Preferenciating Global Free Trade: A coevolving network model of free trade negotiation*

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Abstract

This study develops a generalized coevolving network model to explain the evolution of multilateral free trade negotiation and the conditions under which a global FTA is most likely to emerge. Our formal and simulation analyses suggest that without having to forgo existing multilateral framework, countries, particularly leading countries, can maximize cooperation in the network toward the achievement of a global FTA through two different mechanisms. First, states can adopt the strategies of their partners that accrue higher accumulated payoffs from the interaction with immediate neighbors. On the other hand, cooperative countries can bypass defecting type partners and switch to more profitable partners to negotiate FTA. The payoffs accumulated through this partner-switching strategy can induce defecting-type partners to cooperate. Thus, a global FTA can be achieved when smaller, more exclusive free trade pacts are allowed to flourish. The application of approximate master equations (AMEs) introduced in this paper also provides more accurate estimation of the time evolution of network. Our more brief discussion of recent FTA cases that owe their origins to small cohesive networks lends additional empirical support to the model.

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1 Introduction

After over a decade's impasse, the long-stalled Doha Development Round (DDR)—the World Trade Organization (WTO) program of multilateral trade talk that commenced in 2001—was presumably pronounced ineffectual by leading member states. Bemoaning the Doha Round's failure to deliver, Michael Froman, the U.S. Trade Representative, in particular, suggested that, "[I]t is time for the world to free itself of the strictures of Doha."[1]

Meanwhile, amidst this multilateralism setback, rose the push for large regional and sectoral trade agreements. Indeed, more and more WTO members have engaged in new waves of free trade negotiations with selected partners to enhance bilateral or regional trade relations. The last decade witnessed the flourishing of preferential trade agreements (PTAs): from the sealing of the Free Trade Area of the Americas (FTAA) in 2005 extending the momentum of the North American Free Trade Agreement (NAFTA) to the closely knit Latin American continent to the signing of the China-Australia Free Trade Agreement (ChAFTA) in 2015 bringing closer the two culturally heterogeneous trading partners across the sparse water of the South Pacific. The Trans-Pacific Partnership (TPP), the U.S. twelve-country trade agreement concluded in January 2016, can be seen as the latest PTA offensive on the WTO pillar of multilateralism. The EU, on the other hand, is pioneering a series of sectoral talks centered on reaching a stand-alone plurilateral Trade in Services Agreement (TiSA) to boost liberalization of the global services sector amongst its members and *willing* WTO members, essentially circumventing the DDR deadlock (European Union, 2013). These initiatives appear to have relegated the DDR to the backseat in a changing global economy.

However, the bifurcated path leading to PTA needs not block the road to a global free trade agreement (FTA), such as the DDR. In fact, by anchoring plurilateral pacts among a smaller group of more homogeneous members, PTA can be an important mechanism through which a global FTA is achieved.

Current academic perspectives are divided over the "stumbling blocs" or the "building blocs" effect of PTA on the emergence of global free trade. Proponents of the first view concerns the static welfare gains from PTAs reduce members' incentives to pursue further trade liberalization (Bhagwati, 1991, 1993; Krishna, 1998). Hence, exclusive trade blocs are detrimental to the attainment of global FTA that maximizes the welfare of all participating countries. The second view contends that the deepening of integration among a subset of countries increases the benefits of PTAs that induces outside countries to seek accession, and as membership expands, a global FTA is achieved (Baldwin, 1996); this later claim is matched by empirical scholarships showing that preferential reduction of tariffs are positively associated with the reduction in most-favored nation (MFN) tariffs in the same sectors (Estevadeordal, Freund and Ornelas, 2008; Baldwin and Seghezza, 2010). Recent formal literature has distinguished sequential from simultaneous approach to multilateral FTA negotiation and underlines the ability of leading countries to transfer utility as the key to the success of global FTA (Aghion, Antràs and Helpman, 2007).

[1] Michael Froman. "We are at the end of the line on the Doha Round of trade talks." *Financial Times*, 13th Dec. 2015.

Proceeding along the same line of inquiry, this study develops a generalized node-based coevolving network model of free trade negotiation. Specifically, we seek to clarify the microfoundation underlying states' incentives to establish PTAs with particular types of partners and the conditions under which such process can promote the attainment of global FTA.

Previous analysts have argued that factors like geography (Ludema, 2002; Baier and Bergstrand, 2007), existing trade linkages (Moser and Rose, 2014), and low market access (Amiti and Romalis, 2006; Gallagher, 2008) explain why the proliferation of PTAs enhances trade relations only among industrialized countries but hinders the prospect for global FTAs. Our model builds, in part, on this widely-acknowledged coalition preference. Yet, we argue that, without having to forgo pending multilateral trade talks, leading countries can promote the attainment of global FTA through prioritizing the formation of trade links with selected group of partners. The payoff accumulated from forming exclusive trade blocs can induce initial defectors to cooperate and thereby become the "building block" for resuming stalled global trade talk. Hence, a global FTA can be achieved when more exclusive trade blocs are allowed to flourish.

Our approach follows Hauert and Szabó (2005) and Fu, Wu and Wang (2009), where any randomly picked pair of countries from a network of N countries engage in a prisoner's dilemma (PD) game with each other over an infinite horizon, and a link (representing a free trade pact) is formed between the pair with some probabilities. Yet, we depart from static network models of FTA formation where the resulting networks are pairwise stable (e.g., Goyal and Joshi 2006) by allowing countries to update their strategies in each period conditional on their payoffs and that of their immediate neighbors. In addition, we also allow for different levels of rewiring—a mechanism we term "partner-switching"—for discordant edges. This mechanism allows cooperative type countries to unilaterally dismiss their defecting counterparts in the pairs at the beginning of each new period and randomly connect to another cooperative type partners from the remaining population. By bypassing defecting countries and rewiring to collaborative partners, the increasing aggregate payoff accruing to cooperation can induce more initially defecting type countries to alter their types when the probability and the cost of being left out are sufficiently large. As this cooperative network expands over time, a global FTA is likely to emerge.

This study contributes to the political economy literature of FTA formation by supplying a dynamic theoretical framework rendering the relationship between preferential trade blocs and global free trade, in which both the free trade network and its participants' strategies evolve over time. Our model not only reconciles the debate between states' incentives to form PTAs with selected partners and the long-term goal of achieving a global FTA that multilateral institutions (such as the WTO) are designed to deliver, but also clarifies the evolution of multilateral trade negotiation—from its stalemate, the spread of bilateral and regional PTAs, and its eventual resumption—and suggests the conditions under which a global FTA can be achieved.

The main methodological contributions is to approximate the time evolution of the network with approximate master equations (AME). The AME method (Marceau et al., 2010; Gleeson, 2011, 2013) considers the states of nodes, node degree, and the states of the central nodes, generating large systems of ordinary differential equations (ODEs) to provide a more accurate approximation of the evolution of networks around critical points of the dynamics. The Monte Carlo simulation result shows that the AME method outperforms existing pair approximation (PA) and mean field (MF) approaches in both static and coevolving networks.

The rest of this work is organized as follows. In Section 2, we describe the structure, parameter space, and the sequence of events of our theoretical model, followed by an analysis. Section 3 introduces the AME method, derives the ODEs for time evolution of each strategy compartment, and perform Monte Carlo simulation 4. Our more brief discussion of recent PTA experiences in Section 5 provides additional empirical support to the model. Section 6 concludes with a discussion of the generality and the limitations of the model developed in this study.

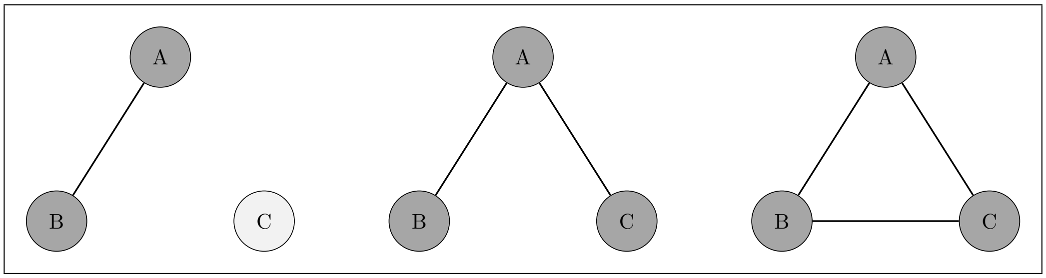
2 From PTA to global FTA: a coevolving network model of free trade negotiation

We consider a free trade network of N member countries under an existing multilateral free trade framework agreement whose goal is the removal or reduction of all trade and non-trade barriers to facilitate free exchange of goods and services among members.[2] We allow each country to establish free trade pact with any partners from the pool of $N-1$ countries in the network to maximize its payoff in a given period t.[3] This setup does not preclude the possibility of the formation of multilateral FTA consists of $n \geq 2$ countries (in the latter case, only bilateral PTAs can exist), which is illustrated in Figure 1. In the left panel of Figure 1 country A establishes a bilateral PTA with country B but leaves out country C, whereas in the middle panel country A forms PTAs with both country B and C. All three country pairs ({A, B}, {A, C}, {B, C}) in the right panel are connected through bilateral PTAs. The network displayed in the middle panel can be interpreted as a trilateral PTA centered on country A, while the right panel depicts a trilateral FTA among country {A, B, C}. Other $n \geq 3$ cases are simply extensions of Figure 1.

