Networks of Free Trade Agreements among Heterogeneous Countries*†

Ana Mauleon[a,c], Huasheng Song[b], Vincent Vannetelbosch[c]

[a]FNRS and CEREC, Facultés universitaires Saint-Louis, Boulevard du Jardin Botanique 43, B-1000 Brussels, Belgium.

[b]CRPE and College of Economics, Zhejiang University, Zheda Road 38, Hangzhou 310027, China, and CORE, Université catholique de Louvain.

[c]FNRS and CORE, Université catholique de Louvain, 34 voie du Roman Pays, B-1348 Louvain-la-Neuve, Belgium.

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Abstract

The paper examines the formation of free trade agreements as a network formation game. We consider an n-country model in which international trade occurs between economies with imperfectly competitive product markets. In each country, the labor market is either unionized or non-unionized. We show that, if all countries are non-unionized, the global free trade network is both the unique pairwise stable network and the unique efficient network. If all countries are unionized, the global free trade network is pairwise stable and the unique efficient network among the class of symmetric networks. If some countries are unionized while others are non-unionized, other networks apart from the global free trade network may be pairwise stable. However, the efficient network is still the global free trade network. Thus, a conflict between stability and efficiency may occur. Moreover, starting from the network in which no country has signed a free trade agreement, all sequences of networks due to continuously profitable deviations do not lead (in most cases) to the global free trade network, even when global free trade is stable.

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*Corresponding author: Prof. Ana Mauleon. E-mail addresses: mauleon@fusl.ac.be (Ana Mauleon), songucl@hotmail.com (Huasheng Song), vincent.vannetelbosch@uclouvain.be (Vincent Vannetelbosch).

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1 Introduction

The institutional structure of labor markets is frequently cited as an important determinant of international competitiveness. Although there is some related literature on the relationship between unions and international trade policy aspects,[1] none of it however deals specifically with unions and formation of free trade agreements. The purpose of this paper is to investigate how institutional features such as unionization will affect the formation of free trade agreements among countries. By doing so, we try to rationalize the commonly made assumption that some countries are high cost while others are low cost. While the presence of unions is not the only possible type of cost asymmetry between countries, wage differences between European and foreign firms and union bargaining strength appear to be empirically relevant for industries involved in EU antidumping cases.[2] Also, labor advocates in the United States argue that developing countries may have an "unfair" competitive advantage because their lower labor standards are the basis for their lower costs, which in turn are reflected in lower prices for goods that compete with those produced in developed countries. In this paper, we show that high labor costs and strong labor unions which characterize some European and US industries could prevent the formation of free trade agreements between these unionized countries and countries with lower labor costs and weaker labor unions.

Since labor is not very mobile, the effects of international integration on labor markets are mostly indirect via product market integration. In the literature, product market integration has been interpreted as a reduction in costs associated with international trade: transport costs, tariffs, taxes, information costs about foreign markets, etc. These costs could be divided into fixed costs or start up costs associated with exporting, and variable costs proportional to the level of exports. Huizinga (1993) showed that a decrease in fixed costs, that implies the move from autarky to fully integrated markets, will increase the degree of competition in the product market and will reduce wages. However, Naylor (1998) showed that a decrease in variable export costs may give rise to a higher wage since a monopoly union responds by increasing the wage rate to the increased employment's demand. But these works proceed by considering only symmetric countries.

In this paper we address the following questions:

(i) What is the relationship between the degree of product market integration and the wage level in presence of asymmetries among countries?

[1] See Brander and Spencer (1988), Mezzetti and Dinopoulos (1991), and Gaston and Trefler (1995).

[2] Vandenbussche, Veugelers and Konings (2001) showed that the presence of European unions leads to an increase in both the likelihood and the level of antidumping protection.

(ii) What are the incentives of unionized and non-unionized countries to form free trade agreements and what is the architecture of stable networks of free trade agreements?

(iii) Are individual incentives to form free trade agreements adequate from a social welfare point of view?

To answer these questions we develop a three-stage game. In stage one, each government decides the bilateral free trade agreements (links) it likes to sign in order to maximize welfare. The collection of pairwise links between countries defines a trading regime (network). In the second stage, given a configuration of free trade agreements, wages are set inside each country either by the union (if the firm is unionized) or by the firm (if the firm is non-unionized). Finally, in the third stage, firms compete in the different markets by choosing quantities. Each firm regards each country as a separate market and chooses the profit-maximizing quantity for each market separately, and on the Cournot assumption that the other firms' outputs in each market are given. We are interested in the network of free trade agreements that emerges in this setting.

We adopt the notion of pairwise stability of Jackson and Wolinsky (1996) in order to analyze the networks that one might expect to emerge in the long run. A network is pairwise stable if no agent benefits from severing one of their links and no other two agents benefit from adding a link between them, with one benefiting strictly and the other at least weakly.[3] We show that the global free trade network (or complete network), i.e., one in which each pair of countries has a bilateral free trade agreement, is a stable outcome if countries are either all unionized or all non-unionized. However, other network architectures are stable if some countries are unionized while other are non-unionized. Thus, it seems that harmonization of labor markets may promote free trade. Indeed, in the last years, it is increasingly common for U.S. trade agreements to include provisions that support the harmonization of labor standards[4] in order to get a robust consensus in the U.S. and in the foreign country in favor of the agreement. Moreover, we find that, in case all countries are non-unionized, the complete network is the efficient network (i.e. the network that maximizes aggregate social welfare) and the unique stable state that results

[3]Strategic models of network formation were first developed by Jackson and Wolinsky (1996) and Bala and Goyal (2000). Jackson (2003, 2005) provided surveys of models of network formation.

[4]Although in the past, the North American Free Trade Agreement (NAFTA), the U.S.-Chile Free Trade Agreement and the U.S.-Singapore Free Trade Agreement have been criticized for ineffective application of protections for labor rights and standards, the more recent free trade agreements signed by the U.S. with Korea, with the Andean countries, with the Dominican Republic-Central American countries, and with Cambodia include stronger labor provisions in order to get the support of organized labor groups. For more information, visit the page of the Global Union Research Network http://www.gurn.info/topic/trade/index.html

from a dynamic process starting at the empty network (in which there is no link) and where agents are adding and deleting links based on the improvement the resulting network offers relative to the current network. We also show that, in case all countries are unionized, the complete network is the unique efficient network among the class of symmetric networks, i.e., networks in which all countries maintain the same number of free trade agreements. Thus, it seems that there is no conflict between stability and efficiency when either all firms are unionized or all firms are non-unionized.

In the first part of the paper we restrict attention to symmetric frameworks in which all countries are either all unionized or all non-unionized. We next examine two asymmetric frameworks in which there are both unionized and non-unionized countries. A general analysis of asymmetric frameworks however turns out to be very complicated; we therefore work with two examples of three countries (a first one with one unionized and two non-unionized countries, and a second one with one non-unionized and two unionized countries) and completely characterized the solution. In this setting there are four possible network architectures: the complete network, the star network, the partially connected network, and the empty network.[5] We find that, when only one country is unionized, the complete network is always pairwise stable, but the partially connected network in which the two non-unionized countries have signed a free trade agreement is also pairwise stable, except for very small values of the cost per unit of the commodity exported (when the initial degree of product market integration is very high). When only one country is non-unionized, the partially connected network in which the two unionized countries have signed a free trade agreement is pairwise stable for small values of the cost per unit of the commodity exported, the star networks in which one of the unionized countries is connected with the other two countries is pairwise stable for intermediates values of the cost per unit of the commodity exported, and the complete network is only pairwise stable for relatively high values of the cost per unit of the commodity exported. However, the complete network is the efficient network in each of these two asymmetric settings. Thus, a conflict between stability and efficiency may occur. Moreover, starting from the network in which no country has signed a free trade agreement, all sequences of networks due to continuously profitable deviations do not lead (in most cases) to the global free trade network, even when global free trade is stable.

