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Keywords: Endogenous network formation, Bilateral trade agreement, Myopic and farsighted behavior,
JEL classification: F15,

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We examine network formation via bilateral trade agreement (BTA) among three symmetric countries. Each government decides whether to form a link or not via a BTA depending on the differential of ex-post and ex-ante sum of real wages in the country. We model the governmental decision in two forms, myopic and farsighted and analyze the effects on the BTA network formation. First, we find that both myopic and farsighted games never induce the formation of star networks nor empty networks. Second, the networks resulting from myopic game coincides with those resulting from farsighted games.

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1 Introduction

In the last decades, developments in information and transportation technology have made it faster to cover the distance between any two countries and smoothened the contract of various transactions. We have also observed the number of trade agreements among countries increase rapidly. Each trade agreement drastically reduces the explicit and implicit trade barriers, such as tariff and administration costs. While developments in technology are exogenous to governments, conclusion of trade agreements is based on governmental decision. The decisions of trade agreements are totally endogenous for each government. As is pointed out by Bhagwati and Panagariya (1996), decentralized decisions among multiple countries result in "building blocs" or " stumbling blocs". When the negotiations of free trade agreements (FTA) are decentralized, the ability of government to foresee the future networks would be critical. While there are several papers on FTA, most of the papers are based on competitive framework.

This paper constructs a monopolistic competition model involving three symmetric countries with positive transportation costs to examine endogenous trade agreements. The geographical unit can be country, international regions or intranational regions if we could assume the immobility of workers. For example, three regions can be referred as Asia, North America, and EU. When reduction of trade costs results in a lower price of goods, it increases domestic welfare unambiguously. However trade agreements among the other countries could deteriorate the welfare at home. The decentralized conclusions of trade agreements could be interpreted as a network formation game. Furusawa and Konishi (2007) analyze network formations among many heterogeneous countries with respect to stability but, the degree of farsightedness is not analyzed. In the study on strategic behavior of governments, while Mukunoki and Tachi (2006) employ Cournot competition model with infinite time, we employ monopolistic competition in finite time. Since BTA requires substantial reduction in trade barriors, the number of BTA concluded between countries is at most finite. Krugman (1993a) noted the limitation of a-twocountry framework and emphasized the role of hubs which he alternatively called star links. With the models of monopolistic competition, for example, by Ago, Isono and Tabuchi (2006), Behrens (2007), Mori and Nishikimi (2002), and Behrens, Gaigne, Ottaviano and Thisse (2006), the emergence of hub and its effects are analyzed in international economics and in economic geography. However, the endogenous determination of trade agreements is still left aside. This paper explicitly considers the effects from changes in trade network on distribution of firms and characterize the behavior of governments as welfare-maximizing with respect to vision, myopic or farsighted in a three-stage game.

Our simple model show that regardless of vision or foresight, a complete network is achieved. While Krugman (1993b) discussed that "world welfare is minimised when there are three blocs", our results imply optimistic *ex-post* path to this discussion. Even though world trading blocs are formed into three and minimizes the world welfare, three blocks will achieve the free trade world in the the end regardless of government vision.

The rest of the paper is organized as follows. In Section II we present the basic framework of the model, while Section III formulates the types of government behavior and compare the outcomes. Finally, we offer some concluding comments.

2 The model

2.1 Consumers and firms

The economy consists of three countries A, B, and C, where the geographical unit can be international regions or intranational regions. For simpler argument, we call the unit as country. There are two types of production sectors, the competitive and manufacturing sectors. In order to highlight the role of government behavior in the following section, three countries are assumed to be symmetric in population, endowments and technology. We normalize each population, the number of firms, and the amount of capital as one. Then the number of firms in each country is identical to the share of firms in this economy. We put the share of firms in country r by $\lambda_r \in [0,1]$ and from definition, $\sum_{r=A,B,C} \lambda_r = 1$ always holds. Each individual supplies one unit of labour inelastically within their residential country and is assumed to be endowed one unit of capital. Their consumption behavior is characterized by the following utility function as,

$$U_r = \frac{C_r^{1-\mu} M_r^{\mu}}{\mu^{\mu} (1-\mu)^{1-\mu}}, \quad \text{and} \quad M_r = \left(\sum_{s=A,B,C} \int_0^{\lambda_s} m_{sr}^{\frac{\sigma-1}{\sigma}} (v)\, dv \right)^{\frac{\sigma}{\sigma-1}}, \tag{1}$$