[2] Here, we refer to an international framework agreement (*accord cadre*) as an agreement on all relevant matters between parties, by which disputed parties can refer to as the basis for the jurisdiction and the seisin for the International Court of Justice (ICJ; Statute of the International Court of Justice (1945) Article 36). An international trade framework agreement, such as the WTO, is an agreement on (but not limited to) trade, services, intellectual property rights, government procurement, and investment among member countries. Under a multilateral trade framework agreement, a member may not reach a final agreement on all issue areas with all other members and would therefore request settlements by the ICJ or have the incentive to establish PTAs with only a subset of member countries. The two defining principles of the WTO, namely the most-favored-nation (MFN) rule (i.e., non-discrimination) and reciprocity, create an incentive for members to negotiate PTAs outside of the existing multilateral framework that will erode the welfare of nonparticipating countries (Bagwell and Staiger, 2002, 2004).

[3] For simplicity, we assume N is fixed. We do not consider situations in which countries continuously accede to or exit the free trade network.

Figure 1: Types of free trade network formation



Note: Countries connected by bilateral PTA are marked in dark gray. The left panel shows a bilateral PTA between country A and B. The middle panel shows a trilateral PTA centered on country A. The right panel can be regarded as symmetric trilateral (or regional) free trade network among country A, B, and C.

We now anchor our analysis on a repeated prisoner's dilemma (PD) game setting. First, let the free trade network be an Erdős-Rényi-type network, where any random graphs (here in this study, a "graph" refers to a "network topology") of N nodes (i.e., countries) with a fixed number of M edges have equal probability to realize (Erdős and Rényi, 1959), such that the realized network is the combination of pairwise choice probabilities taken by all country pairs. We initialize each country to have equal probability of being a cooperator (C) or a defector (D), where $\{C,\ D\} \to s = [0,\ 1]^T$, on one end of each edge and engage in pairwise interaction with partners drawn from its immediate neighbors. In each period, a random country i forms (or rejects) a free trade link with its n partners and, conditional on its type $\{C,\ D\}$, obtains a payoff

$$P_i = \sum_{j \in n_i} s_i^T P s_j,\ \forall\ i \neq j, \tag{1}$$

where n_i is the neighborhood set of country i and P denotes the 2 by 2 payoff matrix

Any $j \in n_i$

i	C	D
C	1 (to i), 1 (to j)	0 (to i), $1+u$ (to j)
D	$1+u$ (to i), 0 (to j)	u (to i), u (to j)

(2)

where the payoffs to i (j) are listed in the lower left (upper right) corner of each cell, and u is a single parameter cost-to-benefit ratio normalized between 0 and 1. Expression (2) is reduced to a symmetric PD game of payoff

$$i(j) \text{ being} \begin{cases} \text{C} & 0.5 \times 1 + (1 - 0.5) \times 0 = 0.5 \\ \text{D} & 0.5 \times (1 + u) + (1 - 0.5) \times u = 0.5 + u. \end{cases}$$

It is clear that defectors may receive more payoff than cooperators since $u \in (0, 1)$, but the accumulated payoff accrues to country i is conditional on the number of immediate neighbors and the parameter value of u given by (1).

We now describe the sequence of moves and focus on the time evolution of C-D pairs as its dynamics is controlled by n_i and u parameters. In each time period t, a discordant edge connecting a pair of countries (i, j) with different strategies, denoted by E_{ij}, is randomly picked. With probability w, country i and j connected by edge E_{ij} update their strategies; otherwise, E_{ij} is rewired with probability $1 - w$.

When country i updates its strategy, it has the probability ϕ—given by the Fermi function (Hauert and Szabó, 2005)—to change its state

$$\phi(s_i \to s_j) = \frac{1}{1 + \exp[\beta(P_i - P_j)]}, \tag{3}$$

where β represents the intensity of "state selection" with $\beta \to 0$ leads to random drift and $\beta \to \infty$ leads to the deterministic imitation dynamics. (3) thus captures a spontaneous Markovian process.

One can think of the exponential expression in the denominator term on the right-hand-side of (3) as comparing the accumulated payoff between country i and j that play different strategies. The probability $\phi(s_i \to s_j)$ that country i replaces its strategy with that of country j is increasing in $P_j > P_i$; correspondingly, the probability that country j's strategy being replaced by that of country i is $1 - \phi(s_i \to s_j)$ and increasing in $P_j < P_i$. This function characterizes the learning processes in multilateral FTA negotiation, in which potential partners imitate the "best practices" of existing members by locking in domestic trade liberalization reforms or, alternatively, existing members toughen their position to send signals to potential defectors (Aggarwal, 2006; Baldwin and Jaimovich, 2012).

Panel (a) of Figure 2 illustrates the calculation of ϕ numerically. Country i obtains an accumulated payoff, $P_i = 1$, from its interaction with immediate neighbors (given by expression (2)) evaluated at $u = 0.5$, compares it with country j's payoff, $P_j = 4$, and replaces its initial state with that of country j with probability

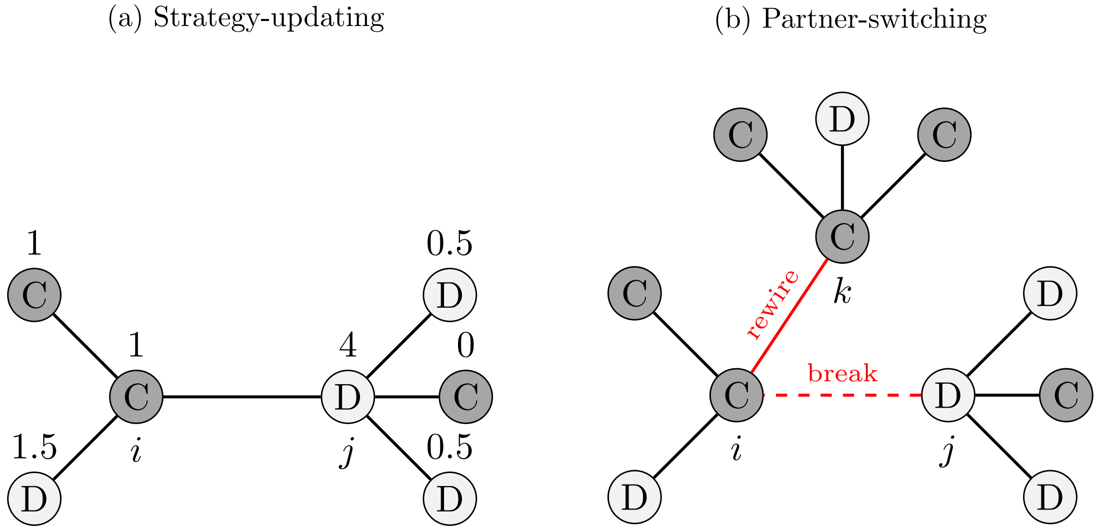
$$\phi(s_i \to s_j) = \frac{1}{1 + \exp[\beta(1 - 4)]}.$$ [4]

The probabilities of strategy-updating for all possible combinations of $\{n, u\}$ cases can be calculated in a similar fashion.

On the other hand, when the network is rewired (with probability $1 - w$), countries of cooperative type (C) unilaterally dismiss their defecting partners (D) and randomly pick another similarly cooperative type country k as its new partner from its neighborhood set to negotiate free trade. This is illustrated in Panel (b) of Figure 2, when the link is rewired, cooperative type country i dismisses its link with defecting partner j and approaches cooperative type country k as its new partner. The rewiring process stops

[4] Note:
$P_i = 0 \times 2$ (C-D link) $+ 1 \times 1$ (C-C link) $= 1$,
$P_j = 0.5 \times 2$ (D-D link) $+ 1.5 \times 2$ (D-C link) $= 4$.

