with taxed commodities expand. Thus, if there are more untaxed commodities than taxed commodities, the second best theory tells us that a bilateral FTA between i and j is likely to raise a consumer's gross utility. The condition $s^{C_i} + (s^j/2) \geq 1/2$ matches exactly to this observation.*

Next, we turn to investigating the effect of an FTA between countries i and j on the industrial trade surplus. Let M_k^i and X_k^i be country i's (per capita) import payments to country k and country i's (per capita) export profits from country k, respectively:

$$M_k^i(\mathbf{t}^i) = (1-\sigma)s^k q_k^i(\mathbf{t}^i)^2, \tag{16}$$

$$X_k^i(\mathbf{t}^k) = \frac{s^i}{\mu^i}(1-\sigma)\mu^k q_i^k(\mathbf{t}^k)^2 \left(= \frac{\mu^k}{\mu^i} M_i^k(\mathbf{t}^k)\right). \tag{17}$$

Then, we can rewrite country i's industrial trade surplus as

$$X^i(\mathbf{t}^{-i}) - M^i(\mathbf{t}^i) = \sum_{k \neq i} \left[X_k^i(\mathbf{t}^k) - M_k^i(\mathbf{t}^i)\right].$$

An FTA between i and j only involves changes in $\mathbf{t}^i$ and $\mathbf{t}^j$ so that it does not affect $X_k^i(\mathbf{t}^k)$ for any $k \neq i, j$. Consequently, a change in country i's industrial trade surplus can be written as

$$\Delta\left[X^i(\mathbf{t}^{-i}) - M^i(\mathbf{t}^i)\right] = \underbrace{\Delta\left[X_j^i(\mathbf{t}^j) - M_j^i(\mathbf{t}^i)\right]}_{\text{Direct surplus effect}} \underbrace{-\sum_{k \neq i,j} \Delta M_k^i(\mathbf{t}^i)}_{\text{Third country effect}}.$$

The third country effect, represented by the last terms, is always positive since the reduction of t_j^i makes commodities imported from country j relatively less expensive, and hence country i's imports from third countries decrease, i.e., $\Delta M_k^i(\mathbf{t}^i) < 0$. The reduction of FTA signatories' imports from all other countries hurts those outsiders, but provides countries i and j with incentives to sign an FTA.

Having shown that the third country effect is positive, let us now investigate the direct surplus effect, which can be rewritten as follows from (16) and (17):

$$\Delta\left[X_j^i(\mathbf{t}^j) - M_j^i(\mathbf{t}^i)\right] = \mu^j(1-\sigma)\Delta\left[\theta^i q_i^j(\mathbf{t}^j)^2 - \theta^j q_j^i(\mathbf{t}^i)^2\right],$$

where $\theta^i = s^i/\mu^i$ as defined above. The higher θ^i and the lower θ^j, the larger an increase in country i's industrial trade surplus. Thus, the direct surplus effect is unbalanced in favor of the relatively more industrialized country.[15] The more industrialized country derives a large

[15]Indeed, if one country's direct surplus effect is positive, the partner's direct surplus effect must be negative since the sum of two countries' direct surplus effects is always zero, i.e., $\Delta X_j^i(\mathbf{t}^j) = \Delta M_i^j(\mathbf{t}^j)$ for any $i, j \in N$ with $i \neq j$.

benefit from the opening of the partner's relatively large market. In addition, opening its own market to the partner's firms does not significantly increase import payments since the resulting penetration by the partner's firms is relatively small. Another important factor that affects the incentives to form an FTA is the difference in the original tariff rates. If $t^i < t^j$, for example, then it is likely that $\Delta q^i_j(\mathbf{t}^i) < \Delta q^j_i(\mathbf{t}^j)$. Country i's export to country j increases more than its import from country j, and hence the FTA between i and j tends to be more beneficial to country i.

3.2 Stable Free Trade Networks

An FTA that involves more than two countries can be considered as a collection of bilateral FTAs between member countries, so in the graph theory an arbitrary network of FTAs can be described as a graph. An FTA between countries i and j can be considered as a *link*, which is an unordered pair of two countries. An *FTA graph* is an undirected graph, (N, Γ), consisting of the set of countries N and a (free trade) *network* Γ that is a collection of links. The set of country i's FTA *partners* in network Γ is $C_i(\Gamma) = \{i\} \cup \{k \in N : (i, k) \in \Gamma\}$, which includes i, as we have already described. We continue to write C_i without confusion, as long as network Γ is fixed.

If external tariff rates are exogenously determined as in this paper, or if they are determined uniquely for each free trade network Γ (such as in the case where all countries set their individual optimal tariffs given a prevailing network Γ), then country i's payoff (social welfare) can be written uniquely by $u_i(\Gamma)$. The set of countries N and their payoff functions define a *network formation game*.

Network formation games are first studied by Jackson and Wolinsky (1996). A *pairwise stable network* is a network Γ^* such that (i) for any $i \in N$ and for any $(i, j) \in \Gamma^*$, $u_i(\Gamma^*) \geq u_i(\Gamma^* \backslash (i, j))$, i.e., no country has an incentive to cut a link with another, and (ii) for any $(i, j) \notin \Gamma^*$ with $i \neq j$, if $u_i(\Gamma^*) < u_i(\Gamma^* \cup (i, j))$ then $u_j(\Gamma^*) > u_j(\Gamma^* \cup (i, j))$, i.e., for any unlinked pair of countries, at least one of them has no incentive to form a link with the other.[16]

We are particularly interested in the situation where global free trade is effectively attained. A *complete* graph is the graph (N, Γ^{comp}) that contains all possible links, i.e., for any $i, j \in N$ with $i \neq j$, $(i, j) \in \Gamma^{comp}$. We call Γ^{comp} a *complete network*. The global free trade is a complete graph in the free trade network formation game.

3.3 Symmetric Countries

We say that countries i and j are *symmetric* if $s^i = s^j$ and $\mu^i = \mu^j$. This subsection considers the case in which the world consists of n symmetric countries so that $s^i = \mu^i = 1/n$ for any $i \in N$. In this case, country i's direct surplus effect can be simplified as

$$\begin{aligned}\Delta\left[X_j^i(\mathbf{t}^{-i}) - M_j^i(\mathbf{t}^i)\right] &= \mu^j(1-\sigma)\Delta\left[\frac{s^i}{\mu^i}q_i^j(\mathbf{t}^j)^2 - \frac{s^j}{\mu^j}q_j^i(\mathbf{t}^i)^2\right] \\ &= \frac{1-\sigma}{n}\left[\Delta(q_i^j(\mathbf{t}^j)^2) - \Delta(q_j^i(\mathbf{t}^i)^2)\right].\end{aligned}$$

The current network structure affects the impact of the FTA between i and j on country i's industrial trade surplus through its effects on commodity demands. Especially important is the size of C_i and C_j.