Regarding the relationship between the degree of product market integration (measured as the level of variable export costs) and the wage level we find that, in presence of asymmetries among countries, it is no longer true that an increase in product market

[5] The star is a network in which there is a central country which is linked to every other country, while none of the other countries have a link with each other. The partially connected network refers to a configuration in which two countries are linked while the third country is isolated.

integration due to a decrease in variable export costs will increase wages as in Naylor (1998). Depending on the strategic position of the domestic country in the network of free trade agreements, the increase in market integration would increase or reduce the demand for labor. Consequently, the monopoly union will respond by increasing or reducing the wage rate to the increased or reduced demand for labor.

Our paper is related to papers that study the incentives of countries to form regional free trade associations and customs unions, and the strategic stability of particular trading regimes.[6] Yi (1996) endogenized the formation of the customs union structure, which is a partition of the set of countries. He showed that the rules of customs union formation are crucial: if open membership is allowed, then the grand coalition (global free trade) is the only stable customs union. However, the grand coalition is not stable under the rule that a union is formed if and only if all potential members agree to its formation.[7]

The works of Goyal and Joshi (2006) and Furusawa and Konishi (2007) also investigate the formation of free trade agreements as a network formation game. By assuming that countries are symmetric with respect to the market size and the number of domestic firms that produce a homogeneous good, Goyal and Joshi (2006) obtained that the process of bilateral trade agreements can generate either a free trade regime or an almost free trade regime. Furusawa and Konishi (2007) analyzed the trading network generated by countries that trade a numeraire good and a continuum of differentiated industrial commodities. They showed that, when all countries are symmetric, the global free trade network in which every pair of countries sign a free trade agreement is stable, and it is the unique stable network if industrial commodities are not highly substitutable. However, if countries are asymmetric in the market size and/or in the size of industrial good sector, the global free trade network may not be attained.[8] The purpose of the present paper is to show that the asymmetry consisting of having unionized and non-unionized countries, could also impede the formation of the global free trade network. We also discuss the conflict between stability and efficiency that may occur in presence of unionized and non-unionized

[6] Levy (1997), Krishna (1998) and Ornelas (2005a) showed in their political economy models that preferential arrangements can hinder multilateral trade liberalization. Krugman (1991), Ethier (1998), and Bagwell and Staiger (1999) focused on the welfare effects of preferential free trade associations and customs unions.

[7] Kennan and Riezman (1990), and Bond and Syropoulos (1996) studied the strategic stability of particular trading regimes. Grafe and Mauleon (2000) studied the consequences of a private externality on the formation of free tade agreements in a general equilibrium framework.

[8] Furusawa and Konishi (2005) extended their previous analysis by introducing the possibility of transfers between the signatories of free trade agreements. In that case, they showed that, even if the world consists of fairly asymmetric countries, the global free trade network is stable, and it is the unique stable network unless industrial commodities are highly substitutable.

countries (conflict that does not exist when all countries are of the same type). We finally study the networks that result from a dynamic process where agents are adding and deleting links based on the improvement the resulting network offers relative to the current network.

The paper is organized as follows. The model is presented in Section 2. In Section 3 we analyze the stability and the efficiency of networks of free trade agreements. We conclude in Section 4.

2 The model

We develop a three-stage game in a setting with n countries, each of which has one firm producing some homogeneous good that can be sold in the domestic market and in each foreign market. A firm's ability to sell in foreign markets, however, depends on the level of import tariffs set by the foreign countries. In the first stage, countries decide the free trade agreements (or links) they are going to establish in order to maximize their respective social welfare level. The collection of pairwise links between the countries defines a network of free trade agreements. If two countries have negotiated a free trade agreement, then each offers the other a tariff-free access to its domestic market; otherwise, each imposes a non-zero tariff T on the imports from the other. Uniform non-discriminatory tariffs are initially assumed to be applied by all countries on imports from other countries. Firms can be either unionized or non-unionized. In the second stage, wages are settled at the firm level by the union or by the firm. Within each country the union or the firm chooses the wage taking as given the wage set in the other countries and taking into account the network of free trade agreements formed at the country level. In the third stage, each firm chooses its output (and hence employment) levels for the separate product markets, taking as given the output decisions of the other firms, the settled wages and the network structure of free trade agreements. We are interested in the network of free trade agreements that emerges in this setting.

We denote by $N = \{1, 2, ..., n\}$ the set of countries which are connected in a network of free trade agreements. We assume that $n \geq 3$. In a network, countries are the nodes and each link indicates a free trade agreement between the two linked countries. Thus, a network g is simply a list of which pair of countries are linked to each other. If we are considering a pair of countries i and j, then $\{i, j\} \in g$ indicates that i and j are linked under the network g and that a free trade agreement between countries i and j has been negotiated. For simplicity, write ij to represent the link $\{i, j\}$, so $ij \in g$ indicates that i and j are linked under the network g. The network obtained by adding link ij to an existing network g is denoted $g + ij$ and the network obtained by deleting link ij from an existing network g is denoted $g - ij$. Let G be the set of all possible networks. For instance, in a model with three countries, there are four possible network architectures (see Figure 1): (i) the complete network, g^c, in which every pair of countries is linked to each other, (ii) the star network, g^s, in which there is one country that is linked to the other two countries, (iii) the partially connected network, g^p, in which two countries have a link and the third country is isolated, and (iv) the empty network, g^e, in which there is no link. In the star network, the country which is linked to the other two countries is called the "hub" country, while the other two countries are called the "spoke" countries. Given the importance of the network position of a country, we denote $g^s(i)$ the star network with country i occupying the hub position, and $g^p(ij)$ the partial network in which countries i and j are linked.

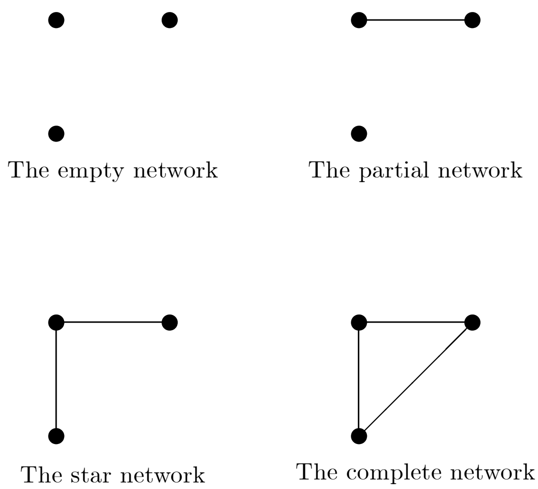

Figure 1: Four possible network architectures.

Let $N(g) = \{i \in N : ij \in g\}$ be the set of countries that are involved in some free trade agreement in the network g. Let $N_i(g) = \{j \in N : ij \in g\}$ denote the set of countries with whom i has a free trade agreement in the network g. We define $i \in N_i(g)$. Let $n_i(g)$ denote the cardinality of $N_i(g)$. A network is said to be *symmetric* if every country has the same number of free trade agreements. In a symmetric network $n_i(g) = n_j(g) = k$ for any two countries i and j. The number k will be referred to as the *degree* of network g.[9] We will denote a symmetric network of degree k by g^k, $k = 0, 1, ..., n - 1$. Notice that symmetric networks allow for non-exclusive relationships. For example, in a four-country model, a symmetric network of degree 2 involves a country having links with countries

[9] If the number of countries is even, then there is always a set of links such that the resulting network is symmetric of degree k where $k = 0, 1, ..., n - 1$.

which are not linked to each other.