Figure 2: Illustration: Strategy-updating and link rewiring in free trade network formation



Note: Cooperative (defecting) type nodes (countries) are marked in dark gray (white), u is set to 0.5. Panel (a) illustrates strategy-updating by country i using country j as reference unit, corresponding to expression (3). The accumulated payoff accrue to each country from its interaction with immediate neighbors is noted above each node. Panel (b) illustrates link rewiring in which cooperative country i breaks its link with defecting partner j and randomly pick another country k (of cooperative type) as its new partner for negotiating bilateral free trade link.

until there are no discordant edges in the network. This mechanism is most pertinently captured by the logic of PTA, by which leading countries sidestep the deadlocks of multilateral FTA negotiation by approaching willing members to negotiate PTAs, leading to the formation of PTA consists entirely of cooperative countries. Figure A in the Appendix visualizes the separation between the cooperative and defecting types during partner-switching before reaching stationary state.

To sum up, the density of FTA network within a country's immediate neighborhood depends on the relative share of its neighbors' types, the payoff of defecting, as well as its partner-switching intensity. When the "defecting type" constitutes the majority of a country's immediate neighbors and the payoff to defection (determined by u) is sufficiently large, cooperative countries actively adopt the strategies of their defecting partners, causing the defecting types to propagate and the growth of free trade network stalled. Alternatively, when the number of cooperative partners is relatively large and u is small, a dense FTA network is likely to emerge. On the other hand, when the probability of rewiring is high (i.e., w is small), meaning that cooperative countries more aggressively turn their FTA tentacles toward same type of partners, the FTA network may also expand even in the presence of large number of defecting partners and high values of u.

More importantly, from the longitudinal perspective, local dynamics can influence the evolution of the network (Gross and Blasius, 2008), as with most real-world networks, such as the WTO. For example, a more intense partner-switching or greater shares of cooperative type nodes in a local (say, regional) network can impart a "building block" effect that promote the attainment of global FTA, while a higher shares of defecting type and/or high values of u work against this goal. The next section introduces our approach, the approximate master equations (AME), for approximating the time evolution of the network. We evaluate its performance via Monte Carlo simulation across the range of parameter values and compare the result with other existing methods.

3 Network approximation and approximate master equations

Analysts have developed many different approaches to approximate the time evolution of regular and random networks with game theoretical applications. Among them, the mean field (MF) theory exploits the large number properties of statistical mechanics by assuming the effect of interaction in a large and complex system can be approximated by a single averaged effect based on agents' optimal strategies (Lasry and Lions, 2007; Weintraub, Benkard and Roy, 2008; Yin et al., 2012; Adlakha and Johari, 2013). The pair approximation (PA) method, originally introduced for ecological models by Matsuda et al. (1992), is an extension of the MF theory supplemented by approximate equations for the frequencies of pairs of each possible type defined by the network. Dickman (1988, 1990) later extend the PA method to study dynamic models.

These methods have generated many important insights on the dynamics of network evolution, but they also carry some limitations. First, the MF theory does not take into account the correlations in the state of indirect neighbors (Givan et al., 2011) and topology, and since it is only an averaged approximation, it is very sensitive to small perturbation of parameter values commonly observed in the time evolution of networks. Second, the PA method is a moment closure that considers additional information of the frequencies of bounded (i.e., C-C link) and unbounded (i.e., D-D link) pairs, but, as with the MF theory, it assumes the states of neighboring pairs have little or no effects on local density (Thomson and Ellner, 2003; Gleeson, 2013).

Since our coevolving network model posits that nodes in a local network actively compare their payoffs with all partners as the basis for strategy-updating and rewiring, we need an approximation method that takes into account the states of nodes, node degree, and the states of the central nodes *for each node*, such that the strategy-updating decision described in expression (3) and the rewiring process conceptualized in Panel (b) of Figure 2 can be faithfully implemented.

The accuracy of both the MF and the PA methods rely on ordinary differential equations (ODEs), which approximate the evolution of the networks as a function of time. The MF approximation uses a single ODE to obtain the average number of cooperative nodes in each time step. The PA method adds two additional ODEs to derive the marginal changes in the number of C-C and D-D pairs with respect to time. The intuition is to use fewer specifications to extract as much information about the networks, but the accuracy of the approximation may also suffer as a result.

One feasible solution to improve the accuracy of the ODEs is to estimate a correction parameter from lattice simulations (Satō, Matsuda and Sasaki, 1994); however, this approach removes the ODE's efficiency advantage as an approximation method. An alternative approach that retains the ODE's efficiency at capturing the node-edge relationship at some cost of computational complexity is to specify a large system of ODEs for each node and discordant pair that susceptible to partner-switching, taking into account the propensity for rewiring, $1 - w$.

We follow Gleeson's (2013) ISI (Susceptible-Infected-Susceptible) model by defining a state transition matrix for the C and D compartments for a network of degree k with l number of defecting nodes

$$\begin{array}{r} \\ C \text{ compartment} \\ D \text{ compartment} \end{array} \begin{array}{c} \qquad C \rightarrow D \qquad\qquad\qquad D \rightarrow C \\ \left[\begin{array}{cc} \frac{\sum_{k,l}(k-l)lC_{k,l}}{\sum_{k,l}(k-l)C_{k,l}} = \beta^C & \frac{\sum_{k,l} l^2 C_{k,l}}{\sum_{k,l} lC_{k,l}} = \gamma^C \\ \frac{\sum_{k,l}(k-l)^2 D_{k,l}}{\sum_{k,l}(k-l)D_{k,l}} = \beta^D & \frac{\sum_{k,l} l^2 D_{k,l}}{\sum_{k,l} lD_{k,l}} = \gamma^D \end{array} \right], \end{array} \tag{4}$$

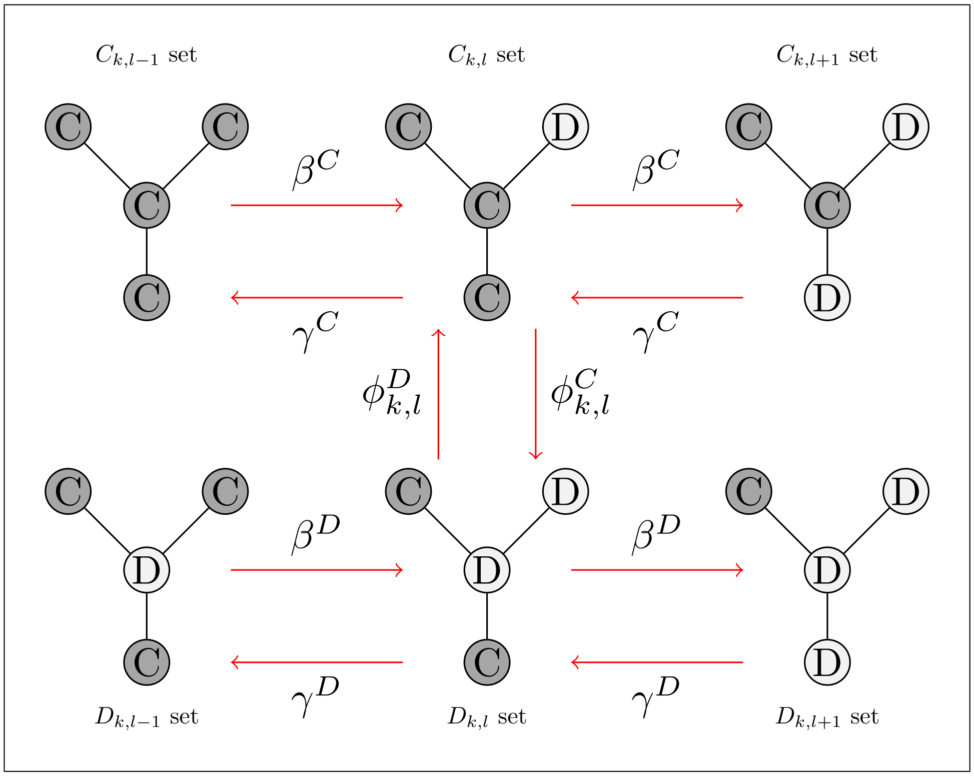
where β^C, γ^C, β^D, and γ^D denote the respective probability of one cooperative (defecting) type neighbor of a central node (of type C (D)) changes its type by way of the Markovian process.[5] It is worth noting that the numerator and the denominator terms in each of the four cells are the second and the first order moments of the C_{kl} and D_{kl} sets, respectively, so the four parameters measure the relative dispersion of the probability distribution for each of the four possible strategy-updating scenarios. The transition paths associated with each parameter for the C and D compartments are illustrated graphically in Figure 3.