where M stands for an index of the consumption of the manufactured good, σ is the elasticity of substitution between any manufactured goods, and the lower subscript, r, expresses the country of consumption or production. While C is the consumption of homogeneous good, e.g. agriculture good, $m_{sr}(v)$ expresses the demand for a differentiated manufactured good indexed v, which is produced at country s and is consumed at country r. Using the same index and subsrcipts, the price for a differentiated manufactured good is denoted by $p_{sr}(v)$. Moreover, while domestic transfer doesn't incur any transportation costs, for any shipment of differentiated goods across countries, transportation costs of the *iceberg* type are incurred. Assuming the symmetric transportation costs between countries, we define this transportation costs as $\tau_{rs} = \tau$, $\tau_{rr} = 1$, where τ is the fraction which melts away during transport. Then the price of country r's product is transferred to country s can be expressed as, $p_{rs} = p_r \tau_{rs} = p_r \tau$. For later reference, we put the measure of trade openness by $\phi = (\tau)^{1-\sigma} \in [0,1]$, which can be interpreted as the fraction of the product that reaches the destination. The budget constraint can be written as,

$$Y_r = w_r + k_r = C_r + P_r M_r, \quad \text{and} \quad P_r = \left(\sum_{s=A,B,C} \int_0^{\lambda_s} (p_{sr}(v))^{1-\sigma} dv \right)^{\frac{1}{1-\sigma}}, \tag{2}$$

where Y, w, k, $p(v)$ and P denote income, wage, capital reward, price of a manufactured good indexed v and the price index of manufactured varieties. A worker in country r maximizes utility in (1), subject to the budget constraint (2). Standard utility maximization yields the following equations;

$$C_r = (1-\mu)\, Y_r, \tag{3}$$

$$m_{sr}(v) = \mu p_s^{-\sigma}(v)\,(\tau_{rs})^{1-\sigma}\, P_r^{\sigma-1} Y_r, \tag{4}$$

$$V_r = \frac{Y_r}{P_r^{\mu}}. \tag{5}$$

V_r is the indirect utility function in country r. The competitive sector produces a homogeneous good under constant returns to scale technology using labor only. This homogeneous good is assumed to be shipped costlessly. Thus we take this as numeraire and normalize the labour wage one, $w_r = 1$. On the other hand, the manufacturing sector requires one unit of capital as fixed input and labor as marginal input requirement and exhibits increasing returns to scale. We set the cost function of the manufacturing sector as $\pi_r + m_r(v)$, where π_r is the rental cost for one unit of capital in country r and m_r is the sum of national demands of a differentiated good, $m_r(v) = \sum_{s=1}^{3} m_{rs}(v)$. Taking the demand of its good as given, each firm sets its price so as to maximize its profit as

$$p(v) = p = \frac{\sigma}{\sigma-1}. \tag{6}$$

In equilibrium all varieties are symmetric. Thus we could drop the variety index (v) for simpler notation. With the normalizations, we could rewrite the price index as,

$$P_r = \frac{\sigma}{\sigma-1}\left(\sum_{s=A,B,C} \lambda_r \phi_{rs}\right)^{\frac{-1}{\sigma-1}}. \tag{7}$$

Since capital is used only for the fixed input and potential entrants in this sector ensure the zero-profit condition, rents to capital is expressed as a form of operating profits:

$$\pi_r(\lambda_r) = m_r(p_r - 1) = \frac{1}{\sigma} m_r. \tag{8}$$

Capital moves to the country which gives the highest returns denoted by $\pi_r(\lambda_r)$. This results in a firm distribution which signifies that the capital rent is identical in all countries in equilibrium. The equilibrium condition implies the following motion of capital arbitrage;

$$\pi \equiv \pi_r(\lambda_r) = \pi_s(\lambda_s), \qquad r \neq s. \tag{9}$$

Then national income is shown to be invariant to the distribution of firms and simply written as $Y_r = \pi + w$.

2.2 Trade agreements

We assume that the conclusion of trade agreements unambiguously decreases trade costs, which is expressed by $\delta > 1$. As mentioned in the introduction, in the post-BTA scenario transportation costs would remain. The reduction of trade costs is evaluated by the level of ex-ante total trade costs which includes transportation costs. Since the measure of trade costs ranges from zero to one, $\phi \in [0, 1]$, even after the conclusion, the improved trade costs should not exceed one.

$$0 < \delta\phi < 1 \tag{10}$$

Then we regard the process to construct a trade agreement as a network formation. In what follows, we call the situation about the conclusion of trade agreements is denoted simply as *network*, which is expressed as an undirected graph on $\{A, B, C\}$(we can also identify it with a subset of the set of links $\{AB, BC, CA\}$[1]). Given a network g, a transportation cost between country r and s is denoted by ϕ^g_{rs},

[1]For instance, since AB expresses the linkage between A and B, it is clear that $BA = AB$.

and hence we have

$$\phi^g_{rs} = \begin{cases} \phi\delta & \text{if } r \neq s, rs \in g, \\ \phi & \text{if } r \neq s, rs \notin g, \\ 1 & \text{if } r = s. \end{cases}$$

Similarly, we denote the share of firms for country r given a network g by λ^g_r. Let $\lambda_r \equiv (\lambda^g_r)_{r=A,B,C}$.