We assume that product demand is linear:

$$P_i = a - \sum_{j \in N} X_{ji}, \text{ with } a > 0,$$

where P_i is the price of the homogeneous good in country i and X_{ji} is production by firm j for consumption in country i. Production technology exhibits constant returns to scale with labor as the sole input and is normalized in such a way that $\sum_{j \in N} X_{ij} = L_i$, where L_i is labor input of firm i and $\sum_{j \in N} X_{ij} = X_i$ is the total production of firm i. The total labor cost to firm i of producing quantity X_i is $W_i \cdot X_i$, where W_i is the wage in firm i. Let I_{ij} be such that $I_{ij} = 1$ if countries i and j have not negotiated a free trade agreement, and $I_{ij} = 0$ if countries i and j have negotiated a free trade agreement. Then, for any network g, firm i's profits can be written as

$$\Pi_i(g) = (P_i - W_i)X_{ii} + \sum_{j \neq i}(P_j - W_i - I_{ij}T)X_{ij},$$

where T is the constant unit trade cost. We restrict parameter T to be $0 \leq T \leq \frac{a}{n+1}$. By doing so, we concentrate on the more interesting cases in which there is positive trade between two countries that have not negotiated a free trade agreement in at least one of the network architectures. When the firm is unionized, a risk-neutral union chooses the wage that maximizes the economic rent,

$$U_i(g) = L_i \cdot (W_i - \overline{W}),$$

where $\overline{W}$ is the reservation wage.[10] Without loss of generality, we assume $\overline{W} = 0$. In case the firm is non-unionized, the firm chooses the wage that maximizes profits, i.e., $W_i = \overline{W} = 0$. For any network g, the social welfare of country i is given by

$$SW_i(g) = CS_i(g) + \Pi_i(g) + U_i(g) + CT_i(g)$$

where $CS_i(g) = \frac{1}{2}(X_i)^2$, is the consumer surplus of country i, $\Pi_i(g)$ is the profit of firm i located in country i, $CT_i(g) = \sum_{j \neq i} I_{ij}T \cdot X_{ji}$ is the tariff revenue of country i, and $U_i(g)$ are the rents of union i. Let $SW(g)$ denote aggregate welfare in network g. Then, aggregate social welfare is given by

$$SW(g) = \sum_{i \in N} SW_i(g).$$

[10] By tractability, we do not consider a version of the right-to-manage model where unions and firms have bargaining power over wages. However, Jones (1989) and Mauleon and Vannetelbosch (2005) showed that, if the union bargaining power is not too big, it is optimal for unions that maximize the rents to send to the negotiating table delegates who maximize the wage, and such negotiations may mimic the monopoly-union outcomes where the unions choose their most preferred wages.

Before looking for the stability and efficiency of networks of free trade agreements, we analyze the relationship between the degree of product market integration (measured as the level of variable export costs) and the wage level in a three-country model. We find that, in presence of asymmetries among firms, an increase in product market integration due to a decrease in variable export costs does not necessarily increase wages as in Naylor (1998). An increase in market integration will increase or reduce the demand for labor depending on the strategic position of the home country in the network of free trade agreements. Consequently, the monopoly union will respond by increasing or reducing the wage rate to the increased or reduced demand for labor. The impact of an increase in market integration on wages in unionized countries is summarized in Table 1 where the symbol "+" means that the impact is positive and that wages increase as a result of higher degrees of market integration, and the symbol "−" means that the impact is negative and that wages decrease as a result of higher degrees of market integration.

	empty network	partial network		star network	
		linked	isolated	spoke	hub
all countries unionized	+	+	+	+	−
only one country non-unionized	+	+	+	±	−
only one country unionized	+	nil	±	±	−

Table 1: The impact of an increase in market integration on wages in unionized countries

For instance, in case all countries are unionized, an increase in product market integration will increase wages in the empty and partially connected networks. In the star network, an increase in product market integration will increase wages of the firms in the spoke countries and will reduce the wage of the firm in the hub country.[11] Indeed, the increase in product market integration makes the firm in the hub country suffering from the increased competition of the firms in the spoke countries. As a consequence, the exports from the hub country to the spoke countries decrease. The monopoly union will respond then to the reduced demand for labor by reducing the wage rate. Thus, we observe that there is no monotonic relationship between the degree of product market integration and the wage rate. While in the empty network greater market integration increases wages, in the partially connected and star networks greater market integration has an ambiguous impact on wages that depend on the strategic position of the domestic country into the network of free trade agreements and on the degree of product market integration.

[11] Of course, the wage levels do not depend on the degree of product market integration in the complete network.

3 Stability and efficiency of free trade networks

A simple way to analyze the networks that one might expect to emerge in the long run is to examine a sort of equilibrium requirement that agents not benefit from altering the structure of the network. A weak version of such condition is the pairwise stability notion defined by Jackson and Wolinsky (1996). A network is pairwise stable if no agent benefits from severing one of their links and no other two agents benefit from adding a link between them, with one benefiting strictly and the other at least weakly.

Definition 1. A network g is pairwise stable if

(i) for all $ij \in g$, $SW_i(g) \geq SW_i(g - ij)$ and $SW_j(g) \geq SW_j(g - ij)$, and

(ii) for all $ij \notin g$, if $SW_i(g) < SW_i(g + ij)$ then $SW_j(g) > SW_j(g + ij)$.

This definition of stability is quite weak and should be seen as a necessary condition for strategic stability.[12]

3.1 Two symmetric frameworks

We first study pairwise stable networks when countries are either all unionized or all non-unionized. The welfare expressions can be found in the appendix.

Proposition 1. *Suppose countries are either all unionized or all non-unionized. The complete network g^c is a pairwise stable network.*

Proof. Condition (ii) in the definition of stability is trivially satisfied since no further agreements are possible.

Assume first the case in which all countries are non-unionized. Since $n \geq 3$, we have that

$$SW_i(g^c) - SW_i(g^c - ij) = T\frac{a(4n-6) + T(2n-3)}{2(n+1)^2} > 0,$$

and the condition (i) of stability is satisfied.

[12] Pairwise stability only considers deviations on a single link at a time. For instance, it could be that an agent would not benefit from severing any single link but would benefit from severing several links simultaneously, and yet the network would still be pairwise stable. Players cannot be farsighted in the sense that they do not forecast how others might react to their actions. Herings, Mauleon and Vannetelbosch (2009) proposed a stability concept, pairwise farsighted stable sets, that predicts which networks are going to emerge among farsighted players. See also Page and Wooders (2009).

Assume next the case in which all countries are unionized. Since $n \geq 3$ and $T \leq \frac{a}{n+1}$, the stability of the complete network is obtained from the fact that

$$\begin{aligned} SW_i(g^c) - SW_i(g^c - ij) &= \frac{2aT(n^3 + 2n^4)(1 + 3n + 4n^2)}{2n^2(n+1)^4(2n+1)} - \\ &- \frac{T^2[4 + (2n^2 + n)(4 - 7n + 17n^2 - 6n^3 - 2n^4 + 4n^5)]}{2n^2(n+1)^4(2n+1)} \end{aligned}$$

is always positive. □

Proposition 1 tells us that the complete network or global free trade is a pairwise stable network when firms are either all unionized or all non-unionized because the non-linked countries in the network $g^c - ij$ have always incentives to form a bilateral trade agreement. Thus, the complete network g^c is always pairwise stable. So, if individual countries care about domestic social welfare then the formation of bilateral trade agreements could generate a global free trade regime.