Let us say that countries i and j are *completely symmetric* if they are symmetric and $|C_i| = |C_j|$. If the original tariffs are the same between completely symmetric countries i and j, i.e., $t^i = t^j = t$, then $\bar{t}^i = \bar{t}^j$ and $q_i^j(\mathbf{t}^j) = q_j^i(\mathbf{t}^i)$, and hence we have $\Delta q_i^j(\mathbf{t}^j) = \Delta q_j^i(\mathbf{t}^i)$ and $\Delta X_j^i(\mathbf{t}^{-i}) = \Delta M_j^i(\mathbf{t}^i)$. Thus, the direct surplus effect disappears if countries i and j are completely symmetric and their original tariffs are the same. An increase in country i's export to country j and an increase in country i's import from county j are completely

[16] Readers may be tempted to formulate a strategic form game such that each player (country) announces the names of players with whom she wants to be linked, and a link is formed if and only if both sides of the link announce each other's names. In such a game, however, there would be too many Nash equilibria, always including the one without any link. It is because a player has no incentive to announce the name of the player who does not announce her name. See Dutta and Mutuswami (1997) for the coalition-proof Nash equilibrium, a refinement of the Nash equilibrium in such games.

canceled out. On the other hand, the third country effect is nonnegative. Thus, we have $\Delta\left[X^i(\mathbf{t}^{-i}) - M^i(\mathbf{t}^i)\right] \geq 0$ if countries i and j are completely symmetric.

Completely symmetric countries always have incentives to sign an FTA as long as the condition in Lemma 2 is satisfied. One important case is that all pairs but (i, j) have already formed free trade links. Since most tariffs are already eliminated, an FTA between i and j reduces distortions, and hence enhances a consumer's gross utility in these countries ($\Delta V^i > 0$). Thus, the two countries can improve social welfare by signing an FTA, which leads to our first proposition.[17]

Proposition 1 *Suppose that there are n symmetric countries in the world, and that their external tariff rates are the same if they are imposed. Then, global free trade (the complete network Γ^{comp}) is a stable network.*

Proof. The second condition for pairwise stability is vacuously satisfied since there is no unlinked pair of countries under the complete free trade network. Therefore, we need only show that a representative country i has no incentive to cut a link with country j. Or equivalently, country i has an incentive to sign an FTA with country j under the network $\Gamma^{comp}\backslash(i, j)$. Now, we know from the above observation that country i's industrial trade surplus does not decrease by signing the FTA since countries i and j are completely symmetric. Moreover, since $s^{C_i} = 1 - (1/n)$ and $s^j = 1/n$, we have $s^{C_i} + (s^j/2) = 1 - (1/2n) > 1/2$ for all $n \geq 3$ under $\Gamma^{comp}\backslash(i, j)$. Then, it follows from Lemma 2 that a consumer's gross utility in country i strictly increases. Therefore, we have $u_i(\Gamma^{comp}) > u_i(\Gamma^{comp}\backslash(i, j))$, implying that Γ^{comp} is a stable network.

Q.E.D.

[17]Bagwell and Staiger (1999a) argue that reciprocal trade liberalization between two countries is beneficial to both countries since it leaves each country's terms of trade unchanged so that it eliminates negative terms-of-trade externalities. An FTA between two completely symmetric countries fits their argument in that it leaves the bilateral (industrial commodity) terms of trade unaffected. In addition, each country's bilateral terms of trade against a third country improves as $q^i_k(\mathbf{t}^i)$ and hence $p^i_k(\mathbf{t}^i)$ declines for $k \neq i, j$.

Remark 2 *Note that this proposition holds even in the case where each country optimally adjusts its tariff rate to a change in the free trade network. If a country cuts a link with another under Γ^{comp}, these countries would impose the same optimal tariff rate by symmetry. Thus, the assumptions of Proposition 1 are satisfied even if tariff rates are endogenously determined at their optimal levels.*

Bagwell and Staiger (2005) show that any Pareto efficient tariff vector is unstable since a pair of countries can benefit from reciprocal reduction of their tariffs against each other while retaining those against other countries. This bilateral opportunism problem arises since the mutual tariff reduction that is discriminatory against third countries will improve their terms of trade against third countries. Their striking proposition also holds in our imperfectly competitive world. The bilateral tariff reduction from a Pareto efficient tariff vector can be tailored so as to nullify the direct surplus effect. Since the third country effect is always positive, however, this tariff reduction will unambiguously improve the industrial trade surplus, so any Pareto efficient tariff vector is vulnerable to the bilateral opportunism. Due to the imperfectness of competition, free trade tariff vector in our model (the origin of the tariff space) lies above the set of Pareto efficient tariff vectors. Therefore, bilateral tariff reduction from free trade, i.e., mutual provision of import subsidies, definitely benefits both countries, implying that free trade is not pairwise stable if a pair of countries can choose discriminatory subsidies when they sign an FTA. Although we restrict the feasible set of tariff vectors to the non-negative orthant following the convention of the literature, allowing countries to choose subsidies can be an interesting extension of our analysis of FTA network formation game.

Now, it is natural to ask if the complete graph is a unique stable network. Unfortunately, it is not the case in general even if countries are symmetric. If $q_i^j(\mathbf{t}^j)$ is significantly smaller than $q_j^i(\mathbf{t}^i)$ and hence $\Delta q_i^j(\mathbf{t}^j)$ is significantly smaller than $\Delta q_j^i(\mathbf{t}^i)$, the direct surplus effect for country i is negative and it may outweigh the third country effect. This situation arises when country j has many FTAs with other countries, while country i has a small number of FTAs.

Lemma 3 *Consider the case where the world consists of* n *symmetric countries that would set a common tariff rate of* t*. Country* i*'s incentive to sign an FTA with country* j *increases with* $|C_i|$ *and decreases with* $|C_j|$*, and hence it is smallest if country* i *does not belong to any FTA while country* j *has FTAs with all countries but* i*.*

Consider the situation where country i's incentive to have an FTA with country j is smallest as described in Lemma 3. If σ is large and close to unity, consumer demands for a commodity are sensitive to prices for other commodities. In the absence of an FTA, therefore, isolated country i does not import much of industrial commodities, and most of industrial commodities consumed are domestically produced. However, once country i signs an FTA with country j, much of (about a half of) the consumption of domestic commodities is substituted by those produced in country j so that country i experiences a dramatic increase in its import payments. In contrast, country j has already opened its market to all but country i before the FTA. Therefore, the FTA with country i does not increase its imports much even if σ is large. Therefore, the direct surplus effect of country i is negative and large in magnitude, which outweighs the third country effect and the effect on $\Delta V^i(\mathbf{t}^i)$. Although it is hoped that (preferential) trade liberalization continues under the GATT Article XXIV, it is quite possible that the process of FTA formation stops prematurely even if all countries are symmetric.