With the above notation, we can obtain the capital rent for each country r given a network g, $\pi_r(\lambda^g)$, as

$$\pi_r(\lambda^g) = \frac{\mu}{\sigma} \sum_{s=A,B,C} \frac{Y_s}{\Delta^g_s} \phi^g_{sr}, \tag{11}$$

where

$$\Delta^g_s = \sum_{t=A,B,C} \lambda^g_t \phi^g_{ts}.$$

for any country s. The capital arbitrage condition should hold among all the countries, which is expressed as $\pi_r(\lambda^g) = \pi_s(\lambda^g)$ for any r and s. Applying the capital arbitrage condition for a given network, we can solve the distribution of firms λ^g as is listed in Appendix A.1. As is shown in Figure 1, we have two cases of corner solutions —– the case of $\lambda^{\{ij\}}_k = 0$ and the case of $\lambda^{\{ij,jk\}}_j = 1$ for distinct countries i, j and k. The former one occurs when a given network is $\{ij\}$, where the two countries i and j share all the firms evenly, and the latter occurs when a given network $\{ij, jk\}$ or what is alternatively called *star network*, where the *hub* country j gets all the firms.

Moreover, we define the objective function of the government, social welfare, of each country r as the indirect utility function of all residents in the country and it may be written as

$$W^g_r = \frac{Y_r}{(P^g_r)^\mu} = Y(\Delta^g_r)^{\frac{\mu}{\sigma-1}} \tag{12}$$

Considering the symmetry assumption among the three countries given a particular population, since wage and capital rent are equal among the countries, the national (regional) incomes are identical. Thus, without loss of generality, we drop the sub-

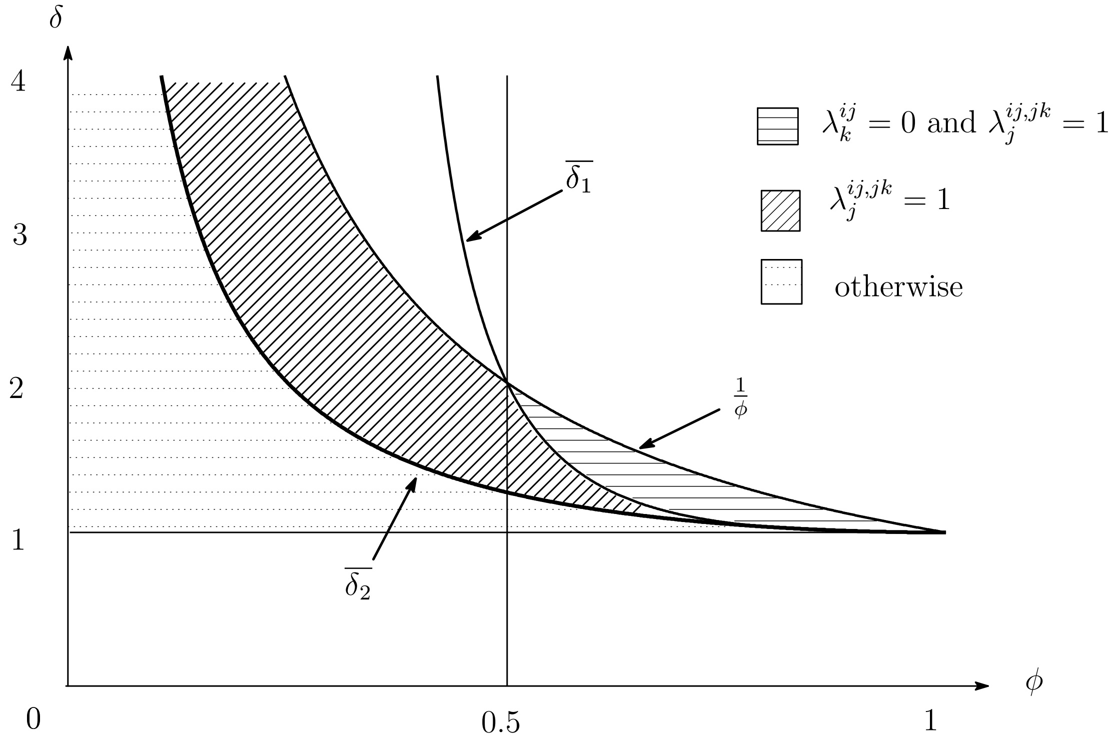

Figure 1: Distribution of firms: concentration and absence

script r in income, Y. Since the price index of country r given a network g, P_r^g, can be expressed as $(\Delta_r^g)^{\frac{1}{1-\sigma}}$, social welfare is dependent only on price indices at each region. The value of W_r^g is listed in Appendix A.2.