Proposition 2. *The complete network g^c is the unique pairwise stable network in case all countries are non-unionized.*

Proof. We have that

$$\begin{aligned} SW_i(g + ij) - SW_i(g) &= \\ \frac{(4n-2)aT + 4nn_i(g)T^2 - 4nn_j(g)T^2 - 4nT^2 + 6n_i(g)T^2 + 5T^2}{2(n+1)^2} &> 0 \end{aligned}$$

when $T \leq \frac{a}{n+1}$. Thus, every pair of non-linked countries has incentives to sign a free trade agreement. Since the network g was arbitrary, the proof follows. □

Proposition 2 tells us that the complete network is the unique pairwise stable network in case all countries are non-unionized. Also, the complete network is the unique pairwise stable network in case of three unionized countries. However, a similar comparison between $SW_i(g)$ and $SW_i(g + ij)$ cannot be done in general with n unionized countries.

Remark 1. The complete network is pairwise stable in case of n symmetric countries that optimally adjust their tariffs rates to changes in the free trade networks.

Indeed, if a country deletes a link with another country from the complete network, these symmetric countries would impose the same optimal tariff rate to each other. So, we can also conclude that the result of Proposition 1 holds in case each country optimally adjusts its tariffs rate to a change in the free trade network. However, it could be that, in that case, the complete network is not the unique pairwise stable network when all countries are non-unionized.[13]

Suppose now that the government maximizes a more general social welfare function with arbitrary weights on consumer surplus, producer surplus, tariff revenues and union's rents in the welfare function. In the polar case in which non-unionized countries care only about domestic consumer surplus then bilateral trade agreements would also generate a global free trade regime because the consumer surplus is increasing with the number of active firms in the country. In the other polar case in which countries maximize domestic profits, the global free trade regime is the unique pairwise stable network in case all countries are non-unionized. Indeed, one can show that $\Pi_i(g+ij) > \Pi_i(g)$ for any g. This suggests that, in case of non-unionized firms, firms will have no incentives to lobby against bilateral trade agreements. This result contrasts with Goyal and Joshi (2006) where tariffs are prohibitively high between countries that do not have a bilateral free trade agreement. Indeed, given that firm's profit under autarky are higher than in any symmetric trading regime in which every country has a given number of active firms, Goyal and Joshi (2006) concluded that other networks apart from the complete network could be stable. In our model, the fact that tariffs are not prohibitive between countries that have not signed a free trade agreement makes non-unionized firms also preferring the free trade regime. So, there is no conflict between firms' objectives and social welfare maximizing countries: both countries and firms support the free trade regime in case all countries are non-unionized.

We now examine aggregate social welfare under the different networks. Remember that aggregate social welfare $SW(g)$ under a network g is given by $SW(g) = \sum_{i\in N} SW_i(g)$. We say that a network g is *efficient* if and only if $SW(g) \geq SW(g')$ for all g'.

Proposition 3. *The complete network g^c is the unique efficient network in case all countries are non-unionized.*

Proof. In order to prove that the aggregate social welfare under the complete network $SW(g^c)$ is higher than the aggregate social welfare under any other network g, we compute

$$SW(g^c) - SW(g) = \sum_{i\in N} \frac{(N - n_i(g))T[2a + (N - n_i(g))T]}{2(N+1)^2}.$$

And this expression is always positive since $n_i(g) < N$ for at least two different countries. □

Proposition 3 shows that, when all firms are non-unionized, there is no conflict between stability and efficiency. The complete network g^c is both the unique pairwise stable and

[13] In a closely related paper, Furusawa and Konishi (2007) also noticed that the complete network is stable even in the case where each country optimally adjusts its tariffs rate to a change in the free trade network.

efficient network. When all firms are unionized, we show below that the complete network g^c is the unique efficient network among the class of symmetric network structures, i.e., networks in which all countries maintain the same number of free trade agreements. Among the non-symmetric networks, we can also show that the complete network g^c is more efficient than $g^c - ij$. A general proof among the non-symmetric network has not been obtained. However, it can be shown that, in a model with only three unionized countries, the complete network is also the unique efficient network.

Proposition 4. *Assume all countries are unionized. The complete network g^c is the unique efficient network among the class of symmetric networks. Moreover, the complete network is more efficient than the network $g^c - ij$.*

Proof. In a symmetric network all countries have the same social welfare; hence, $SW(g) = \sum_{i \in N} SW_i(g) = n \cdot SW_i(g)$. So, in order to prove that the complete network is the unique efficient network among the class of symmetric networks we have to compare $SW_i(g^c)$ with $SW_i(g^{k-1})$ for any $k = 1, ..., n-1$. We have

$$SW_i(g^c) - SW_i(g^{k-1}) = \frac{aT[(n-k)(4n^2+2n)] + T^2(n^4 + n^2k^2 - 2n^3k)}{2(n+1)^4} > 0$$

for any $k = 1, ..., n-1$ since $T \leq \frac{a}{n+1}$.

Moreover, among the asymmetric networks, we can also show that $SW(g^c) > SW(g^c - ij)$. Notice that

$$\begin{aligned} SW(g^c) - SW(g^c - ij) &= \frac{aT(12n^5 + 30n^4 + 12n^3 - 8n^2 - 4)}{n(n+1)^4(2n+1)} - \\ &\quad - \frac{T^2(4n^6 + 6n^5 - 14n^4 - 13n^3 + 32n^2 + 33n + 6)}{n(n+1)^4(2n+1)}, \end{aligned}$$

and this expression is always positive because $T \leq \frac{a}{n+1}$. □

Finally, we explore which pairwise stable networks are likely to be reached from a situation in which no country has signed a free trade agreement (in fact the empty network). Such networks are called stable states. We first define the notions of improving paths and stable states due to Jackson and Watts (2001, 2002). An improving path from a network g to a network g' is a finite sequence of networks $g_1, ..., g_K$ with $g_1 = g$ and $g_K = g'$ such that for any $k \in \{1, ..., K-1\}$ either: (i) $g_{k+1} = g_k - ij$ for some ij such that $SW_i(g_k - ij) > SW_i(g_k)$, or (ii) $g_{k+1} = g_k + ij$ for some ij such that $SW_i(g_k + ij) > SW_i(g_k)$ and $SW_j(g_k + ij) \geq SW_j(g_k)$. An improving path is thus a sequence of networks that might be observed in a dynamic process where agents are adding and deleting links based on the improvement the resulting network offers relative to the current network.[14] A network g is a stable state if it is pairwise stable and there exists an improving path connecting the empty network to g.

Corollary 1. *The complete network g^c is the unique stable state in case all countries are non-unionized.*

This corollary follows from the proof of Proposition 2, where we have shown that $SW_i(g+ij) - SW_i(g) > 0$ for any arbitrary network g. Hence, starting from the network in which no country has signed a free trade agreement, sequences of networks due to continuously profitable deviations will always lead to the complete network. Remember that the complete network g^c is also the efficient one. In case of three unionized countries, the complete network g^c is also the unique stable state. However, a general proof for n unionized countries has not been obtained.

3.2 Two asymmetric frameworks

To analyze the networks of free trade agreements that unionized and non-unionized countries are going to form, we now consider a world with three countries.[15] In particular, we are going to examine two different situations: an asymmetric setting with only one unionized country and two non-unionized countries, and another asymmetric setting with two unionized countries and one non-unionized country. The welfare expressions can be found in the appendix.