Now, we seek the condition under which every pair of countries has incentive to form an FTA regardless of the current FTA network. In such a case, the complete network (global free trade) becomes a unique stable network. The next proposition states that the complete FTA network is a unique stable network if tariffs are small or if the industrial commodities are not highly substitutable from one another.

Proposition 2 *Suppose that the world consists of n symmetric countries that would set a common external tariff rate of t. Any pair of countries without an FTA have incentives to form a free trade link under any network Γ, and thus the complete FTA network Γ^{comp} is a unique stable network if and only if either*

(i) $A(\sigma, n) \equiv -4n + 4(5n-8)\sigma - \left(11n - 23 + \frac{4}{n}\right)\sigma^2 \leq 0$, *or*

(ii) $t \leq \tau(\sigma, n) \equiv \frac{8(1-\sigma)(n-2\sigma)}{A(\sigma,n)}$ *when* $A(\sigma, n) > 0$

is satisfied. Condition (i) is satisfied if σ is smaller than or equal to the smaller root of $A(\sigma, n) = 0$, which we call $\bar{\sigma}(n) \in (0, 1)$. The critical tariff rate $\tau(\sigma, n)$ in condition (ii) is decreasing in σ.

Figure 1 depicts the threshold for the uniqueness of the stable network. The condition in Proposition 2 is satisfied if (σ, t) lies to the left of the graph of $\tau(\cdot, n)$. If this condition is violated, there exists a pairwise stable network, in addition to the complete FTA network, such that one country is isolated while all other countries have FTAs with one another. If $n = 15$ and $\sigma = .98$, for example, the condition in Proposition 2 is violated for $t = .04$. In such a situation, all but country 1, say, have FTAs with one another. This network is stable since the isolated country 1 does not have an incentive to have a bilateral FTA with any other country.

This proposition suggests that FTA formation and multilateral trade negotiation under the auspices of the WTO are complementary. As tariff rates decline through multilateral negotiations, it becomes more likely that unlinked pairs of countries have FTAs, leading to the complete network of FTAs.

Moreover, under the condition where Proposition 2 applies, the world free trade network will eventually reach the complete network such that global free trade is effectively attained if countries myopically make decisions as to whether or not they sign FTAs with other countries. For dynamic network formation games, Watts (2001) defines a stable state as the network in which any randomly selected pair of myopic players have no incentive to severe the link if they are currently linked and to form a link if they are not linked. The complete FTA network is the unique stable state if the condition of Proposition 2 is satisfied. This result can also be extended to the case of farsighted countries with an arbitrary discount rate. Applying Theorem 3 of Dutta, Ghosal, and Ray (2005), we can conclude that if the condition of Proposition 2 is satisfied, there is a Markov perfect equilibrium in which the complete FTA network is eventually reached from any FTA network.

3.4 Asymmetric Countries

Let us turn to a more realistic case in which countries are asymmetric. As we infer from the preceding analysis, countries are less likely to have FTAs and the complete FTA network is less likely to be pairwise stable in an asymmetric world. Of course, a pair of countries with similar size of the market and industry still signs a bilateral FTA. Moreover, we show in this subsection that countries with similar industrialization levels, but not necessarily similar in the absolute size of the market and industry, tend to sign a bilateral FTA. To this end, we assume here that $\sigma = 0$. Although this simplification is restrictive, it highlights how the asymmetry of countries affects the FTA network formation.

In this special case of no substitution among industrial commodities, we can easily calculate social welfare of each country. Since commodity demands are independent of one another when $\sigma = 0$, the main part of a consumer's gross utility can be written as a simple sum of utilities derived from the consumption of all individual commodities. Let $p(t)$ and $q(t)$ denote the equilibrium producer price and quantity of the industrial commodity that is faced with the tariff rate t, and let $v(t)$ denote a consumer's utility derived from the consumption of that commodity. Then, we can write

$$
\begin{aligned}
V^i(\mathbf{t}^i) &= \sum_{k \in C_i} s^k v(0) + \sum_{h \notin C_i} s^h v(t) + l, \\
X^i(\mathbf{t}^{-i}) &= \frac{s^i}{\mu^i} \left[\sum_{k \in C_i \setminus \{i\}} \mu^k p(0) q(0) + \sum_{h \notin C_i} \mu^h p(t^h) q(t^h) \right], \\
M^i(\mathbf{t}^i) &= \sum_{k \in C_i \setminus \{i\}} s^k p(0) q(0) + \sum_{h \notin C_i} s^h p(t^h) q(t^h).
\end{aligned}
$$

As Figure 2 shows we have, for $t \leq 1$, that

$$
\begin{aligned}
p(t) &= \frac{1+t}{2} - t = \frac{1-t}{2}, \\
q(t) &= \frac{1-t}{2},
\end{aligned}
$$

and hence

$$
\begin{aligned}
v(t) &= \frac{(1-t)(3+t)}{8}, \\
p(t)q(t) &= \frac{(1-t)^2}{4}.
\end{aligned}
$$

If countries i and j sign an FTA, then C_i expands to include j. Thus, the impact on country i's welfare is

$$
\begin{aligned}
\Delta W^i(\mathbf{t}) &= s^j [v(0) - v(t^i)] + \frac{s^i \mu^j}{\mu^i} [p(0)q(0) - p(t^j)q(t^j)] - s^j [p(0)q(0) - p(t^i)q(t^i)] \\
&= \mu^j \left[\frac{\theta^j t^i (2 + t^i)}{8} + \frac{\theta^i t^j (2 - t^j)}{4} - \frac{\theta^j t^i (2 - t^i)}{4} \right] \\
&= \frac{\mu^j}{8} [\theta^j t^i (3t^i - 2) + 2\theta^i t^j (2 - t^j)] \qquad (18)
\end{aligned}
$$

The first observations we derive from (18) are rather obvious. Excluding prohibitive tariffs from consideration, we find that the higher is t^j the higher is $\Delta W^i(\mathbf{t})$. Country i benefits more from the FTA with country j as country j's original tariff rate is high. As for country i's own tariff, we should distinguish between two cases, whether or not t^i is smaller than the optimal tariff 1/3. If $t^i \leq 1/3$, the lower is t^i, the higher is $\Delta W^i(\mathbf{t})$. If $t^i > 1/3$, on the other hand, the opposite is true. If t^i is higher than the optimal tariff for some reason, country

i has an incentive to unilaterally cut its tariff at least to the optimal level. This incentive becomes greater as t^i increases. Indeed, as (18) indicates, $\Delta W^i(\mathbf{t})$ is unambiguously positive if $t^i > 2/3$. Henceforth, we restrict our attention to the case where $t^i \leq 1/3$ for any $i \in N$, as no country has an incentive to select a higher tariff rate than its optimal level.