The time evolution of cooperative and defecting compartments of the network of degree k and l number of defecting neighbors, $C_{kl}(t)$ and $D_{kl}(t)$, per time period t can be approximated by a master equation of k^2 number of ODEs for the C compartment.

$$\left.\begin{aligned} \frac{dC_{kl}}{dt} = w \{ & \phi^D_{k,l}(k-l)D_{k,l} - \phi^C_{k,l} lC_{k,l} \\ & + \phi^C_{k,l+1}\gamma^C(l+1)C_{k,l+1} - \phi^C_{k,l}\gamma^C lC_{k,l} \\ & + \phi^C_{k,l-1}\beta^C(k-l+1)C_{k,l-1} - \phi^C_{k,l}\beta^C(k-l)C_{k,l} \} \end{aligned}\right\} \text{Strategy-updating}$$
$$\left.\begin{aligned} & + (1-w)\left\{ \frac{N_C}{N}\left[(l+1)C_{k,l+1} - lC_{k,l}\right] \right. \\ & \left. + \frac{N_{CD}}{N}\left[C_{k-1,l} - C_{k,l}\right] \right\}, \end{aligned}\right\} \text{Partner-switching} \tag{5}$$

[5] A local network with a central node of cooperative (defecting) type belongs to the C (D) compartment.

Figure 3: Graphical illustration of transitions to/from the C_{kl} and D_{kl} sets in the AME



Note: The number of neighbors shown for each set are not exact, they are shown only for illustration purpose. Set classes are noted in the superscripts.

We explain each term in (5) as follows. The first three lines in the big curly brackets after w list all possible comparisons that a cooperative type node (country) references when deciding whether to update its strategy with probability w.[6] The first line says a cooperative type central node of k degree and l defecting neighbors $C_{k,l}$ compares its current payoff to that of itself playing defecting strategy (i.e., being defecting type) surrounded by $k-1$ cooperative type neighbors ($D_{k,l}$). The second line says this cooperative type central node compares the change in its payoff when one of its defecting neighbors changes type, adding one node to the $D \to C$ state transition probability γ^C. Similarly, the third line says the same cooperative central node compares the change in its payoff when one of its cooperative neighbors becomes defecting type, adding one node to the $C \to D$ state transition probability β^C.

The last two lines in the big curly brackets after $(1-w)$ describe this cooperative type node's partner-switching consideration. The first line measures the change in country i's payoff as a result of rewiring to one of the $\frac{N_C}{N}$ share of cooperative type nodes in the network. The second line measures change in country i's payoff when it breaks from one of the $\frac{N_{CD}}{N}$ share of discordant edges in the network.

The ODE for the time evolution of the D set can be written analogously

[6] The definitions of w and ϕ are given in section 2 and in expression (3), respectively.

$$\frac{dD_{kl}}{dt} = w\left\{-\phi^D_{k,l}(k-l)D_{k,l} + \phi^C_{k,l}lC_{k,l}\right.$$
$$+ \phi^D_{k,l+1}\gamma^D(l+1)C_{k,l+1} - \phi^D_{k,l}\gamma^D lC_{k,l}$$
$$\left.+ \phi^D_{k,l-1}\beta^D(k-l+1)C_{k,l-1} - \phi^D_{k,l}\beta^D(k-l)C_{k,l}\right\}$$
$$+ (1-w)\left[(k-l+1)D_{k+1,l} - (k-l)D_{k,l}\right]$$
$$\left.+ \frac{N_{CD}}{N}\left[D_{k-1,l} - D_{k,l}\right]\right\}, \tag{6}$$

with the same interpretation as (5).

Finally, we calculate (5) and (6) for all central nodes in the network, generating a total of k^2 ODEs.

The transition process and the calculation of transition parameters are further explained in the Appendix.

3.1 Monte Carlo simulation

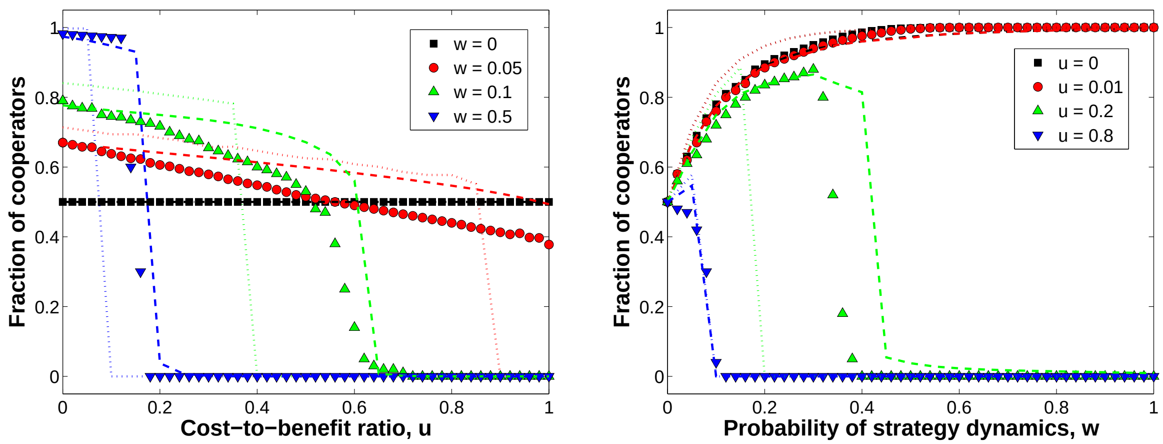
We turn to Monte Carlo simulation to evaluate the evolution of the proposed coevolving network model of FTA formation across the range of parameter values of u and w using both the AME and PA methods. We first initialize a random graph containing 1000 isolated nodes, assign equal probability to all graphs of exactly 5000 edges with an average degree $k = 10$, and fix the imitation parameter β at 30. We operationalize the level of cooperation by the parameter $\rho \in (0, 1)$, which measures the fraction of cooperators in the network, as a function of u and w for their marginal effects on (5) and (6), holding other things constant. Finally, we initialize ρ at 0.5 since we have no *a priori* reasons to expect this network to contain more cooperative nodes than defecting ones.

We then perform Monte Carlo simulation. In each time period (t), we fix w at a given value $\in (0, 1)$ and vary u across 0 to 1, a network is generated by the Erdős-Rényi random graph model from 1000 nodes and 5000 edges. We do the same for u. The process stops until there are no discordant edges or when t reaches 1000. We perform 1000 simulated runs for each u and w per time period by the AME and PA methods and average over these 1000 simulations to get a mean estimate for ρ at a unique $\{u, w\}$. The result is plotted in Figure 4 where each dot represents the average of 1000 simulations.[7]

Panel (a) of Figure 4 shows the time evolution of the network as a function of the cost-to-benefit ratio, u. One caveat is that because w is set to constant, the effect of marginal change in u on ρ captures only the "strategy-updating" dynamics but not "partner-switching," which is aligned with the specifications of the model developed in Section 2. Nevertheless, the implications of the result shown in Panel (a) are straight-

[7] To solve the large system of ODEs, we use the ode45 solver in `MATLAB` until the solutions converge to a steady state.

Figure 4: Fraction of cooperators simulated across the range of u and w using PA and AME methods.



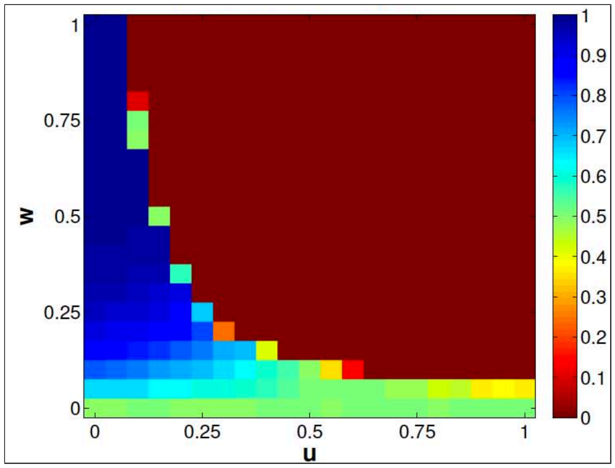
(a) u: cost-to-benefit ratio (b) w: probability of strategy dynamics

Note: Each dot represents the average of 100 simulation results. Symbols for the *true* parameter values are labelled in the legend. Simulation results using PA (AME) are marked by dotted (dashed) lines.

forward. First, higher cost-to-benefit ratio, u, reduces the fraction of cooperators in the network. Although greater probability of strategy-updating (w) is associated with higher initial fraction of cooperators (ρ), at more aggressive levels of strategy-updating ρ declines at a much faster rate as u increases. This is so because a cooperative central node updates its strategy by comparing its payoff with that of its immediate neighbors', and as cooperation becomes more costly, cooperative central nodes have greater incentive to adopt the strategies of their defecting neighbors, which causes ρ to decrease. This explains why multilateral free trade negotiations often stall when the MFN and reciprocity rules are too costly for members to uphold, and leading countries eventually cease to be cooperative for fear of being free-ridden on. Secondly, the simulation results evaluated at different w all exhibit the same monotonically decreasing pattern, but the AME method (dashed lines) outperforms the PA method (dotted lines) in fitting the *true* values of ρ at every level of w across the range of u.