We first consider countries' incentives to form bilateral free trade agreements. Lemma 1 tells us that any pair of symmetric countries (with respect to the network position and the unionization level) has always incentives to negotiate a free trade agreement.

Lemma 1. *Any pair of symmetric countries has always incentives to form a bilateral free trade agreement.*

The proof of Lemma 1 and all the proofs in this subsection are available from the authors upon request. There are two effects when two symmetric countries sign a free trade agreement implying a tariff-free access to their respective markets. First, the foreign firm can enter the domestic market without paying tariffs. It has an ambiguous impact

[14] Each network in the sequence differs by one link from the previous one. If a link is added, then the two agents involved must both agree to its addition, with at least one of the two strictly benefiting from the addition of the link. If a link is deleted, then it must be that at least one of the two agents involved in the link strictly benefits from its deletion.

[15] This oligopolistic perspective has been recently adopted by Krishna (1998) and Ornelas (2005a), and is also consistent with recent empirical evidence that shows that trading blocs that are small in world markets can affect outsiders significantly (see Chang and Winters, 2002).

on the social welfare of the home country since it increases domestic competition and thus increases consumers surplus but lowers profits of the domestic firm from domestic operations and collected tariffs. Second, the domestic firm gets greater access to the foreign market. It raises profits of the domestic firm from foreign operations. However, the net impact on the social welfare of the home country is positive. So, any pair of symmetric countries has an incentive to form a bilateral free trade agreement.

Lemma 2 tells us that any pair of countries, one unionized and one non-unionized but having a similar position in the network, has not always incentives to negotiate a free trade agreement. Moreover, these incentives are smaller the bigger the number of unionized countries and the smaller the number of free trade agreements already signed. Indeed, when a country signs a free trade agreement, the domestic firm gains greater access to the foreign market and suffers in the domestic market because of increased competition. The negative effect of increased competition is shared by the domestic firm with the other active foreign firms in the home market and, thus, it is smaller the greater the number of free trade agreements (the active firms) the home country has already signed.

Lemma 2. (*i*) *In the asymmetric setting with only one country unionized, the spoke unionized and non-unionized countries in the star network always want to form a bilateral free trade agreement, while the unionized country in the empty network only wants to form a bilateral free trade agreement with one of the non-unionized countries if and only if* $T < \frac{15a}{149}$. (*ii*) *In the asymmetric setting with two countries unionized, the spoke unionized country in the star network only wants to form a bilateral free trade agreement with the non-unionized spoke country if and only if* $\frac{63a}{275} < T \leq \frac{a}{4}$, *while any unionized country in the empty network never wants to form a bilateral free trade agreement with the non-unionized country.*

Under unionization, a large share of the profits of the domestic firm goes to the union which diminishes its competitive advantage with respect to the non-unionized foreign firm. Hence, the positive impact on social welfare of the home country due to greater access to the foreign market can be relatively small compared to the large decrease on profits of the domestic firm in the domestic market in case the number of active firms in the home country is small enough. Thus, the net impact on the social welfare of the home country of a bilateral free trade agreement can be negative. This prevents sometimes the unionized country from forming a bilateral free trade agreement with a non-unionized country.

We now analyze which networks are pairwise stable when one country is unionized and two countries are non-unionized.

Proposition 5. *Suppose country k is unionized and countries i and j are non-unionized.* (*i*) *If* $T \leq \frac{5a}{167}$, *then the complete network* g^c *is the unique pairwise stable network.* (*ii*) *If*

$\frac{5a}{167} < T \leq \frac{a}{4}$, *then the complete network* g^c *and the partially connected network* $g^p(ij)$ *are the only pairwise stable networks.*

Proposition 5 shows the pairwise stable networks when the firm of country k is unionized and the firms of countries i and j are non-unionized. As shown by Lemma 1, the empty network g^e and the star network $g^s(k)$ are never stable because two symmetric non-unionized countries have always incentives to form a bilateral trade agreement. By Lemma 2, the star networks $g^s(i)$ and $g^s(j)$ are never pairwise stable because the spoke unionized country and the spoke non-unionized country have incentives to form a bilateral free trade agreement. Thus, the complete network g^c is always pairwise stable. By Lemma 2, the partial networks $g^p(ik)$ and $g^p(jk)$ are not pairwise stable for $\frac{15a}{149} < T \leq \frac{a}{4}$ because the unionized country would have incentives to delete its link with the non-unionized country. Moreover, for $T \leq \frac{15a}{149}$, the partial networks $g^p(ik)$ and $g^p(jk)$ are not pairwise stable because the non-unionized countries have incentives to form a link moving to the star network $g^s(i)$ or $g^s(j)$. Finally, the partially connected network $g^p(ij)$ is pairwise stable if and only if $\frac{5a}{167} < T \leq \frac{a}{4}$ because the unionized country has no incentives to sign a free trade agreement with any of the linked non-unionized countries. The intuition is the same as the one in Lemma 2. Under unionization, a large share of the profits of the domestic firm goes to the union which diminishes its competitive advantage with respect to the non-unionized foreign firm. Hence, the positive effect due to greater access to the foreign market is relatively small compared to the large negative effect on profits of the domestic firm in the domestic market. This prevents the isolated unionized country from forming a bilateral free trade agreement with any of the two linked non-unionized countries.[16]

We now analyze which networks are pairwise stable when the firms of countries i and j are unionized and the firm of country k is non-unionized.

Proposition 6. *Suppose countries i and j are unionized and country k is non-unionized. (i) If* $T \leq T' \simeq 0.089a$, *then the partially connected network* $g^p(ij)$ *is the unique pairwise stable network. (ii) If* $T' < T \leq \frac{63a}{275}$, *then the star networks* $g^s(i)$ *and* $g^s(j)$ *are the only pairwise stable networks. (iii) If* $\frac{63a}{275} < T \leq \frac{a}{4}$, *then the complete network* g^c *is the unique pairwise stable network.*

As shown in Lemma 1, the empty network g^e and the star network $g^s(k)$ are never stable because two symmetric non-unionized countries have always incentives to form a bilateral trade agreement. From Lemma 2, the partially connected networks $g^p(ik)$ and $g^p(jk)$ are

[16] In the paper, we assume that unionized and non-unionized countries apply the same tariff rates to imports. Indeed, Brander and Spencer (1988) showed that the effect of the domestic union on the size of the optimum tariff is ambiguous. Thus, unionized countries do not necessarily use higher tariffs than non-unionized.

never pairwise stable because the unionized country would have incentives to delete its link with the non-unionized country. The star networks $g^s(i)$ and $g^s(j)$ are not pairwise stable for $\frac{63a}{275} < T \leq \frac{a}{4}$ because the spoke unionized country and the spoke non-unionized country have incentives to form a bilateral free trade agreement. Thus, the complete network g^c is always pairwise stable for $\frac{63a}{275} < T \leq \frac{a}{4}$. Moreover, the star networks $g^s(i)$ and $g^s(j)$ are not pairwise stable for $T \leq T' \simeq 0.089a$, because the unionized hub country has incentives to delete its link with the non-unionized spoke country moving to the partially connected network $g^p(ij)$. Then, the star networks $g^s(i)$ and $g^s(j)$ are pairwise stable if and only if $T' < T \leq \frac{63a}{275}$. Finally, the partially connected network $g^p(ij)$ is pairwise stable if and only if $T \leq T' \simeq 0.089a$. For such values of T any unionized country has no incentive either to form a link with the isolated non-unionized country or to delete the link with the other unionized country.