How do the countries' industrialization levels affect country i's incentive to sign the FTA? It follows from (18) that country i has an incentive to sign the FTA with country j if and only if

$$\frac{\theta^j}{\theta^i} \leq \frac{2t^j(2-t^j)}{t^i(2-3t^i)}. \tag{19}$$

Country i benefits from the FTA with country j if country j's industrialization level, relative to its own, is not so large. FTAs are reciprocal concessions: Each signatory gives up exercising its market power in import good markets in exchange for obtaining better access to export good markets in its partner countries. Thus, it is intuitive that the FTA is more beneficial if the resulting increase in its export to the partner is large (i.e., s^i and μ^j are large) and the resulting increase in its import from the partner is small (i.e., s^j and μ^i are small). Changes in country i's export and import depend, in general, on the FTA configuration of countries j and i, respectively. In the current case of $\sigma = 0$, however, they hinge on the bilateral trade relationship between i and j. Gains from the FTA are the simple sum of individual gains across the varieties. If s^i, μ^i, s^j, and μ^j are all doubled (so that θ^j/θ^i is unchanged), for example, the gains from the FTA are also doubled as (19) indicates, leaving the sign of $\Delta W^i(\mathbf{t})$ as it was.

In order for the FTA between countries i and j to be signed by both countries, the counterpart of (19) for country j must also be satisfied. Assuming $t^i = t^j \equiv t$ for clarity, we find that the FTA is signed if and only if

$$\frac{2-3t}{4-2t} \leq \frac{\theta^j}{\theta^i} \leq \frac{4-2t}{2-3t}. \tag{20}$$

As t increases from 0 to 1/3, this range of θ^j/θ^i expands from $[1/2, 2]$ to $[3/10, 10/3]$. The higher is t, the greater is the benefit of the FTA; hence even asymmetric countries sign an

FTA. We record the finding for the case of $t^i = t^j$ in the following proposition.

Proposition 3 *Suppose that $\sigma = 0$ and that countries would impose the common tariff rate t as their external tariffs. Countries i and j form a link if their industrialization levels are similar such that (20) is satisfied. The stable network is a generically unique collection of all links, each of which connects such a pair of countries.*

If countries' industrialization levels are not too different, then they have incentives to form an FTA. Countries with similar industrialization levels tend to form a link since (i) each country wants to sign an FTA with a country whose industrialization level is not so large compared with its own and (ii) an FTA is put into force only if it is signed by both parties. Suppose that there are two groups of countries: one is a group of developed countries with similar and high industrialization levels, and the other is a group of less developed countries with similar and low industrialization levels. Suppose also that every country selects its external tariff at its optimal level 1/3 for concreteness. Then, if the industrialization level of each developed country is far greater (more than 10/3 times) than the one of any less developed country, the FTA formation process leads to a stable network in which all countries within each group are linked with each other, while there is no link across the two groups. The FTA formation process may end with two (stumbling) trading blocs if industrialization levels of two groups are very different from each other.

4 Free Trade Agreements vs. Customs Unions

This section investigates the difference in member countries' incentives to sign a new FTA emphasizing the fact that a CU requires that all members be involved when a member country wants to have a free trade link with an outside country. The main goal of the paper is to assess how far the process of PTAs continues and whether or not global free trade is effectively attained as a complete world-wide web of PTAs. The analysis in this section possibly tells us which form of PTAs, CU or FTA, should be encouraged for facilitating more PTAs in the world. In order to focus on the issue, we assume that external tariff rates are the same in both cases.

We compare country i's incentives to have a new free trade link with country $j \notin C_i$ between two cases: the case where C_i forms a CU and the case where C_i is a *regional FTA* such that every pair of countries in C_i has a bilateral FTA. We begin with investigating the impact on a consumer's gross utility V^i. As Section 3.1 shows, the impact on V^i is ambiguous in both cases. However, these effects are exactly the same between the two cases, since V^i only depends on $\mathbf{t}^i$ and changes in $\mathbf{t}^i$ are the same between the two cases. Thus, the difference in changes of the industrial trade surplus between these two cases will determine whether or not country i's incentive to have an FTA with country j is higher in the case where C_i is a CU rather than a regional FTA. Here, we decompose the third country effect into the member country and nonmember country effects:

$$\Delta X^i - \Delta M^i = \underbrace{\left(\Delta X^i_j - \Delta M^i_j\right)}_{\text{Direct surplus effect}} + \underbrace{\sum_{k \in C_i \setminus \{i\}} \left(\Delta X^i_k - \Delta M^i_k\right)}_{\text{Member country effect}} + \underbrace{\sum_{h \notin C_i \cup \{j\}} \left(\Delta X^i_h - \Delta M^i_h\right)}_{\text{Nonmember country effect}},$$

where country k is a representative partner of i, i.e., $k \in C_i \setminus \{i\}$, and country h is a representative outsider of i, i.e., $h \notin C_i \cup \{j\}$.

Table 1 depicts the signs of the effects, and compares these two cases item by item. Similarly to the impacts on V^i, the effects of an FTA with country j on $M^i_j = M^i_j(\mathbf{t}^i)$ are the same between the two cases, since country i's imports from country j are solely determined by $\mathbf{t}^i$. This effect is positive since country i lowers its tariff rate for commodities imported from country j. In contrast, the effects on $X^i_j = X^i_j(\mathbf{t}^j)$ are different especially when $|C_i|$ is large. It is because country j eliminates tariffs against all countries in C_i in the case of CU while it eliminates tariffs only for commodities imported from country i in the case of FTA. Since industrial commodities are substitutable from one another, it is obvious that an increase in X^i_j is smaller in the case of CU. Consequently, the direct surplus effect is smaller in the case of CU than in the case of FTA.

Next, we investigate the effects on country i's industrial trade surplus with a member country $k \in C_i \backslash \{i\}$. As before, the effects on $M_k^i = M_k^i(\mathbf{t}^i)$ are the same in both cases. However, the effects on $X_k^i = X_k^i(\mathbf{t}^k)$ are different again. In the case of FTA, $\mathbf{t}^k$ is unaffected and hence X_k^i does not change. In the case of CU, on the other hand, country k also eliminates tariffs against country j, and country i's export to country k is reduced due to the substitution effect. Country i's industrial trade surplus with a member country k is again lower in the case of CU. Finally, it is easy to see that the third country effects with nonmembers are the same in both cases. Import payments to country h decrease by the same amount due to the tariff reduction for commodities imported from country j, and country i's exports to country h stay the same in both cases since $\mathbf{t}^h$ is not affected.

We have shown that the impacts of a new FTA on a consumer's gross utility are the same between the two cases, but the changes in the industrial trade surplus is unambiguously smaller in the case of CU. We record this result as a lemma.