We then look at Panel (b) that shows the competing effects of u and w on the levels of cooperation. When the cost of cooperation (u) is low, the fraction of cooperators increases dramatically at lower levels of w (until around $w = 0.45$) within which "partner-switching" is more likely to occur (with probability $1 - w$), but then falls flat as the probability of "strategy-updating" (w) increases. Yet, when the cost of cooperation becomes extremely high, even initially cooperative nodes may be motivated to change their types at lower levels of w—causing ρ to fall rather quickly—where rewiring to cooperative nodes is expected to occur at greater probability. This is illustrated in the blue dashed line with triangles ($u = 0.8$). In addition, the AME method once again provides better fit to the true values of ρ than the PA method. The empirical implication of this analytical result

Figure 5: Simulation result of ρ corresponding to each unique combination of $\{u, w\}$.



Note: u and w increase by the gradient of 0.05 per pixel. The value in each pixel represents the average of 50 simulated runs.

is that higher probability of partner-switching can overcome the initial hurdle of finding cooperative partners in multilateral free trade negotiation and therefore help promote the attainment of global FTA when the cost of cooperation (or, alternatively, the payoff to defection) is relatively low.

For a better visual presentation of the simulation result across the full range of parameter values, Figure 5 plots a heat map to map each unique combination of $\{u, w\}$ at the gradient of 0.05 per pixel to their corresponding simulated ρ obtained above. It shows that the level of cooperation is very sensitive to marginal increase in u: there are high levels of cooperation at extremely small u, but defecting type soon begins to dominate the network as u increases beyond 0.2. On the other hand, when w is close to 0, there exists medium levels of cooperation regardless of the value of u. Yet, as w increases, it needs to be coupled with small u in order to maintain higher levels of cooperation ($\rho \geq 0.5$) in the network.

Our analysis in this section assesses the effects of the two strategy mechanisms on the levels of cooperation in a free trade network. Building on this simulation evidence, in the next section, we turn to three case studies to probe the extent to which the mechanisms we elaborate here have helped to produce the observed FTA formation.

4 Evidences from recent FTAs

Building on the analytical results presented in previous sections, we turn our analytical lens to three recent FTA cases not only to assess the predictive power of our model in the empirical world but also, importantly, to describe how the mechanisms of strategy-updating and partner-switching influence FTA formation over time and at different levels.

Our first case, the TiSA, supports the validity of "partner-switching" that leading countries switch to more cooperative partners to maximize cooperation in specific issue area. Secondly, the TPP deal is consistent with the observable implications of link properties that leading countries attach different priorities to different partners in the negotiation of this very exclusive regional FTA. Finally, the expansion of South Korea's FTA network, the most ambitious free trade initiative by a single country in recent decades, tells the story of a trade-oriented economy constantly switching around highly profitable partners to negotiate FTAs and adopt their strategies with a view to maximizing trade and investments.

4.1 TiSA

The TiSA owes its origin to the stalemate of the negotiation on the General Agreement on Trade in Services (GATS) of the DDR. Like its counterpart in merchandise trade, the GATS aims to create an international framework agreement to liberalize and promote trade in services—which now accounts for over 60% of global production and employment (though no more than 20% of total trade)—among WTO members.

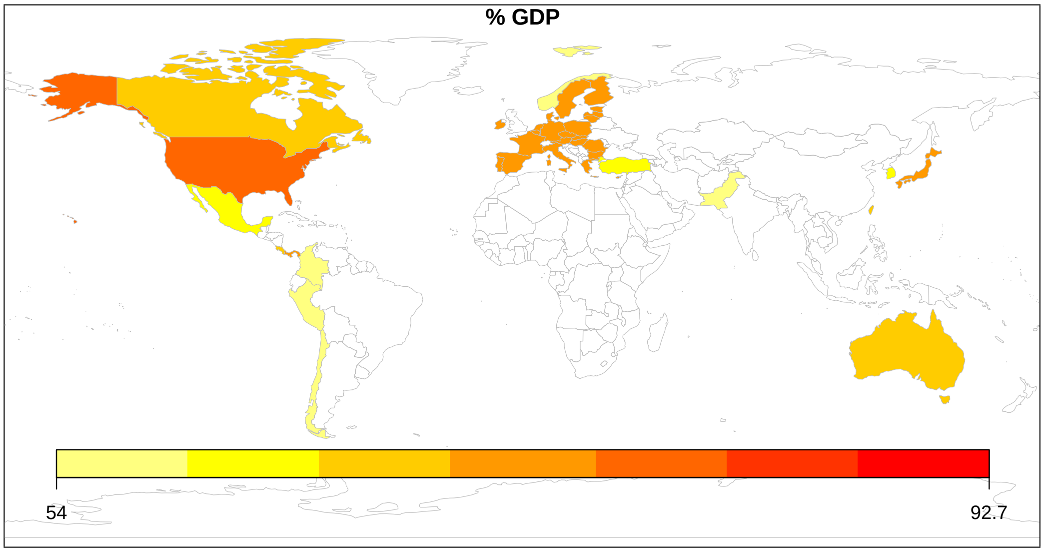
Notably, many erstwhile domestically-sourced service provisions are becoming increasingly privatized and, particularly, internationalized. For example, capital spending by the private sector under private finance initiative (PFI, a form of public-private partnerships in the provision of public services) contracts amounted to nearly 68% of the UK's projected capital spending during 2014-15 (HM Treasury, 2014), and participants include many leading multi-national corporations (MNCs) providing services ranging from transportation, health care and pension, banking, telecommunication, and even defense. For countries whose tertiary sectors are less-developed or are monopolized by the governments, the liberalization of trade in services would bring home intensified competitive pressures on domestic service industries and pose concerns about the erosion of national security at the hands of MNCs. Moreover, the clause on intellectual property rights can also put developing countries at a disadvantage relative to advanced economies. Hence, the opposition to the GATS by many developing countries.

Yet, the stalemate in GATS negotiation did not block the incentive to advance a stand-alone agreement by members who are most likely to benefit from services trade liberalization. The TiSA is thus a proposed international treaty on services trade between a subgroup of 23 WTO parties (called "Really Good Friends of Services" (RGFS)) committed to open up trade in services.[8] Together, this coalition of developed and developing countries accounts for more than two-thirds of global trade in cross-border services as of 2010 (European Union, 2013). Moreover, the service sector share displayed in Figure 6 shows that the RGFS group all have relatively developed service sector, so they represent a very concentrated interest in services trade liberalization.

The TiSA initiative pledges to work out an agreement that complies with the GATS, but it differs from the latter's multilateral framework in two important respects. First, the

[8] The 28 EU member states are jointly represented by the EU in the TiSA negotiation.

Figure 6: Service sector share as % of GDP in RGFS members.



Note: Service sector share values use 10-year (2006-2015) mean for each RGFS member. TiSA members data from http://data.worldbank.org/indicator/NV.SRV.TETC.ZS. Taiwan's service sector share data from Directorate General of Budget, Accounting and Statistics, Executive Yuan. Israel does not release its service sector share data to the OECD and the World Bank. The lower and upper ends of the scale come the data itself: 54% for Pakistan and 92.7% for Hong Kong (SAR).

TiSA takes a "plurilateral" approach in that only the 23 RGFS, but not all WTO members, are parties to the agreement. It seeks to bypass the MFN and reciprocity rules of the WTO by forging an agreement among willing members most likely to cooperate before multilateralizing the agreement to the rest of the WTO at a later stage.[9] Second, the proposed agreement is not exhaustive in its coverage of services sectors or modes of supply. Current RGFS and prospective participants could make suggestions to include new rules and additional sectors and types of services to be covered. As more service-based economies joining the TiSA talks, the final agreement may tilt toward their wider coverage of and sophisticated regulation on services trade. In a sense, this constantly expanding scope of coverage not only further concentrates the interests of more industrialized members of the WTO, it also raises the cost of not complying with the GATS for non-RGFS WTO members by privileging their RGFS counterparts in global services trade market.