The fact that the partially connected network $g^p(ij)$ is pairwise stable only for high enough degrees of product market integration can be explained as follows. Since the profits of the unionized hub firm are increasing with T, the lower the degree of product market integration the greater the incentives of any unionized linked country to form a link with the isolated non-unionized country. Then, for small enough degrees of product market integration the star network $g^s(i)$ or $g^s(j)$ will be formed. Any of these two star networks is pairwise stable for $T' < T \leq \frac{63a}{275}$. Smaller degrees of product market integration give incentives to the spoke unionized country to form a link with the spoke non-unionized country moving to the complete network. Contrary to the previous cases, the complete network is pairwise stable only for small enough degrees of product market integration, $\frac{63a}{275} < T \leq \frac{a}{4}$. Indeed, for such values of T, the firm of the spoke unionized country prefers not to sell the good in the spoke non-unionized country. The formation of a bilateral free trade agreement between both countries results then advantageous for both of them.

Notice that the complete network "survives" (in the sense that it remains pairwise stable for some values of the external tariffs) the introduction of asymmetries in countries (unionized or non-unionized), and this could be seen as something positive for multilateral trade liberalization. However, the conclusion that follows from the previous analysis is that harmonization of labor markets may promote free trade, in the sense that the complete network is always pairwise stable whatever the number of countries.

We now examine aggregate social welfare under the different networks.

Proposition 7. *In any of the two asymmetric settings, the complete network g^c is the unique efficient network and aggregate social welfare is increasing with the number of links.*

Proposition 7 shows that, when only one country is unionized, a conflict between pairwise stability and efficiency may occur (see Figure 2). Meanwhile the efficient network is always pairwise stable, the reverse is not true since the partially connected network $g^p(ij)$ is sometimes pairwise stable but is never efficient. When only one country is non-unionized, a conflict between pairwise stability and efficiency occurs (see Figure 3). Indeed, for $T \leq \frac{63a}{275}$, the efficient network is never pairwise stable and vice versa. Only for $\frac{63a}{275} < T \leq \frac{a}{4}$, the complete network g^c is both the unique pairwise stable network and the efficient network.

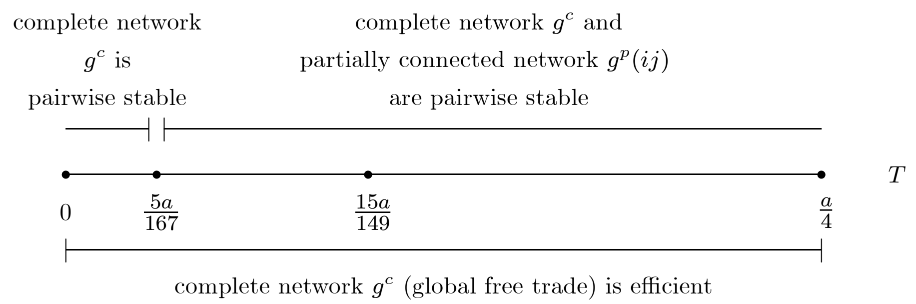

Figure 2: Conflict between stability and efficiency when only country k is unionized.

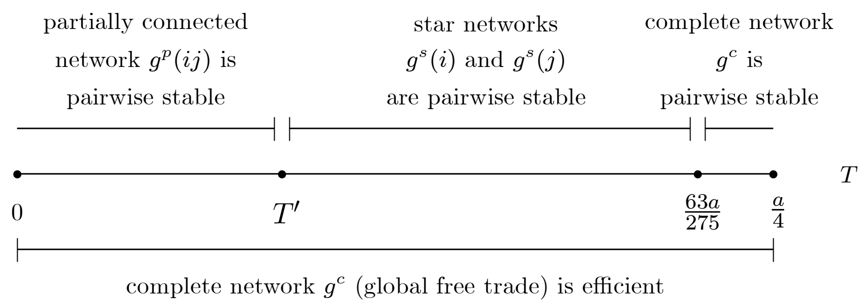

Figure 3: Conflict between stability and efficiency when only country k is non-unionized.

Finally, we want to mention the fact that, once countries are of different types, a conflict between efficiency and stable states is likely to occur.

Corollary 2. *Suppose country k is unionized, countries i and j are non-unionized. (i) If $T \leq \frac{5a}{167}$, then the complete network g^c is the unique stable state. (ii) If $\frac{5a}{167} < T \leq \frac{15a}{149}$, then the complete network g^c and the partially connected network $g^p(ij)$ are the stable states. (iii) If $\frac{15a}{149} < T \leq \frac{a}{4}$, then the partially connected network $g^p(ij)$ is the unique stable state.*

Corollary 3. *Suppose countries i and j are unionized, country k is non-unionized. (i) If $T \leq T' \simeq 0.089a$, then the partially connected network $g^p(ij)$ is the unique stable state.*

(ii) If $T' < T \leq \frac{63a}{275}$, then the star networks $g^s(i)$ and $g^s(j)$ are the stable states. (iii) If $\frac{63a}{275} < T \leq \frac{a}{4}$, then the complete network g^c is the unique stable state.

We observe that, starting from the network in which no country has signed a free trade agreement, sequences of networks due to continuously profitable deviations will not lead in most cases to the global free trade network, even when global free trade is efficient and pairwise stable. Thus, the conflict between stable states and efficient ones is far from being negligible when there are countries of different types.

4 Concluding remarks

In this paper we have examined the formation of free trade agreements as a network formation game. We have considered a n-country model in which international trade occurs between economies with imperfectly competitive product markets. In each country, the labor market is either unionized or non-unionized. We have shown that, if all countries are non-unionized, the global free trade network is the unique pairwise stable and efficient network and the unique stable state that results from a dynamic process starting from the empty network. If all countries are unionized, the global free trade network is pairwise stable and the unique efficient network among the class of symmetric networks. Thus, it seems that there is no conflict between stability and efficiency when either all firms are unionized or all firms are non-unionized. But if some countries are unionized while others are non-unionized, other networks apart from the global free trade network are likely to be pairwise stable. However, the efficient network is always the global free trade network. Thus, a conflict between stability and efficiency may occur when some countries are unionized and others non-unionized. So, the harmonization of labor markets may promote free trade, in the sense that the complete network is always pairwise stable. In addition, starting from the network in which no country has signed a free trade agreement, all sequences of networks due to continuously profitable deviations do not lead (in most cases) to the global free trade network, even when global free trade is stable.

The scope of the three-country analysis presented here for the two asymmetric frameworks is limited in that it does not include such possibilities as, for instance, the formation of two free trade agreements between two unionized and two non-unionized countries, respectively, where further liberalization implies a symmetric elimination of preferential access in both bilateral arrangements. However, we think that our results are general enough and that, in case of n-countries of different type, the conflict between stability and efficiency will persist. But the particular trading regime that would be stable in such case is an open question. Also, the generalization taking into consideration a different demand function and a different technology are left for further research.

In this paper, we have assumed that a trade treaty is costless. However, in practice, a free trade agreement is the result of long protracted negotiations between countries and it could be costly. What would be the effect of introducing a cost of link formation? Obviously, the answer depends on the relative importance of the link cost compared to the benefits of forming such link. Our intuition is that the cost of negotiating a free trade agreement is small compared to the benefits the countries could derive. Hence, although the introduction of such costs could destabilize the complete network, our results would still hold for small enough link costs.

We have also assumed that countries can form or delete one link at a time. Clearly, the negotiations to form a new free trade agreement take place one by one. But why not to allow a country to delete several links at a time? Indeed, the consideration of such possibility here would not alter the results of the paper.