Lemma 4 *Country i has less incentive to have a free trade link with country $j \notin C_i$ when C_i forms a CU rather than a regional FTA, unless the industrial commodities are independent of one another, i.e., $\sigma = 0$, in which case the incentives are the same.*

Whether or not country i's incentive to have a free trade link with country j is lower when C_j forms a CU rather than a regional FTA is generally ambiguous, however. The difference between these two cases in our terminology is that country i adds only one link with country j in the case of a regional FTA, whereas in the case of a CU country i adds $|C_j|$ links simultaneously with all individual countries in C_j. The latter case is effectively equivalent to the case where country i has an FTA with an integrated economy that consists of all countries in C_j. Whether country i prefers having a free trade link with country j alone or with the whole C_j depends on the relative characteristics of j and C_j.

However, we can make a strong statement in the case of symmetric countries with a low substitution parameter σ. Proposition 2 indicates that if all countries are symmetric and if σ is not very high, country i has an incentive to have an FTA with any country in any FTA configuration, in particular with country j alone or with all countries comprising C_j. Therefore, country i wants to have a free trade link with country j regardless of whether C_j forms a CU or an FTA. Combining this observation together with Lemma 4, we find that two countries are less likely to form a link if either of them is a member of a CU. Indeed, the complete FTA network is the unique stable network if all PTAs take a form of FTA (Proposition 2), whereas several CUs of asymmetric size may co-exist in a stable network if all FTAs take a form of CU.[18]

Proposition 4 *Suppose that countries are symmetric, imposing the same external tariff rate and that the condition in Proposition 2 is satisfied. Then, a pair of countries is less likely to have a free trade link if either of them is a member of a CU rather than a regional FTA.*

If countries are not symmetric, CUs can facilitate global trade liberalization more than FTAs. Consider again the case of asymmetric countries with $\sigma = 0$ in which every country would select its external tariff rate at its optimal level 1/3. We order n asymmetric countries according to their industrialization levels such that $\theta^1 \geq \theta^2 \geq \cdots \geq \theta^n$. Proposition 3 implies that if $\theta^1/\theta^n > 10/3$, countries 1 and n will not sign an FTA, and the process of bilateral FTA formation will never reach global free trade. However, if all PTAs take a form of CU, the process of CU formation may reach global free trade. Let us consider a CU by $C(k) \equiv \{1, 2, ..., k\}$, the set of k countries with highest industrialization levels. The industrialization level of the entire $C(k)$, i.e., $\theta^{C(k)} \equiv \sum_{h \in C(k)} s^h / \sum_{h \in C(k)} \mu^h$, is the "average" industrialization level of all individual members of $C(k)$, so that $\theta^1 \geq \theta^{C(k)} \geq \theta^k$. Now, it follows from Proposition 3 that $C(k)$ and $k+1$ sign an FTA, or in other words, CU

[18]Employing a coalition bargaining game, Yi (1996) shows that in equilibrium, two CUs of different size are formed when the world consists of a reasonable number of symmetric countries. We can conduct the same exercise in our model and obtain qualitatively the same result.

by $C(k)$ expands to include $k+1$, if $\theta^{C(k)}/\theta^{k+1} \leq 10/3$. Notice that this inequality can hold even if $\theta^1/\theta^{k+1} > 10/3$. The CU formation averages out member countries' industrialization levels, and hence encourages a less industrialized country to join the group. In particular, if $\theta^{C(k)}/\theta^{k+1} \leq 10/3$ for any $k = 1, \cdots, n-1$, CUs serve as "building blocks" and the process of CU formation will reach global free trade.[19]

5 Concluding Remarks

We have introduced a general analytical framework that is suitable for the investigation of PTAs and shown how countries' incentives vary with the country size, industrialization level, substitutability among industrial commodities, etc. We have found that if all countries are symmetric, the complete FTA network is pairwise stable and it is the unique stable network if industrial commodities are not highly substitutable from one another or if predetermined external tariff rates that countries would choose are small. We have also compared FTAs and CUs as to which of these two regimes facilitates PTA formation. We have shown that in the symmetric country case where industrial commodities are not highly substitutable, countries are likely to have less incentive to have a new free trade link if one of the countries is a member of a CU rather than an FTA. If countries are asymmetric, however, CU formation averages out member countries' industrialization levels, which may help further CU formation.

The present paper introduces a model that fits the analysis of FTAs and derives some useful results that are summarized above. However, it is naturally far from a complete analysis of FTAs. We examine elsewhere (Furusawa and Konishi, 2005) FTA network formation when transfers between signatories are allowed. With transfers, a pair of countries signs an FTA if and only if the FTA enhances the joint social welfare. Since the third country effects are always positive and the sum of the direct surplus effects is zero regardless of the hetero-

[19]We should note that history of CU expansion may matter. It is possible for the CU expansion to stop prematurely if two unions, one by developed countries and the other by less developed countries, are formed, and the difference in the industrialization levels of these two unions is quite large.

geneity between the countries, they are quite likely to sign the FTA. Indeed, Propositions 1 and 2 in this paper can be generalized to the case of asymmetric countries. Although we obtain stronger results when transfers between FTA signatories are allowed, feasible amounts of transfer are usually limited in practice. Thus, both of this paper and the companion paper provide useful insights of the problem. As for a further extension in this direction, it may be interesting to consider more generalized forms of transfers such as subsidizing other links in a more general environment (see Bloch and Jackson, 2004).

Another obvious extension is to relax the assumption on the selection of external tariffs. We have assumed throughout the paper that external tariff rates are exogenously fixed, since it is necessary to simplify the model for analyzing various forms of complicated FTA networks. If we assume instead that countries always set optimal tariffs given their FTA link structures, then they have incentives to lower their external tariffs as they form more free trade links, which Bagwell and Staiger (1999b) call the tariff complementarity effect. Indeed, Richardson (1993), Bagwell and Staiger (1999b), Yi (2000), and Ornelas (2005a) demonstrate in their respective models that if FTA signatories optimally adjust their individual external tariffs, an FTA induces the signatories to cut their tariffs so deeply that their imports from nonmember countries increase, i.e., the nonmember country effect, which is part of the third country effect, is negative. It can be shown that the same result obtains in our model if we allow FTA signatories to optimally adjust their external tariff. Yi (2000) and Ornelas (2005c) further show that global free trade may not be realized due to the free rider problem caused by this tariff complementarity effect. A similar result is expected to obtain in our extended model, i.e., there may be an asymmetric incomplete stable FTA network such as only one country is isolated from the rest of the countries. Nevertheless, as Remark 2 indicates, the complete FTA network continues to be stable even if the external tariffs are optimally adjusted.