As our analysis in Section 3 has suggested, higher probability of partner-switching

9 The European Commission memo interprets the "partner-switching" aspect of the TiSA in a more direct manner:

> "In order to avoid free-riding, the automatic multilateralisation of the agreement based on the Most Favoured Nation (MFN) principle should be temporarily suspended as long as there is no critical mass of WTO members joining the agreement."

tends to promote cooperation in the network when the payoff to defection is sufficiently low. In the case of TiSA, its exclusive nature coupled with the advantageous access to global services trade market granted to its participants should allure more WTO members to join its negotiation. This is exactly borne out by China's expressed interest in participating in the TISA negotiations to secure a foothold for its booming service industries.[10] In the aftermath of periodic global recessions occurring in the last decade, more developing countries are expected to experience relative growth in their service sectors and therefore have more to lose from being excluded from the TiSA.

4.2 TPP Agreement

Unlike the TiSA, the TPP grew out of the Trans-Pacific Strategic Economic Partnership Agreement (TPSEP) concluded by four small Pacific Rim economies (Brunei, Chile, New Zealand, and Singapore) in 2005. The idea soon drew the participation of other countries from the regional FTA blocs along the Pacific Rim which the four TPSEP signatory countries share memberships with. From 2008 onward, the inclusion of eight additional parties in the negotiations brought the total number of participants to twelve and shifted the center of coalition formation dynamics to the leading country in this region as well as the world's largest economy, the US.[11]

The US took the lead to coordinate the TPP negotiations, seeing it as a way to anchor itself into other regional FTA networks and strengthen bilateral trade and investment relationships with countries where US businesses were at a disadvantage. President George W. Bush's *2008 Annual Report on the Trade Agreements Program* reveals US's objectives in seeking accession to this emerging regional FTA network:

> "United States' participation in the TPP could position United States businesses better to compete in the Asia-Pacific region, which is seeing the proliferation of preferential trade agreements among United States competitors and the development of several competing regional economic integration initiatives that exclude the United States." (United States Trade Representative, 2008, 127)

According to one study, the TPP will increase 0.5 percent of America's real GDP and boost annual exports by 9.1 percent over baseline projections by 2030 (Petri and Plummer, 2016). As such, we would expect the US to be more cooperative in its negotiation with participants belonging to FTA blocs it is not a member of in order to access the benefits of free trade that it would otherwise not eligible to in the absence of TPP.[12] Moreover,

[10] Shawn Donnan. "China in push to join US-led $4tn services trade talks." *Financial Times*. 23rd September, 2013.

[11] The eight other participants are Australia, Canada, Japan, Malaysia, Mexico, Peru, the US, and Vietnam.

[12] Alternatively, one can think of this as reducing the cost (u) American firms have to pay in the absence of some form of FTA between the US and foreign markets.

because the TPP is a cross-FTA coalition, the adoption of rules from out-FTAs should promote cooperation by participants belong to other FTAs when the rules are expected to increase their payoffs from staying in the TPP but otherwise engender deadlocks when the rules go against participants' interests. These observable implications are embodied in the negotiations of yarn-forward rules and intellectual property rights (IPR).

A. Yarn-Forward Rule

"Yard-forward rule" is the Textiles and Apparel Product-Specific Rules of Origin (Annex 4-A) adopted from the NAFTA (Annex 401), meaning that the yarn used to form the fabric must originate in signatory countries. Under this provision, materials from yarn exporting TPP members (e.g., Australia, Canada, Mexico, Peru, and the US) will be privileged over cheaper imports from non-TPP countries (e.g., China, India) sourced by TPP members' garment industries as the latter are now subject to higher import duties.

Despite its discriminatory effect, this origin rule imparts significant investment and export opportunities to non-yarn exporting TPP members, such as Vietnam who sources yarn materials from China and manufacture them into apparel products for export: it encourages North American and Japanese clothing brands to take advantage of low-cost TPP partners by relocating production there and exporting finished products to major apparel markets (Australia, Canada, Japan, US) covered by the TPP's tariff benefits. In fact, both the US Trade Representative and American clothing companies see their new TPP partners in the Asia-Pacific as rising partners in apparel trade, if not as a substitute to the NAFTA. Between 2010 and 2014, five years before the conclusion of the TPP Agreement, Vietnam's textiles and apparel industry registered a fantastic 15% annual growth with 70 percent of its exports goes to other TPP countries (Vietnam Trade Promotion Agency, 2014). In 2013, US imports of clothing from Vietnam were more than twice the value of apparel imports from Mexico (Platzer, 2014, 13). Malaysia and Peru also experienced similar growth in their textiles and apparel industries.

The alignment of American firms' commercial impulse with Vietnam's export interests has led the US to extend a less restrictive "cut-and-sew rule" and a preferential "Cotton Woven Bottom-Weight Apparel" program to Vietnam in order to secure the latter's support during the negotiation of the Textiles and Apparel Chapter, even though the final rule of origin is a diluted version of the original proposal (National Council of Textile Organizations, 2015).[13] More importantly, Vietnam's accession into the TPP alarmed its regional competitors in textiles and apparel export markets. The anticipated market access erosion has motivated Philippines, Thailand, Taiwan, South Korea, and Indonesia to express interests in the second-round TPP accession. In short, by presenting the benefits of existing network to a new set of partners, the yarn-forward rule serves as a "building block" that increases the payoffs of cooperation in TPP talks.

[13] Mexico and Peru were the only two TPP participants that sided with the US in negotiations on the yarn-forward rule. The reason being that Mexico has long been accustomed to similar NAFTA regulation and Peru is itself a yarn exporter, so the payoffs of joining a FTA network that favors the interests of downstream garment manufacturers at the expense yarn producers are not as great.

B. Intellectual Property Rights: The case for biologics

The US has long been the staunchest advocate of stronger IPR rules, given its position on the technology pecking order. Enforcing IPR is essential to protect American firms' technology edge against patents infringement in international trade. In the case of pharmaceutical innovation, the strength and length of IPR are positively associated with the competitiveness of American biopharmaceutical industry (Branstetter, Chatterjee and Higgins, 2014). But this incentive distanced the US from other TPP participants. Canada, for example, profits from cross-border generic drugs trade; countries like Mexico and Peru that periodically plagued by the outbreaks of infectious diseases may be tempted to override pharmaceutical patents in the interests of public health (UNITAID, 2014).

The consequences of attaching stricter IPR rules to a multilateral agreement can be powerfully explained by our model which posits that a costly link can hinder cooperation in the network *or* motivate leading country to "rewire" to more cooperative partners. The Patentable Subject Matter Article (Article 18.37), a non-patent form of market exclusivity that prevents generic competition during designated data protection period, was a source of controversy during IPR talks. Michael's (2015) dyad-based network analysis of the TPP's intellectual property chapter draft released by WikiLeaks showed that the US is uniquely positioned in this issue area and only weakly linked to other participants, particularly with Canada who is most resistant to the US's proposal.

However, this isolation did not block the US's attempt to seal the TPP deal. Without giving up its IPR agenda, the US altered its multilateral approach by negotiating with TPP partners individually. Negotiating data protection terms on a bilateral basis allows the US to propose more flexible terms to each TPP participant—cater to their unique issue positions—to increase their cooperation (Silverman, 2014). The final data protection period for biologics exhibits a great deal of bilateral specialities along the dimensions of global hierarchy of pharmaceutical research and development and public health concerns. Contra the twelve-year biologics data protection period proposed by the US, TPP members are provisioned to grant five (Singapore, Australia) or up to eight years' (Canada, Japan, and THE US) exclusivity for patent holders, whereas there is no protection term provision for biologics for Peru, Vietnam, Malaysia and Mexico.

Following the conclusion of the IPR talks, the most contentious "stumbling block" in the road to the TPP, the TPP Agreement was signed on February 4th, 2016.

4.3 South Korea's FTA network

The South Korea patches its FTA jigsaw puzzles in a convoluted way. Beginning in 1998, the crisis-stricken South Korea accepted the liberalization measures stipulated by the IMF and embarked on an aggressive FTA strategy (known as "the FTA roadmap") to promote export and investment with particular emphasis placed on forging regional FTAs with important trading partners (Sohn and Yoon, 2001, 13-5).