Using the above obtained welfare, we assume governments compare the welfare scenario for the given different networks in the following way. First we define W_r^{gh} for any distinct network g, h and any country r as

$$W_r{}^{gh} \equiv \frac{W_r^h}{W_r^g} = \left(\frac{P_r^g}{P_r^h}\right)^{\mu} = \left(\frac{\Delta_r^h}{\Delta_r^g}\right)^{\frac{\mu}{\sigma-1}}. \tag{13}$$

Note that the decision on the approval of BTA by country r depends on the value of Δ_r^h/Δ_r^g. Then we define and use D_r^{gh} for any distinct network g, h and any country r as

$$D_r^{gh} \equiv \left(W_r^{gh}\right)^{\frac{\sigma-1}{\mu}} - 1, \quad \text{for } r = A, B, C \text{ and distinct } g, h \subset \{AB, BC, CA\}, \tag{14}$$

which implies the welfare change of country r from network g to network h. Furthermore, for the brief notation, we define

$$D_r^{g+ij} \equiv D_r^{gg\cup\{ij\}} \tag{15}$$

for any network g and any link $ij \notin g$. Each government can evaluate their decision based on this welfare differential in (13). The outcome networks and the corner solutions where there are no firms in a country or where all firms concentrate in a single country are summarized in Figure 1. Since profit of monopolistic companies are constant among any network g, as is shown in Appendix A, the source of trade agreements the reduction in trade costs resulted from the conclusion of BTA affects real wage only through price indices, and the distribution of firms.

3 Vision of government

Now, we introduce a simple dynamic game for conclusion-network formation by national government. Suppose that countries A, B and C are facing situations to determine which BTA to conclude. Every country is concerned only with its own social welfare. In order to maximize its own social welfare, each government organizes conferences to discuss the reduction of trade barriers by BTA. In this game, we focus only on bilateral conferences and later discuss multilateral conference case. Each conference has to conclude at most one BTA between participants. We assume decisions are irreversible so that all countries decide their own actions without considering the break of connected links.

For further understanding, we specify a word, “Conference”. “Conference” is defined as a meeting to consult about forming a link between two participating governments, which represent the end points of the link. The conference on forming link X is denoted by Conference X for $X = AB$, BC, CA. In order to clarify the difference of these networks from the outcome network, we refer to a network formed on the way as "*en route* network". In addition, we suppose that the welfare of each country is not transferable. Hereon, we consider and compare two types ofvision of governments: myopic and farsighted.

3.1 Myopic games

First, we consider the case that all governments of countries are myopic decision makers: we suppose that participants of each conference take into account only how their payoffs change when they link, not how those finally change after all conferences. We denote the conclusion-network formation game with myopic governments by $\Gamma_M(\phi, \delta)$. In our paper, we simply call $\Gamma_M(\phi, \delta)$ the "myopic game" for (ϕ, δ).

By the above setup, we can assert the result of every conference with each change of the participant's social welfare by forming a link: a conference makes a conclusion to link only if both the welfares of the participants are strictly improved; otherwise it decides not to link. Moreover, any conference does not make a conclusion once the previous one determines not to link since it faces the same situation as the previous one by symmetry. Hence the possible outcome networks are only $\varnothing$, $\{AB\}$, $\{AB, BC\}$ and $\{AB, BC, CA\}$. Then we show that actually $\varnothing$ and $\{AB, BC\}$ can not be outcome networks and exhibit the condition where the outcome network is complete and where it becomes $\{AB\}$.

Proposition 1 *Suppose all the governments of countries make choices myopically, then the outcome network is always complete.*

Therefore, star networks can not be formed due to the fact that there is always Pareto improvement for region C and A from the conclusion of $\{CA\}$ under $\{AB, BC\}$.

3.2 Farsighted games

Next, we consider the case that all governments are farsighted decision makers: we suppose that they take into account the social welfares gains after all conferences. Therefore, they make actions thinking over how their actions affect the subsequent conferences, so that we need to specify the optimal strategy for each country by backward induction. We denote the conclusion-network formation game with farsighted governments by $\Gamma_F(\phi, \delta)$. In our paper, we simply call $\Gamma_F(\phi, \delta)$ the "farsighted game" for (ϕ, δ).

In order to simplify the discussion, we use the following scenario tree as in Figure 2.