Moreover, Proposition 2 suggests that the complete FTA network may survive as a unique stable network as countries *symmetrically* expand their FTA network, lowering their external tariffs symmetrically in the process. Let us imagine a dynamic FTA formation such that in each step, all countries have the same number of FTA links. As the FTA formation proceeds, their external tariffs decline and eventually enter the region where the complete FTA network is a unique stable network when external tariffs are fixed (see Proposition 2). Consider a pair of countries that form a new FTA link in this phase of the FTA formation. Due to the symmetry, the direct surplus effect is nil. The third country effect may be negative as the nonmember country effect is negative as we have seen above. But in the phase where they have already formed several FTAs, the member country effect, which is positive as a decrease in the external tariff further reduces the import from member countries, is likely to outweigh the nonmember country effect so that the entire third country effect is positive. Indeed, our extensive numerical analysis, which is available upon request, indicates that every pair of completely symmetric countries has incentive to sign an FTA so that if all countries symmetrically expand their FTA networks, the FTA formation continues until the complete FTA network is reached even though the external tariffs are optimally adjusted in each step.

Introducing governments' political motivation to the model, such as Ornelas (2005a,b,c), is also an interesting extension. In practice, it is often the developed countries that are reluctant to have FTAs with less developed countries. In many cases, it is because they want to protect politically sensitive (import-competing) industries such as agriculture. We can broadly interpret our results to claim that developed countries are reluctant to have the FTAs since the political costs of opening such sensitive market is large and hence the direct surplus effect (including the political costs) is negative and large in magnitude. In order to address this issue more properly, however, we should explicitly reformulate the problem in the political economy framework.

We can also enrich the model by adding more industries with possibly different degrees of substitution within each sector. Extending the model to a dynamic setting with far-sighted governments is important, but is more challenging unless the number of countries is restricted to three or four.

Appendix

Proof of Lemma 2. It follows from (6) that

$$\begin{aligned}\sum_{k=1}^{n} s^k q_k^i(\mathbf{t}^i) &= \frac{1}{2-\sigma} - \frac{1}{2(1-\sigma)}\sum_{k=1}^{n} s^k t_k^i + \frac{\sigma}{2(1-\sigma)(2-\sigma)}\bar{t}^i \\ &= \frac{1}{2-\sigma}\left(1-\bar{t}^i\right).\end{aligned}$$

By substituting this result and (6) into $\partial V^i/\partial t_j^i$ in Lemma 1, we obtain

$$\frac{\partial V^i}{\partial t_j^i} = s^j\left[-\frac{1-\sigma}{(2-\sigma)^2} + \frac{\sigma^2}{4(1-\sigma)(2-\sigma)^2}\bar{t}^i - \frac{1}{4(1-\sigma)}t_j^i\right].$$

Let $\mathbf{t}(\gamma)$ denote the bilateral tariff reform schedule between countries i and j. This schedule satisfies $t_j^i(\gamma) = (1-\gamma)t^i$ and $t_i^j(\gamma) = (1-\gamma)t^j$ for $\gamma \in [0,1]$, and hence $t_j^i(0) = t^i$ and $t_j^i(1) = 0$, for example. All other tariff rates are kept unchanged, i.e., $t_k^i(\gamma) = t^i$ and $t_k^j(\gamma) = t^j$ for any $k \neq i,j$. Notice that $\bar{t}^i$ also changes in the course of tariff reform such that $\bar{t}^i(\gamma) = \sum_{k\notin C_i\cup\{j\}} s^k t^i + s^j(1-\gamma)t^i = (1-s^{C_i}-\gamma s^j)t^i$, and similarly for $\bar{t}^j(\gamma)$. By substituting $\bar{t}^i(\gamma)$ and $t_j^i(\gamma)$ for $\bar{t}^i$ and t_j^i, respectively, and using $dt_j^i/d\gamma = -t^i$, we obtain

$$\frac{dV^i(\mathbf{t}^i(\gamma))}{d\gamma} = s^j t^i\left[\frac{1-\sigma}{(2-\sigma)^2} - \frac{\sigma^2}{4(1-\sigma)(2-\sigma)^2}(1-s^{C_i}-\gamma s^j)t^i + \frac{1}{4(1-\sigma)}(1-\gamma)t^i\right].$$

By integrating over γ, the welfare change of country i due to the FTA with j becomes

$$\begin{aligned}\Delta V^i(\mathbf{t}^i) &= s^j t^i\left[\frac{1-\sigma}{(2-\sigma)^2} - \frac{\sigma^2}{4(1-\sigma)(2-\sigma)^2}(1-s^{C_i}-\frac{s^j}{2})t^i + \frac{1}{8(1-\sigma)}t^i\right] \\ &= \frac{s^j t^i}{8(1-\sigma)(2-\sigma)^2}\left\{8(1-\sigma)^2 + \left[4(1-\sigma)-(1-2s^{C_i}-s^j)\sigma^2\right]t^i\right\}. \quad (21)\end{aligned}$$

The sufficient condition immediately follows.

Q.E.D.

Proof of Lemma 3. Recall the proof Lemma 2. The definition of the bilateral tariff reform schedule between countries i and j, denoted by $\mathbf{t}(\gamma)$, where $t_j^i(\gamma) = (1-\gamma)t$ and

$\bar{t}^i(\gamma) = (1 - s^{C_i} - s^j\gamma)t = [1 - (|C_i|/n) - (\gamma/n)]t$, and similarly for j, while $\mathbf{t}^k(\gamma) = \mathbf{t}^k$ for any $k \neq i, j$, and any $\gamma \in [0,1]$. Then, it follows from (6) that

$$\begin{aligned} q_j^i(\mathbf{t}^i(\gamma)) &= \frac{1}{2-\sigma} - \frac{1}{2(1-\sigma)}(1-\gamma)t + \frac{\sigma}{2(1-\sigma)(2-\sigma)}\left(1 - \frac{|C_i|}{n} - \frac{\gamma}{n}\right)t, \\ q_k^i(\mathbf{t}^i(\gamma)) &= \frac{1}{2-\sigma} - \frac{1}{2(1-\sigma)}t + \frac{\sigma}{2(1-\sigma)(2-\sigma)}\left(1 - \frac{|C_i|}{n} - \frac{\gamma}{n}\right)t. \end{aligned}$$

Consequently, we have

$$\begin{aligned} \frac{dq_j^i}{d\gamma} &= \frac{[n(2-\sigma)-\sigma]t}{2n(1-\sigma)(2-\sigma)}, \\ \frac{dq_k^i}{d\gamma} &= -\frac{\sigma t}{2n(1-\sigma)(2-\sigma)}. \end{aligned}$$

Now, we can rewrite a change in country i's industrial trade surplus.