The Korea-Chile FTA (2004) sets the precedent for South Korea's subsequent FTA negotiations. The deal is regarded as a successful first attempt because the two countries' economic profiles are complementary while South Korea's manufacturing goods were previously at a disadvantage in the Chilean markets (Cheong, 2002, 26-27, 41). Yet, this FTA is discriminating in its treatment of agricultural products. Certain Chilean agricultural products were subject to tariff limitation schedule in exchange for similar protectionist measures against Korean home appliance products.

Despite this initial success, South Korea was reluctant to extend its free trade network to other South American economies for fear of exacerbating competitive pressures on its agricultural sector, reflecting its selectiveness in seeking FTA partners. Instead, it turned to Singapore, a small trade-dependent economy with almost non-existent agricultural sector, as a springboard to the high-growth ASEAN (Association of Southeast Asian Nations) community of which Singapore is a member.[14] The signing of a bilateral FTA with Singapore (signed August 2005, effective March 2006) was soon followed by the launch of a new round of negotiations with the ASEAN that first came into effect in 2006,[15] during this period bilateral trade grew by more than 10 percent per annum (WTO, various years).

Meanwhile, South Korea also concluded a FTA agreement with the EFTA (European Free Trade Association)—a free trade area consists of four small non-EU northwestern European economies closely tied to the EU—in December 2005. After these inter-regional trade pacts had fallen into place, the time was ripe for the Korean government to extend its FTA network to the hubs of these links, the US and the EU, but excluding other, potentially less profitable partners (namely, members of the Andean Community and Mercosur), as candidates for negotiating FTAs.

Trade talk with the US was first commenced in February 2006 and proceeded rather quickly. By June 2007, the US-South Korea Free Trade Agreement (hereafter, KORUS FTA) was signed and ready for ratification by the legislatures of both countries. This ambitious deal immediately drew the attention of the EU, citing concerns from the automobile and textile industries that the KORUS FTA would erode their competitiveness in the US markets relative to their Korean competitors (Guerin et al., 2007, 29-37). Proposal to negotiate a South Korea-EU Free Trade Agreement (hereafter, KOREU FTA) that will strengthen the already strong bilateral trade ties was set in motion in May 2007.[16]

The KORUS FTA, however, came to a halt in April 2008 due to concerns and mounting protests in South Korea over sanitary rules for US beef imports, which called for a lengthy renegotiation for a "voluntary private sector" arrangement to salvage this trade pact (Jurenas and Manyin, 2010). In the face of such unexpected deadlock, South Korea pursued an aggressive "partner-switching" strategy. The Korean government first diverted its attention toward speeding up its negotiation with the EU; it then approached Australia, a resource-rich Southern Hemisphere economy whose trade profile is highly complementary to South Korea's own, to negotiate FTA. Amid its pending trade talk with the US and the EU, South Korea reached the Comprehensive Economic Partnership

[14] To anchor this point into our theoretical model, this implies South Korea rewired its link to a potentially more profitable set of partners for cooperation.

[15] For trade in goods (2006), trade in services (2007), on investment (2009).

[16] In 2006-2007, the EU and South Korea were the second and eighth largest importer of goods to each other, totalling €64 billion. See European Commission, Countries and regions briefing – South Korea.

Agreement with India (in 2009) and altered its previous approach to the Andean Community by fast-tracking the intermittent FTA negotiation with Peru that the latter first proposed in 2005 with the agreement concluded in August 2010,[17] but still shunned from engaging major Central and Latin American economies (e.g., Argentina, Brazil, Mexico).

These emerging trade pacts apparently gave South Korea better position to renegotiate the FTAs with the US and the EU because its new FTA partners were either already anchored in these economic powerhouses' free trade networks or were in the process of negotiating FTA with them.[18] Forming FTA with South Korea would therefore improve American and European firms' access to the Korean market or at least offset the competitiveness of their Korean counterparts operating in the same foreign markets. In other words, the accumulated payoff from the formation of these new FTAs increased the payoff (cost) for establishing (not establishing) FTA with South Korea.

The negotiation of the KOREU FTA accelerated in the second half of 2009 and the agreement was signed on October 6th, 2010. The signing of the KOREU FTA raised the pressures from Members of the US Congress and affected sectoral interests to sidestep the issues that have almost derailed the KORUS FTA (in particular, the US beef imports), since this trade pact, which was expected to enter into force on July 1st, 2011 aiming to eliminate 98.7% of all tariffs within five years, could give European and Korean firms "first mover advantage" and divert some of their trade away from the US (Cooper et al., 2011). The tone of the top executives also became more conciliatory over time. President Obama, who vociferously claimed the KORUS deal as "badly flawed" during his 2008 Presidential Campaign,[19] now urged to resolve the "outstanding issues" of the KORUS FTA prior to the November G-20 summit while South Korean President Lee Myung-bak agreed to renegotiate during their upcoming bilateral meeting in November.[20] The two sides agreed to single out US beef and automobile products for renegotiation without touching other components of the KORUS FTA. On December 4th, 2010, a deal had been reached for South Korea to fully re-open US beef imports, regardless of age, with 40% tariff on beef muscle cut imports and tariffs on other beef products to be eliminated in fifteen years. The deal also granted significant concession to American automobile industries. In a year's time, the KORUS FTA received ratification by both houses on October 12th and passed by the South Korean National Assembly on November 22nd, 2011, only four months after the KOREU FTA went into effect — the largest FTA that South Korea has entered into seconded only by the coming KORUS FTA that was scheduled to take effect in March 2012.

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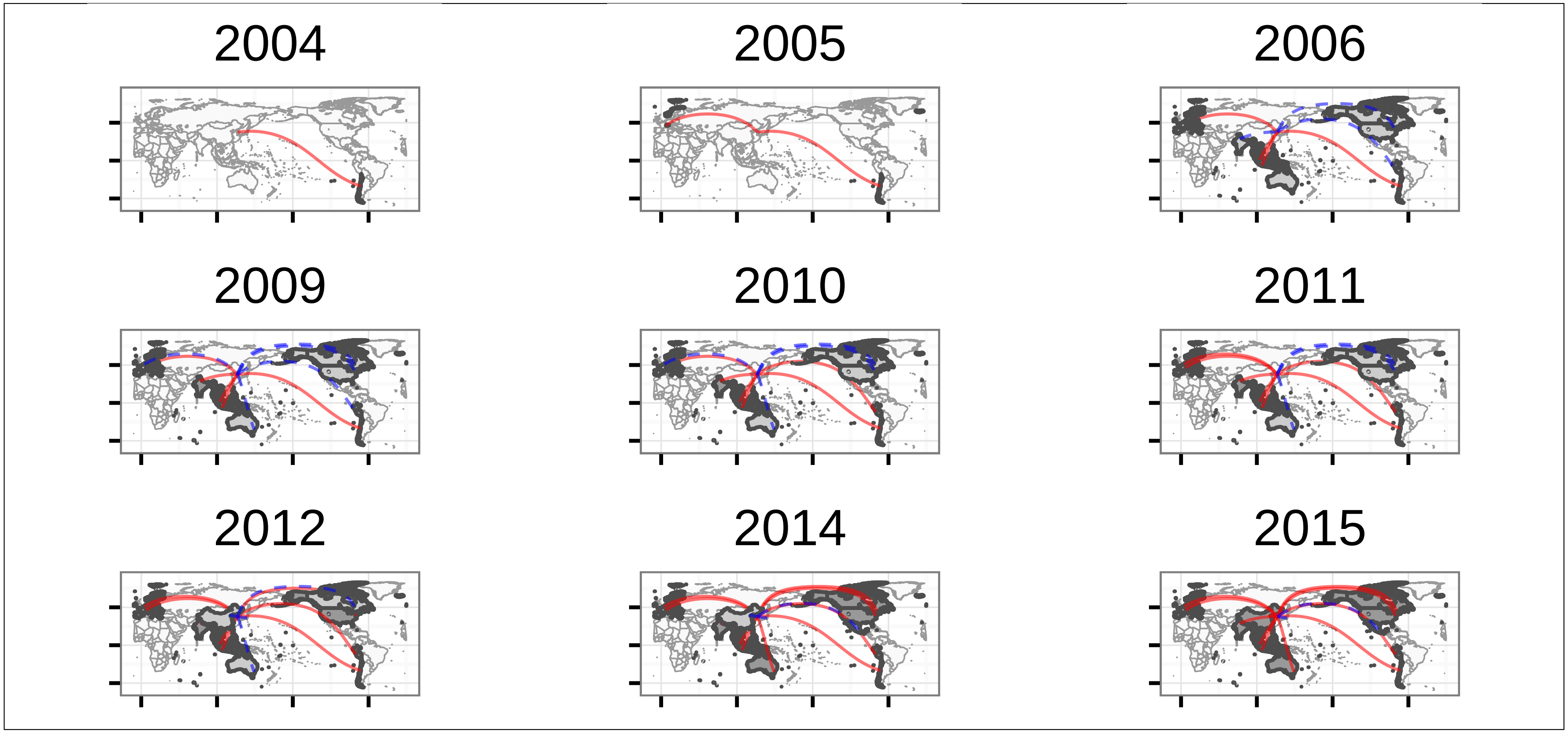
17 The final agreement was signed by both parties on March 21st, 2011 and took effect on August 1st of the same year.