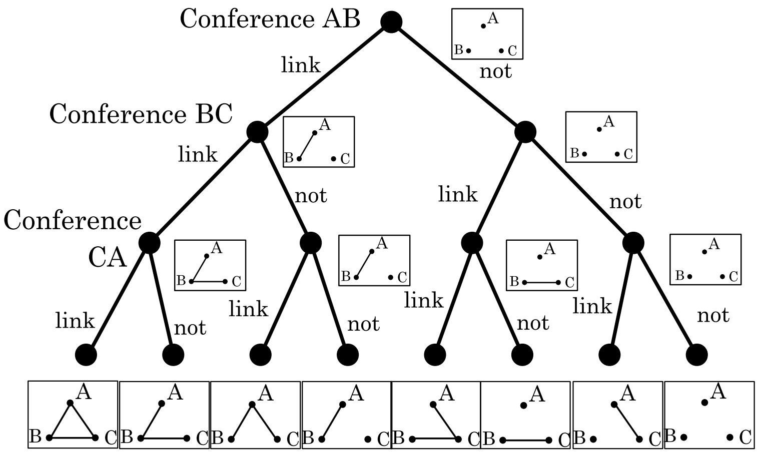

Figure 2: The scenario tree

The time flows from the top to the bottom as follows. The node at the top describes the turn of Conference AB which is of course given the empty network $\varnothing$ as the *en route* network, and the two branches grown from that node indicate the decision of Conference AB, linking together and not linking. Therefore, both of the two nodes at the second highest level describe the turns of Conference BC, but the *en route* network one node faces is different from that another faces. In fact, the *en route* networks are $\{AB\}$ and $\varnothing$. Similarly to Conference AB, the branches grown from the nodes indicate the decisions of Conference BC. Finally, the four nodes at the lower level describe the turns of Conference CA, whose *en route* networks are respectively $\{AB, BC\}$, $\{AB\}$,$\{BC\}$ and $\varnothing$, and the eight nodes at the bottom describe the outcome networks.

With the scenario tree, we analyze the outcomes of the dynamic games comparing it with those of the myopic games. Since we proved that the outcome network in a myopic game can be the complete network $\{AB, BC, CA\}$, we consider all the farsighted profiles (ϕ, δ) at once. When the outcome network is complete in $\Gamma_M(\phi, \delta)$, by symmetry, each conference must conclude to link whichever *en route* network it faces in $\Gamma_F(\phi, \delta)$. Hence, the outcome network in $\Gamma_F(\phi, \delta)$ is also complete. This is the case that strategically avoiding from ending as a star network by the others, any of two governments agree to conclude BTA for any given *en route* network. Summarizing the above, we conclude by the following proposition.

Proposition 2 *The outcome of the farsighted game* $\Gamma_F(\phi, \delta)$ *is also the complete network.*

4 Discussion and Conclusion

In the process of growing trade networks, we examine pairwise improvements of trade costs among three countries via bilateral trade agreements. We extensively analyze the different outcome networks depending on government vision. In the previous section, we show that myopic and farsighted games never induce a star network and that for any (ϕ, δ), the myopic game and farsighted game yields the complete network. Our results suggest an optimistic view to Krugman's discussion that free trade among varioous countries in the world will be achieved regardless of the vision of governments, even though the world is divided into three symmetric FTA-regions which gives the worst social welfare.

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Appendix A

A.1 Distribution of firms

By specifying each phase, we explicitly solve for the distribution of firms and the welfare differential for each countries. While the rotation of the conferences are specified in this appendix, due to the symmetry of three countries the results remain unchanged.

A.1.1 Profit at each phase

From the assumption of equally endowed capital and normalization in wage, population and the number of firms, the reward from capital can be written as $N\pi/3 = \pi/3\,(= k)$. Plugging this capital reward into the regional income in (2) with (11), then we may rewrite equation (11) as $\pi^g = Y\Omega^g = \left(1 + \frac{\pi^g}{3}\right)\Omega^g$ where $\Omega^g \equiv \mu/\sigma \sum_{r=A,B,C} \phi^g_{sr}/\Delta^g_s$ expresses the distribution of firms weighted by distance. Solving for the profit at any phase, we have, $\pi^g = \frac{\Omega^g}{1-\Omega^g/3}$. From the capital arbitrage results which follows below, the equilibrium at each phase Ω is the same regardless of location. Moreover, substituting the above mentioned variables into (11), obtaining the result, $\Omega^g = 3\mu/\sigma$, $\forall g$ is straightforward. Thus profit is constant across all networks.