$$\begin{aligned} &\Delta\left[X^i(\mathbf{t}^{-i}) - M^i(\mathbf{t}^i)\right] \\ &= \int_0^1 \left[\frac{dX_j^i(\mathbf{t}^j(\gamma))}{d\gamma} - \frac{dM_j^i(\mathbf{t}^i(\gamma))}{d\gamma} - \sum_{k\neq i,j}\frac{dM_k^i(\mathbf{t}^i(\gamma))}{d\gamma}\right]d\gamma \\ &= \frac{1-\sigma}{n}\int_0^1 \left[2q_i^j(\mathbf{t}^j)\frac{dq_i^j}{d\gamma} - 2q_j^i(\mathbf{t}^i)\frac{dq_j^i}{d\gamma} - \sum_{k\neq i,j}2q_k^i(\mathbf{t}^i)\frac{dq_k^i}{d\gamma}\right]d\gamma \\ &= \frac{2t(1-\sigma)}{n}\int_0^1 \left\{\frac{\sigma(|C_i|-|C_j|)}{2n(1-\sigma)(2-\sigma)}\frac{[n(2-\sigma)-\sigma]t}{2n(1-\sigma)(2-\sigma)}\right. \\ &\quad \left. + \left(\frac{\sigma}{2n(1-\sigma)(2-\sigma)}\right)\sum_{k\neq i,j}\left[\frac{1}{2-\sigma} - \frac{1}{2(1-\sigma)}t + \frac{\sigma}{2(1-\sigma)(2-\sigma)}\left(1-\frac{|C_i|}{n}-\frac{\gamma}{n}\right)t\right]\right\}d\gamma \\ &= \frac{\sigma t}{n^2(2-\sigma)}\int_0^1 \left\{\frac{(|C_i|-|C_j|)[n(2-\sigma)-\sigma]t}{2n(1-\sigma)(2-\sigma)}\right. \\ &\quad \left. + \frac{n-2}{2-\sigma} - \frac{n-2}{2(1-\sigma)}t + \frac{\sigma(n-2)}{2(1-\sigma)(2-\sigma)}\left(\frac{n-|C_i|-\gamma}{n}\right)t\right\}d\gamma. \end{aligned}$$

The value of this formula decreases with $|C_j|$ since $n(2-\sigma)-\sigma > 0$. Whereas it increases with $|C_i|$ since

$$\frac{n(2-\sigma)-\sigma}{2n(1-\sigma)(2-\sigma)} - \frac{\sigma(n-2)}{2n(1-\sigma)(2-\sigma)} = \frac{2n(1-\sigma)+\sigma}{2n(1-\sigma)(2-\sigma)} > 0.$$

As for the impact on a consumer's gross utility, recall again the proof of Lemma 2. Let $s^k = 1/n$ for all $k = 1, ..., n$. Then, we find that

$$\Delta V^i(\mathbf{t}^i) = \frac{t}{8n(1-\sigma)(2-\sigma)^2}\left\{8(1-\sigma)^2 + \left[4(1-\sigma) - \left(1 - \frac{2|C_i|+1}{n}\right)\sigma^2\right]t\right\}$$

also increases with $|C_i|$.

Q.E.D.

Proof of Proposition 2. Substituting $|C_i| = 1$ and $|C_j| = n-1$ into the formulae obtained in the proof of Lemma 3, we have

$$\begin{aligned}
&\Delta\left[X^i(\mathbf{t}^{-i}) - M^i(\mathbf{t}^i)\right] \\
&\geq \frac{\sigma t}{n^2(2-\sigma)} \int_0^1 \left[\frac{(2-n)[n(2-\sigma)-\sigma]t}{2n(1-\sigma)(2-\sigma)}\right. \\
&\quad \left. + \frac{n-2}{2-\sigma} - \frac{n-2}{2(1-\sigma)}t + \frac{\sigma(n-2)(n-1-\gamma)t}{2n(1-\sigma)(2-\sigma)}\right] d\gamma \\
&= \frac{(n-2)\sigma t}{2n^2(1-\sigma)(2-\sigma)^2} \int_0^1 \left\{2(1-\sigma) - 2(2-\sigma)t + \frac{(n-\gamma)\sigma t}{n}\right\} d\gamma \\
&= \frac{(n-2)\sigma t}{2n^2(1-\sigma)(2-\sigma)^2}\left[2(1-\sigma) - 2(2-\sigma)t + \frac{(2n-1)\sigma t}{2n}\right],
\end{aligned}$$

and

$$\Delta V^i(\mathbf{t}^i) \geq \frac{t}{8n(1-\sigma)(2-\sigma)^2}\left[8(1-\sigma)^2 + 4(1-\sigma)t - \frac{(n-3)\sigma^2 t}{n}\right].$$

Thus,

$$\begin{aligned}
\Delta u^i &= \Delta V^i + \Delta\left[X^i(\mathbf{t}^{-i}) - M^i(\mathbf{t}^i)\right] \\
&\geq \frac{t}{8n(1-\sigma)(2-\sigma)^2}\left[8(1-\sigma)^2 + 4(1-\sigma)t - \frac{(n-3)\sigma^2 t}{n}\right] \\
&\quad + \frac{(n-2)\sigma t}{2n^2(1-\sigma)(2-\sigma)^2}\left[2(1-\sigma) - 2(2-\sigma)t + \frac{(2n-1)\sigma t}{2n}\right] \\
&= \frac{t}{8n^2(1-\sigma)(2-\sigma)^2}[8(1-\sigma)(n-2\sigma) - A(\sigma,n)t],
\end{aligned}$$

where $A(\sigma,n) \equiv -4n + 4(5n-8)\sigma - [11n - 23 + (4/n)]\sigma^2$. It is now obvious that $\Delta u^i \geq 0$ if and only if either (i) $A(\sigma,n) \leq 0$ or (ii) $t \leq \tau(\sigma,n) \equiv 8(1-\sigma)(n-2\sigma)/A(\sigma,n)$ when $A(\sigma,n) > 0$ is satisfied.

Next , we show that $\tau(\sigma, n)$ is decreasing in $\sigma \in (0, 1)$ for any $n \geq 3$. We have

$$\begin{aligned}
\frac{\partial \tau}{\partial \sigma}(\sigma, n) &= -\frac{8}{A(\sigma, n)^2} \Bigg\{ A(\sigma, n)[n - 2\sigma + 2(1-\sigma)] \\
&\quad +(1-\sigma)(n-2\sigma)\left[4(5n-8) - 2\sigma\left(11n - 23 + \frac{4}{n}\right)\right]\Bigg\} \\
&= -\frac{8}{A(\sigma, n)^2} \Bigg\{ 2(1-\sigma)A(\sigma, n) \\
&\quad +(n-2\sigma)\left[4(5n-8) - 4n + \sigma(\sigma-2)\left(11n - 23 + \frac{4}{n}\right)\right]\Bigg\}.
\end{aligned}$$

Since $2(1-\sigma)A(\sigma, n) > 0$ and $n - 2\sigma > 0$, what remains to be shown is that the expression in the square brackets is positive. Now, $11n - 23 + (4/n) > 0$ for any $n \geq 3$ and $\sigma(\sigma - 2)$ takes its minimum of -1 at $\sigma = 1$, so that we have

$$\begin{aligned}
&4(5n-8) - 4n + \sigma(\sigma-2)\left(11n - 23 + \frac{4}{n}\right) \\
&\geq 4(5n-8) - 4n - \left(11n - 23 + \frac{4}{n}\right) \\
&= 5n - 9 - \frac{4}{n},
\end{aligned}$$

which is positive for $n \geq 3$.