Some extensions may be worthwhile. First, it would be interesting to treat the trade regime, as well as the choice of external tariffs under each trade regime, as endogenous decisions. We have concentrated on the incentives for liberalization on a non-discriminatory basis by assuming that uniform non-discriminatory tariffs are applied by all countries on imports from other countries. We have also considered that external tariffs remain constant with the formation of a free trade agreement. These assumptions are necessary to simplify the model for analyzing various forms of complicated free trade networks in the presence of unionized and non-unionized countries. Since the World Trade Organization precludes members of free trade areas from using these arrangements as a justification to bypass their previous tariff bindings and raise external tariffs, one could allow for the possibility that external tariffs decrease with the formation of a free trade agreement. Nevertheless, in the case of symmetric countries (either all unionized or all non-unionized), the complete network continues to be stable even in the case in which each country optimally adjusts its tariffs rate to a change in the free trade network. Second, it would be interesting to consider other objective functions for the countries. Krishna (1998) showed that multilateral liberalization that is initially politically feasible could be rendered infeasible by a preferential arrangement when the external tariffs to non-members are fixed and countries maximize domestic firms' profits. Ornelas (2005b) extended Krishna's framework by endogenizing external tariffs to non-members and assuming that governments maximize a welfare function that assigns a higher weight to profits. But these two papers treat as given the trading regimes. Thus, it would be very interesting to study the robustness of Krishna (1998) and Ornelas (2005b) results when trading regimes are endogenized.

Appendix

A All countries are non-unionized

The social welfare of country i in any network g is given by

$$\begin{aligned} SW_i(g) &= \frac{1}{2}\left(\frac{na - T(n-n_i(g))}{n+1}\right)^2 + \sum_{j\in N_i(g)}\left(\frac{a+T(n-n_j(g))}{n+1}\right)^2 \\ &+ \sum_{k\notin N_i(g)}\left(\frac{a-T(n_k(g)+1)}{n+1}\right)^2 + T(n-n_i(g))\left(\frac{a-(n_i(g)+1)T}{n+1}\right). \end{aligned}$$

The aggregate social welfare in any network g is given by

$$\begin{aligned} SW(g) &= \sum_{i\in N} SW_i(g) = \sum_{i\in N}\frac{1}{2}\left(\frac{na-T(n-n_i(g))}{n+1}\right)^2 \\ &+ \sum_{i\in N} n_i(g)\left(\frac{a+T(n-n_i(g))}{n+1}\right)^2 + \sum_{i\in N}(n-n_i(g))\left(\frac{a-T(n_i(g)+1)}{n+1}\right)^2 \\ &+ \sum_{i\in N} T(n-n_i(g))\left(\frac{a-(n_i(g)+1)T}{n+1}\right). \end{aligned}$$

B All countries are unionized

The social welfare of country i in any network g is given by $SW_i(g) = CS_i(g) + \Pi_i(g) + U_i(g) + CT_i(g)$, where

$$\begin{aligned} CS_i(g) &= \frac{1}{2}\left(a - \frac{(2n^2+n)a + (\sum_{i\in N} n_i(g) + n^3 - n^2 n_i(g) - nn_i(g))T}{n(n+1)^2}\right)\times \\ &\left(\frac{(2n^2+n)a + (\sum_{i\in N} n_i(g) + n^3 - n^2 n_i(g) - nn_i(g))T}{(n+1)^2} - \right. \\ &\left. -\frac{n^2 a - (n^2 - \sum_{i\in N} n_i(g))T}{n(n+1)} - (n-n_i(g))T\right), \end{aligned}$$

$$\begin{aligned} \Pi_i(g) &= \sum_{j\in N}\left(\frac{(2n^2+n)a + (\sum_{i\in N} n_i(g) + n^3 - n^2 n_i(g) - nn_i(g))T}{n(n+1)^2} - \frac{a}{(n+1)}\right. \\ &\left. + \frac{(2n^2 - 2nn_i(g) - n^2 n_i(g) + n\sum_{i\in N} n_i(g) + n - n_i(g))T}{(n+1)(2n^2+n)} - I_{ij}T\right), \end{aligned}$$

$$
\begin{aligned}
U_i(g) &= \left(\frac{a}{(n+1)} - \frac{(2n^2 - 2nn_i(g) - n^2 n_i(g) + n\sum_{i\in N} n_i(g) + n - n_i(g))T}{(n+1)(2n^2+n)}\right) \times \\
&\left(\frac{(2n^2+n)a + (n^3 - n\sum_{i\in N} n_i(g))T}{(n+1)^2} - \right. \\
&n\left(\frac{a}{(n+1)} - \frac{(2n^2 - 2nn_i(g) - n^2 n_i(g) + n\sum_{i\in N} n_i(g) + n - n_i(g))T}{(n+1)(2n^2+n)}\right) - \\
&\left. -(n - n_i(g))T\right),
\end{aligned}
$$

$$
\begin{aligned}
CT_i(g) &= (n - n_i(g))\left(\frac{(2n^2+n)a + (\sum_{i\in N} n_i(g) + n^3 - n^2 n_i(g) - nn_i(g))T}{n(n+1)^2} - T\right)T \\
&- \sum_{j\in N} I_{ij} T\left(\frac{a}{(n+1)} - \frac{(2n^2 - 2nn_j(g) - n^2 n_j(g) + n\sum_{i\in N} n_i(g) + n - n_j(g))T}{(n+1)(2n^2+n)}\right)
\end{aligned}
$$

C One unionized country, two non-unionized countries

The empty network.

For the unionized country:

$$W_i^*(g^e) = \frac{3a - 2T}{18}, SW_i^*(g^e) = \frac{(3a-2T)(1245a + 1186T)}{10368b}$$

For a non-unionized country:

$$SW_i^*(g^e) = \frac{(3a-2T)(1749a + 274T)}{10368b}$$

and the global welfare is $SW^*(g^e) = \frac{17(3a-2T)(93a+34T)}{3456b}$

The partially connected network.

Suppose the isolated country is non-unionized. For a linked unionized country:

$$W_i^*(g^p) = \frac{a}{6}, SW_i^*(g^p) = \frac{415a^2 + 132aT - 396T^2}{1152b}$$

For a linked non-unionized country:

$$SW_i^*(g^p) = \frac{11(53a^2 + 12aT - 36T^2)}{1152b}$$

For the isolated non-unionized country:

$$SW_i^*(g^p) = \frac{583a^2 - 600aT + 576T^2}{1152b}$$

and the global welfare is

$$SW^*(g^p) = \frac{527a^2 - 112aT - 72T^2}{384b}$$

When the isolated country is unionized, we should distinguish two cases.
[Case 1] $T \leq \frac{3a}{14}$
For a linked non-unionized country:

$$SW_i^*(g^p) = \frac{5247a^2 - 1140aT - 1868T^2}{10368b}$$

For the isolated unionized country:

$$W_i^*(g^p) = \frac{3a - 4T}{18}, SW_i^*(g^p) = \frac{5(747a^2 - 48aT + 464T^2)}{10368b}$$

and the global welfare is

$$SW^*(g^p) = \frac{4743a^2 - 840aT - 472T^2}{3456b}$$

[Case 2] $\frac{3a}{14} < T \leq \frac{a}{4}$. Then, $X_{ij}^*(g^p) = X_{ik}^*(g^p) = 0$, $i \neq j$, $i \neq k$, when i denotes the unionized spoke country.
For a linked non-unionized country:

$$SW_i^*(g^p) = \frac{5(61a^2 - 28aT + 20T^2)}{576b}$$

For the isolated unionized country:

$$W_j^*(g^p) = \frac{a + 2T}{6}, SW_i^*(g^p) = \frac{(331a - 298T)(a + 2T)}{1152b}$$

and the global welfare is

$$SW^*(g^p) = \frac{(33a - 14T)(47a + 14T)}{1152b}$$

The star network.
Suppose the hub country is unionized. For the unionized hub country:

$$W_i^*(g^s) = \frac{3a + 2T}{18}, SW_i^*(g^s) = \frac{3735a^2 + 1308aT + 940T^2}{10368b}$$

For a non-unionized spoke country:

$$SW_i^*(g^s) = \frac{5247a^2 - 1536aT - 872T^2}{10368b}$$

and the global welfare is:

$$SW^*(g^s) = \frac{4743a^2 - 588aT - 268T^2}{3456b}$$

When the hub country is non-unionized, we should distinguish two cases.