A.1.2 Empty network and complete networks

The solution for the distribution of firms are given by

$$\lambda^g_A = \lambda^g_B = \lambda^g_C = \tfrac{1}{3}, \quad where\ g = \phi\ or\ \{AB, BC, CA\}$$

A.1.3 When the network has only one link

Let i, j and k be distinct countries. Suppose that a BTA is concluded only between countries i and j. Applying the capital arbitrage condition, the solution for the distribution of firms are given by

$$\lambda_i^{\{ij\}} = \lambda_j^{\{ij\}} = \frac{1}{3}\frac{-3\phi+\phi^2+\delta\phi+1}{(1-\phi)(-2\phi+\delta\phi+1)} > \lambda_k^{\{ij\}}$$
$$\lambda_k^{\{ij\}} = \frac{1}{3}\frac{\phi\delta(1-3\phi)+\left(4\phi^2-3\phi+1\right)}{(1-\phi)(-2\phi+\delta\phi+1)}$$

Note that although λ_r^g should not exceed 1 and zero, keeping the restriction of $\delta\phi < 0$, we have $\lambda_r^g \in [0,1]$. We have the case such that $\lambda_k^{\{ij\}} = 0$ and $\lambda_i^{\{ij\}} = \lambda_j^{\{ij\}} = \frac{1}{2}$. Equating to zero, we have the critical value for this corner solution, $\frac{1+4\phi^2-3\phi}{\phi(3\phi-1)} \equiv \overline{\delta_1} \leq \delta < \frac{1}{\phi}$. When δ exceeds $\overline{\delta_1}$, $\lambda_k^{\{ij\}}$ is always zero. This result is illustrated in Figure 1.

A.1.4 When the network is a star network with two links

Suppose that BTAs are concluded between countries i and j and between countries j and k. Let i, j and k distinct.

As is the same procedure for A.1.2, we obtain the solution for the distribution of firms by,

$$\lambda_i^{\{ij.jk\}} = \lambda_k^{\{ij.jk\}} = \frac{1}{3}\frac{\phi+\delta^2\phi^2-3\delta\phi+1}{(1-\delta\phi)(1-\phi(2\delta-1))} < \lambda_j^{\{ij.jk\}}$$
$$\lambda_j^{\{ij.jk\}} = \frac{1}{3}\frac{\phi+4\delta^2\phi^2-3\delta\phi-3\delta\phi^2+1}{(\delta\phi-1)(-\phi+2\delta\phi-1)}$$

Restriction in the parameter, $\delta\phi < 0$, allows us to keep the variable of interest in the reasonable range, $\lambda_r^g \in [0,1]$. We have the case such that $\lambda_i^{\{ij.jk\}} = \lambda_k^{\{ij.jk\}} = 0$ and $\lambda_j^{\{ij.jk\}} = 1$. The critical value for this corner solution is $\frac{3-\sqrt{5-4\phi}}{2\phi} \equiv \overline{\delta_2} \leq \delta < \frac{1}{\phi}$. When δ exceeds $\overline{\delta_2}$ in the possible range, $\lambda_i^{\{ij.jk\}}$ and $\lambda_k^{\{ij.jk\}}$ are always zero. This result is illustrated in Figure 1.

A.2 Welfare

Using the above results, (12) and (13), we obtain welfare and decision criteria for each country at each phase as in Table 1 and 2. The conditions listed in the table indicate that $\lambda_k^{\{ij\}} = 0$ when $\overline{\delta_1} \leq \delta < \frac{1}{\phi}$ and $\lambda_j^{\{ij,jk\}} = 1$ when $\overline{\delta_2} \leq \delta < \frac{1}{\phi}$, which is obtained in Appendix A.1.

	W_r^ϕ	$W_r^{\{ij\}}$		$W_r^{\{ij,jk\}}$		$W_r^{\{ij,jk,ki\}}$
$r = i$	$\frac{1+2\phi}{3}$	$\frac{1+\delta\phi}{2}$	when $\lambda_k^{\{ij\}} = 0$	$\delta\phi$	when $\lambda_j^{\{ij,jk\}} = 1$	$\frac{1+2\delta\phi}{3}$
		$\frac{\delta\phi+1-2\phi^2}{3(1-\phi)}$	otherwise	$\frac{1+\phi-2\delta^2\phi^2}{3(1-\delta\phi)}$	otherwise	
$r = j$	$\frac{1+2\phi}{3}$	$\frac{1+\delta\phi}{2}$	when $\lambda_k^{\{ij\}} = 0$	1	when $\lambda_j^{\{ij,jk\}} = 1$	$\frac{1+2\delta\phi}{3}$
		$\frac{\delta\phi+1-2\phi^2}{3(1-\phi)}$	otherwise	$\frac{2\delta^2\phi^2-1-\phi}{3(2\delta\phi-1-\phi)}$	otherwise	
$r = k$	$\frac{1+2\phi}{3}$	ϕ	when $\lambda_k^{\{ij\}} = 0$	$\delta\phi$	when $\lambda_j^{\{ij,jk\}} = 1$	$\frac{1+2\delta\phi}{3}$
		$\frac{\delta\phi+1-2\phi^2}{3(\delta\phi+1-2\phi)}$	otherwise	$\frac{1+\phi-2\delta^2\phi^2}{3(1-\delta\phi)}$	otherwise	