Q.E.D.

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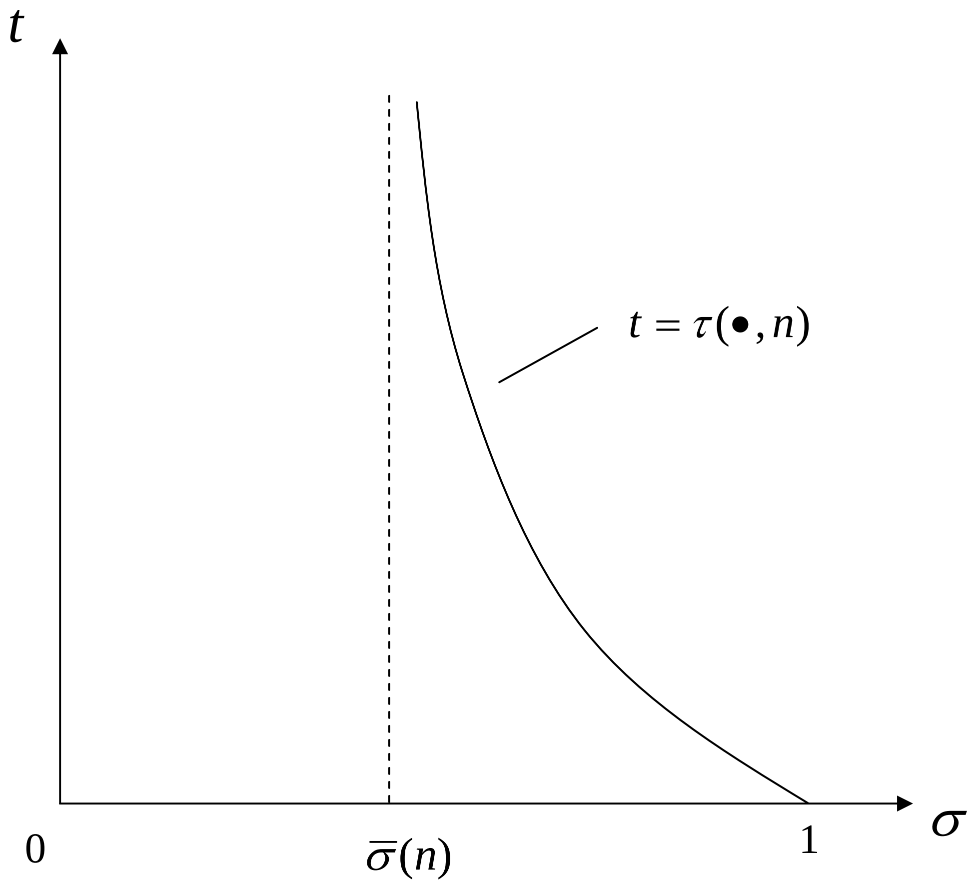

Figure 1. The Region Where the Global Free Trade Is a Unique Stable Network

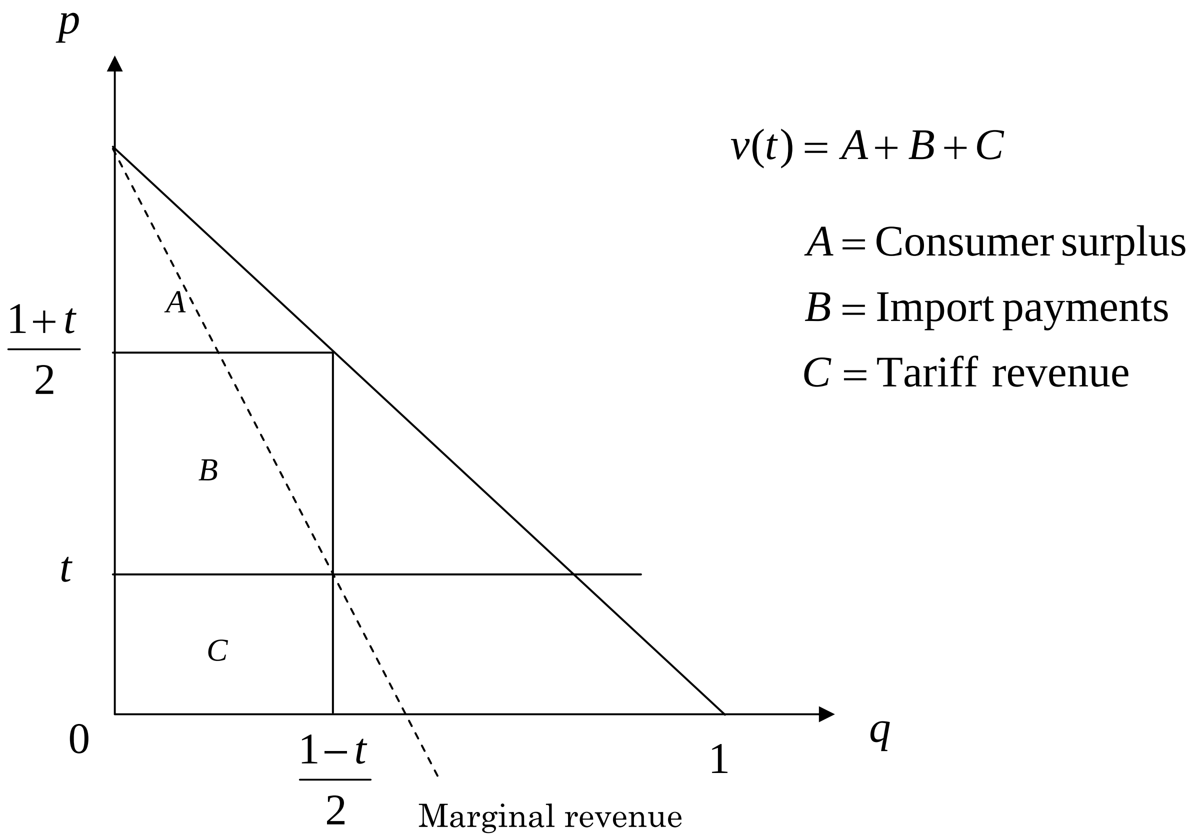

Figure 2. Equilibrium in a Commodity Market

	FTA		CU
ΔV^i	?	$=$	?
ΔM_j^i	$+$	$=$	$+$
ΔX_j^i	$+$	$>$	$+$
ΔM_k^i	$-$	$=$	$-$
ΔX_k^i	0	$>$	$-$
ΔM_h^i	$-$	$=$	$-$
ΔX_h^i	0	$=$	0

Table 1. FTA vs. CU ($\sigma > 0$)