[Case 1] $T \leq \frac{3a}{16}$

For the unionized spoke country:

$$W_i^*(g^s) = \frac{3a - 2T}{18}, SW_i^*(g^s) = \frac{3735a^2 - 120aT - 1688T^2}{10368b}$$

For the non-unionized hub country:

$$SW_i^*(g^s) = \frac{5247a^2 + 2724aT + 1036T^2}{10368b}$$

For the non-unionized spoke country:

$$SW_i^*(g^s) = \frac{5247a^2 - 3864aT + 136T^2}{10368b}$$

and the global welfare is

$$SW^*(g^s) = \frac{4743a^2 - 420aT - 172T^2}{3456b}$$

[Case 2] $\frac{3a}{16} < T \leq \frac{a}{4}$. Then, $X_{ik}^*(g^s(j)) = 0$, $i \neq k$, when i denotes the unionized country.

For the unionized spoke country:

$$W_i^*(g^s) = \frac{2a + T}{12}, SW_i^*(g^s) = \frac{1492a^2 + 796aT - 2963T^2}{4608b}$$

For the non-unionized hub country:

$$SW_i^*(g^s) = \frac{2452a^2 + 716aT + 341T^2}{4608b}$$

For the non-unionized spoke player:

$$SW_i^*(g^s) = \frac{580a^2 - 476aT + 613T^2}{1152b}$$

and the global welfare is

$$SW^*(g^s) = \frac{3132a^2 - 196aT - 85T^2}{2304b}$$

The complete network.

For the unionized country:

$$W_i^*(g^c) = \frac{a}{6}, SW_i^*(g^c) = \frac{415a^2}{1152b}$$

For the non-unionized country:

$$SW_i^*(g^c) = \frac{583a^2}{1152b}$$

and the global welfare is

$$SW^*(g^c) = \frac{527a^2}{384b}$$

D Two unionized countries, one non-unionized country

The empty network.

For the unionized country:

$$W_i^*(g^e) = \frac{3a-2T}{15}, SW_i^*(g^e) = \frac{(3a-2T)(177a+122T)}{1440b}$$

For the non-unionized country:

$$SW_i^*(g^e) = \frac{(1389a-206T)(3a-2T)}{7200b}$$

and the global welfare is

$$SW^*(g^e) = \frac{13(3a-2T)(81a+26T)}{2400b}$$

The partially connected network.

Suppose the isolated country is unionized. For the linked unionized country:

$$W_i^*(g^p) = \frac{a}{5} - \frac{4T}{105}, SW_i^*(g^p) = \frac{3717a^2-294aT-1921T^2}{10080b}$$

For the isolated unionized country:

$$W_i^*(g^p) = \frac{7a-8T}{35}, SW_i^*(g^p) = \frac{3717a^2-1428aT+2480T^2}{10080b}$$

For the linked non-unionized country:

$$SW_i^*(g^p) = \frac{29169a^2-5502aT-9221T^2}{50400b}$$

and the global welfare is

$$SW^*(g^p) = \frac{1053a^2-224aT-102T^2}{800b}$$

Suppose the isolated country is non-unionized. For the linked unionized country:

$$W_i^*(g^p) = \frac{a}{5}, SW_i^*(g^p) = \frac{59a^2+30aT-55T^2}{160b}$$

For the isolated non-unionized country:

$$SW_i^*(g^p) = \frac{463a^2-580aT+400T^2}{800b}$$

and the global welfare is

$$SW^*(g^p) = \frac{1053a^2-280aT-150T^2}{800b}$$

The star network.

Suppose the hub country is non-unionized. We distinguish two cases.

[**Case 1**] $T \leq \frac{9a}{41}$

For the unionized spoke country:

$$W_i^*(g^s) = \frac{3a - 2T}{15}, SW_i^*(g^s) = \frac{531a^2 - 258aT - 79T^2}{1440b}$$

For the non-unionized hub country:

$$SW_i^*(g^s) = \frac{4167a^2 + 1824aT + 532T^2}{7200b}$$

and the global welfare is

$$SW^*(g^s) = \frac{3159a^2 - 252aT - 86T^2}{2400b}$$

[**Case 2**] $\frac{9a}{41} < T \leq \frac{a}{4}$. Then, $X_{ij}^*(g^s) = X_{ji}^*(g^s) = 0$, $i \neq j$, when i and j are the unionized countries.

For the unionized spoke country:

$$W_i^*(g^s) = \frac{7a}{31}, SW_i^*(g^s) = \frac{13807a^2}{46128b}$$

For the non-unionized hub country:

$$SW_i^*(g^s) = \frac{185035a^2}{276768b}$$

and the global welfare is

$$SW^*(g^s) = \frac{350719a^2}{276768b}$$

Suppose the hub player is unionized. We distinguish two cases.

[**Case 1**] $T \leq \frac{63a}{275}$

For the unionized hub country:

$$W_i^*(g^s) = \frac{a}{5} + \frac{2T}{21}, SW_i^*(g^s) = \frac{1239a^2 + 504aT + 260T^2}{3360b}$$

For the unionized spoke country:

$$W_i^*(g^s) = \frac{a}{5} - \frac{2T}{21}, SW_i^*(g^s) = \frac{1239a^2 + 126aT - 475T^2}{3360b}$$

For the non-unionized spoke country:

$$SW_i^*(g^s) = \frac{9723a^2 - 6090aT + 25T^2}{16800b}$$

and the global welfare is

$$SW^*(g^s) = \frac{1053a^2 - 140aT - 50T^2}{800b}$$

[Case 2] $\frac{63a}{275} < T \leq \frac{a}{4}$. Then, $X^*_{ik}(g^s(j)) = 0$, $i \neq k$, when i denotes the unionized spoke country.

For the unionized hub country:

$$W^*_i(g^s) = \frac{22a + 7T}{102}, SW^*_i(g^s) = \frac{287341a^2 + 55766aT + 47407T^2}{7490886b}$$

For the unionized spoke country:

$$W^*_i(g^s) = \frac{62a + 29T}{306}, SW^*_i(g^s) = \frac{236749a^2 + 200504aT - 458462T^2}{7490886b}$$

For the non-unionized spoke country:

$$SW^*_i(g^s) = \frac{221930a^2 - 175658aT + 189275T^2}{374544b}$$

and the global welfare is

$$SW^*(g^s) = \frac{322650a^2 - 31682aT - 10835T^2}{249696b}$$

The complete network.

For the unionized country:

$$W^*_i(g^c) = \frac{a}{5}, SW^*_i(g^c) = \frac{59a^2}{160b}$$

For the non-unionized country:

$$SW^*_i(g^c) = \frac{463a^2}{800b}$$

and the global welfare is

$$SW^*(g^c) = \frac{1053a^2}{800b}.$$

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