Table 1: Welfare of three countries

	$D_r^{\phi+ij}$	$D_r^{\{ij\}+jk}$	$D_r^{\{ij,jk\}+ki}$	D_r^{13}
$r=i$	$\frac{3\delta\phi+1-4\phi}{2(2\phi+1)}>0$ when $\lambda_C^1=0$ $\frac{(\delta-1)\phi}{(2\phi+1)(1-\phi)}>0$ otherwise	$-\frac{1-\delta\phi}{1+\delta\phi}<0$ when $\lambda_C^1=0$ and $\lambda_B^2=1$ $\frac{2\phi^2-3\delta\phi^2+2\delta\phi-1}{\delta\phi+1-2\phi^2}<0$ when $\lambda_B^2=1$ $\frac{2\phi-\delta^2\phi^2-1}{3(1-\delta\phi)(\delta\phi+1)}<0$ when $\lambda_C^1=0$ $-\frac{\phi^2(\delta-1)(\delta(1-\phi)+1-\delta\phi)}{(1-\delta\phi)\left(\delta\phi+1-2\phi^2\right)}<0$ otherwise	$\frac{1}{3}\frac{1-\delta\phi}{\delta\phi}>0$ when $\lambda_C^1=0$ and $\lambda_B^2=1$ $\frac{1}{3}\frac{1-\delta\phi}{\delta\phi}>0$ when $\lambda_B^2=1$ $\frac{(\delta-1)\phi}{\phi-2\delta^2\phi^2+1}>0$ when $\lambda_C^1=0$ $\frac{(\delta-1)\phi}{\phi-2\delta^2\phi^2+1}>0$ otherwise	$-\frac{1-\delta\phi}{3(1+\delta\phi)}<0$ when $\lambda_C^1=0$ $\frac{2\phi\left(\frac{1}{2}-\phi\right)(\delta-1)}{1+\delta\phi-2\phi^2}$ otherwise
$r=j$	$\frac{3\delta\phi+1-4\phi}{2(2\phi+1)}>0$ when $\lambda_C^1=0$ $\frac{(\delta-1)\phi}{(2\phi+1)(1-\phi)}>0$ otherwise	$\frac{1-\delta\phi}{1+\delta\phi}>0$ when $\lambda_C^1=0$ and $\lambda_B^2=1$ $\frac{3\phi-2\phi^2+\delta\phi-2}{2\phi^2-\delta\phi-1}>0$ when $\lambda_B^2=1$ $-\frac{1}{3}\frac{-\phi+2\delta^2\phi^2+3\delta\phi-3\delta\phi^2-1}{(-\phi+2\delta\phi-1)(\delta\phi+1)}>0$ when $\lambda_C^1=0$ $\phi\left(\delta-1\right)\frac{\phi+2\phi^2-2\delta\phi^2-1}{(-\phi+2\delta\phi-1)\left(-2\phi^2+\delta\phi+1\right)}>0$ otherwise	$-\frac{2(1-\delta\phi)}{3}<0$ when $\lambda_C^1=0$ and $\lambda_B^2=1$ $-\frac{2(1-\delta\phi)}{3}<0$ when $\lambda_B^2=1$ $\frac{2\delta\phi^2(\delta-1)}{-\phi+2\delta^2\phi^2-1}<0$ when $\lambda_C^1=0$ $\frac{2\delta\phi^2(\delta-1)}{-\phi+2\delta^2\phi^2-1}<0$ otherwise	$-\frac{1-\delta\phi}{3(1+\delta\phi)}<0$ when $\lambda_C^1=0$ $\frac{2\phi\left(\frac{1}{2}-\phi\right)(\delta-1)}{1+\delta\phi-2\phi^2}$ otherwise
$r=k$	$-\frac{1-\phi}{2\phi+1}<0$ when $\lambda_C^1=0$ $-\frac{2\phi^2(\delta-1)}{(2\phi+1)(-2\phi+\delta\phi+1)}<0$ otherwise	$\delta-1>0$ when $\lambda_C^1=0$ and $\lambda_B^2=1$ $\frac{2\phi^2+3\delta^2\phi^2+2\delta\phi-6\delta\phi^2-1}{-2\phi^2+\delta\phi+1}>0$ when $\lambda_B^2=1$ $\frac{1}{3}\frac{2\phi+2\delta^2\phi^2-3\delta\phi^2-1}{\phi(\delta\phi-1)}>0$ when $\lambda_C^1=0$ $\phi\left(\delta-1\right)\frac{2\delta^2\phi^2+\delta\phi-2\delta\phi^2-1}{(\delta\phi-1)\left(-2\phi^2+\delta\phi+1\right)}>0$ otherwise	$\frac{1}{3}\frac{1-\delta\phi}{\delta\phi}>0$ when $\lambda_C^1=0$ and $\lambda_B^2=1$ $\frac{1}{3}\frac{1-\delta\phi}{\delta\phi}>0$ when $\lambda_B^2=1$ $\frac{(\delta-1)\phi}{\phi-2\delta^2\phi^2+1}>0$ when $\lambda_C^1=0$ $\frac{(\delta-1)\phi}{\phi-2\delta^2\phi^2+1}>0$ otherwise	$\delta-1+\frac{1-\delta\phi}{3\phi}>0$ when $\lambda_C^1=0$ $\frac{2\phi(\delta-1)(1-\phi+\delta\phi)}{1+\delta\phi-2\phi^2}>0$ otherwise

Table 2: Decision criteria for BTA

Appendix B

B.1 The proof of Proposition 1

Proof. We check the condition to form a link at each conference:

Conference AB $D_A^{\phi+AB} > 0$ and $D_B^{\phi+AB} > 0$, so $\delta > 1$. Therefore countries A and B always link together.

Conference BC By the result of Conference AB, the *en route* network Conference BC faces is $\{AB\}$. In any case, $D_B^{\{AB\}+BC} > 0$ and $D_C^{\{AB\}+BC} > 0$ always hold. Therefore countries B and C always link together.

Conference CA By the result of Conference AB and Conference CA, the *en route* network Conference CA faces is $\{AB, BC\}$. In any case, $D_C^{\{AB,BC\}+CA} > 0$ and $D_A^{\{AB,BC\}+CA} > 0$ always hold. Therefore countries C and A always link together.

Finally, the outcome network of $\Gamma_M(\phi, \delta)$ is always complete. ■

B.2 The proof of Proposition 2

Proof. We solve by backward induction. Note that for any distinct i, j and k, $D_i^{\phi+\{ij\}} > 0$, $D_i^{\{jk\}+ij} > 0$, $D_j^{\{jk\}+ij} > 0$ and $D_i^{\{ij,jk\}+ki} > 0$.

Conference CA In any case, $D_C^{\phi+CA} > 0$ and $D_A^{\phi+CA} > 0$, $D_C^{\{AB\}+CA} > 0$ and $D_A^{\{AB\}+CA}$, $D_C^{\{BC\}+CA} > 0$ and $D_A^{\{BC\}+CA} > 0$ and, $D_C^{\{AB,BC\}+CA} > 0$ and $D_A^{\{AB,BC\}+CA} > 0$. Therefore for any *en route* network, countries C and A always link together.

Conference BC Conference BC consider the strategy of Conference CA. When the *en route* network Conference BC faces is ϕ, the outcome network is $\{BC, CA\}$ if countries B and C conclude a BTA, and $\{CA\}$ if not. Since $D_B^{\{CA\}\{BC,CA\}} =$

$D_B^{\{CA\}+BC} > 0$ and $D_C^{\{CA\}\{BC,CA\}} = D_C^{\{CA\}+BC} > 0$ in any case, countries B and C decide to link together. When the *en route* network Conference BC faces is $\{AB\}$, the outcome network is $\{AB, BC, CA\}$ if countries B and C conclude a BTA, and $\{AB, CA\}$ if not. Since $D_B^{\{AB,CA\}\{AB,BC,CA\}} = D_B^{\{AB,CA\}+BC} > 0$ and $D_C^{\{AB,CA\}\{AB,BC,CA\}} = D_C^{\{CA\}+BC} > 0$ in any case, countries B and C decide to link together.

Conference AB Conference AB consider the strategies of Conference CA and Conference BC. Since the *en route* network Conference AB faces is ϕ, the outcome network is $\{AB, BC, CA\}$ if countries A and B conclude a BTA, and $\{BC, CA\}$ if not. Since $D_A^{\{BC,CA\}\{AB,BC,CA\}} = D_A^{\{BC,CA\}+AB} > 0$ and $D_B^{\{BC,CA\}\{AB,BC,CA\}} = D_B^{\{BC,CA\}+AB} > 0$ hold in any case, countries A and B decide to link together.

Finally, the outcome network of $\Gamma_F(\phi, \delta)$ is also always complete. $\blacksquare$