18 The Australia has held a FTA with the US since 2005. The first round of FTA negotiation between India and the EU was launched in 2007. The US-Peru Trade Promotion Agreement (PTPA) came into effect on February 1st, 2009, allowing US firms greater access to the Peruvian goods and services markets.

19 Mark Drajem. "Obama Urges Bush to Withhold Korean Trade Pact, Not Force Vote." *Bloomberg*, 23rd May, 2008.

20 Office of the Press Secretary. "Remarks by President Obama at G-20 Press Conference in Toronto, Canada." 27th June, 2010.

Figure 7: Evolution of South Korea's FTA network.



Note: Countries that have established FTA with South Korea are marked in dark grey and connected by solid red line. Countries that are in the process of negotiating FTA with South Korea are connected by dashed blue line.

Building on this momentum, South Korea and Canada rekindled their long-overdue FTA talk in November 2011,[21] first resulted in the lifting of ban on Canadian beef (a vital Canadian export to South Korea) in 2012 followed by the settlement of tariff schedules on automobile and agricultural products. The deal was concluded in March 2014. In fact, the bilateral FTA with Canada is a logical next step for South Korea to extend its KORUS FTA into a more profitable FTA network, the NAFTA; conversely, it would be costly for Canada to not having established this link because its trade with South Korea (its sixth largest trading partner in 2012) had dropped by a third since the conclusion of KOREU FTA and KORUS FTA.[22] On December 11th, 2014, the Korea-Australia FTA (signed in April) entered into force. Finally, before these bilateral FTAs took effect, South Korea began negotiating bilateral FTA with Mexico, another NAFTA member.

Yet, this aggressive FTA formation dynamic did not stop at North America. According to our theory, increased payoff from playing cooperative strategy will promote cooperation in the network by inducing defecting partners to update their strategies *or* when central nodes are allowed to switch partners at greater probability, which is corroborated by South Korea's recent FTA engagement. After anchored itself in the two giant trade blocs, South Korea rewired its FTA link to China, the emerging economic hub of East Asia, to negotiate a FTA that will eventually cover Japan — an idea that has been brewing since 2004 (MOFCOM, N.d.). The bilateral negotiation with China was formally launched in May 2012, and immediately followed by the commencement of China-Japan-South Korea trilateral negotiation in August of the same year. Bolstered by constantly renewed mutual commitments in each of the ensuing 14 rounds of talks, the China-South Korea FTA was hammered down in June 2015 and went into effect in December, becoming South Korea's largest bilateral FTA in trade terms (Schott, Jung and Cimino-Isaacs, 2015). Although the state of the China-Japan-South Korea FTA is marred by political tension in this region, its realization is expected to enhance trilateral trade and bridge South Korea's FTA network to China's and Japan's trading partners in Eurasia and the Asia-Pacific.

Figure 7 summaries the evolution of South Korea's FTA network discussed in this section. The graph provides a reference for tracing the year when a certain FTA negotiation was commenced, the year it was concluded, the length of negotiation, and its effect on adjacent countries' propensities to establish free trade relations with South Korea.

5 Conclusion

PTA among smaller, cohesive set of countries is viewed as the main centripetal force in contemporary international economic integration. The faltering of the DDR in recent years foresaw the birth of regional and inter-regional FTA blocs from within the WTO framework: the TPP, the TiSA, and the proposed Transatlantic Trade and Invest-

[21] A total of 13 rounds of talk were held as of 2011 since the negotiation first launched in 2005.

[22] Nathan VanderKlippe. "With South Korean deal, Canada secures free-trade foothold in Asia." *The Globe and Mail*, 11th March, 2014.

ment Partnership (TTIP) between the EU and the US. The stalemate also motivated countries—countries who want to free themselves from the strictures of the DDR and maximize the benefits of free trade—to negotiate bilateral FTAs to expand their own FTA networks, as evidenced by the South Korean case analyzed in the previous section. Although these recent trends are in favor of the "stumbling blocs" argument that views regionalism and exclusive trade blocs as the impediments to global free trade, according to our analysis, these "stumbling blocs" can be an important mechanism for achieving larger free trade networks. This study argues that, without having to forgo stalled efforts at multilateral free trade deals (such as the WTO), states can maximize cooperation in a given free trade network by adopting the strategies of high-payoff counterparts or, alternatively, by bypassing less cooperative partners and switching to more cooperative partners to negotiate FTA. As our simulation results suggest, maximum number of free trade links are more likely to be achieved when defection is more costly and when countries are allowed to switch to more cooperative partners with greater probability. Thus, a global FTA can be achieved in the long run when these strategies are diffused over the entire network. The maintained claim is that a global FTA is attainable only when the formation of smaller, more exclusive trade blocs are prioritized.

This paper also makes an important methodological contribution to the study of network evolution. Our use of the AME method generates a large system of ODEs, taking into account the initial state of nodes, their distribution and changes, which provides a more accurate approximation for the time evolution of networks at only a slight computational cost.

Two policy implications are in order. First, even in the face of decade-long impasse, it is possible to revive the lost causes of the DDR through initiatives that involve only a small subset of WTO members. It may be easier for a committed sub-group to overcome the initial hurdle of coordinating with a large heterogeneous mass in multilateral free trade negotiation and to generate benefits necessary to sustain the momentum of the agenda. As this study has demonstrated, in order for the cooperative strategy to propagate, the network must make defection less rewarding (than cooperation) to induce more members in the same neighborhood to become cooperative types in the strategy-updating process; on the other hand, the network should also allow cooperative type members to more actively rewire to similar type partners to quickly assemble a winning coalition for their cause. This can only be attained by a "coalition of the willing" committed to further trade liberalization beyond existing WTO provisions, with the view of eventually integrating these new rules into the WTO system.

However, for non-members of these advanced agreements, this plurilateral approach portends the chipping away of their bargaining power as well as their future payoffs. They would have to agree to the terms set by the powerful bloc of the willing should they choose to join these agreements later. Because these agreements entrench the oligopolistic position of the willing in the sectors being liberalized, the upfront cost paid by latecomers of opening up their markets to foreign competition could outweigh the benefits of enlarged market access when they are comparatively disadvantaged in those sectors. For example, study by Amiti and Romalis (2006) finds that the preferential access granted to least-developed countries (LDC) are often offset by the latter's low product coverage and the complex rules of origin. Proposals have been made to provide duty-free and quota-free market access (DFQF), the so-called "early harvest," for all LDC products no later than the conclusion of the DDR and similar such agreements (WTO, 2003). But so far the progress has not been satisfactory (UNCTAD, 2011).

This study also carries several theoretical implications for further research. First, the model we developed here assumes the two strategy mechanisms influence the levels of co-operation in the network as separate processes: the values of cost-to-benefit ratio (u) that determine the probability of strategy-updating (ϕ) are unconditional on the probability of partner-switching ($1 - w$), and the latter is unaffected by the value of u, holding other parameters constant. Empirically and as Panel (b) of Figure 2 indicates, when coopera-tion becomes too costly (i.e., high u), even aggressive partner-switching fails to drive up link formation dynamics. On the other hand, partner-switching may influence strategy-updating dynamics through its effect on the cost-to-benefit ratio (u). To be sure, intense partner-switching (i.e., low w) maximizes cooperation in the network by accelerating the connection between cooperative pairs that expands the size of accumulated payoff to this cooperative network, P (ref. (1)). Yet, marginal increases in P plausibly imply changes in its constituent term u that determines the payoff to strategy-updating: it decreases (increases) the cost (benefit) of cooperation *relative* to defection, inducing more defecting type nodes to adopt cooperative strategy. This explains the quick jump in ρ at very low levels of w followed by a sharp fall immediately afterwards, as captured in Panel (a) of Figure 2. An integrated framework in which w and u are functions of each other will the direction for our future research.

Finally, beyond providing an explanatory framework for FTA formation, our model can serve as theoretical foundation for *predicting* emerging FTAs. Recent advance in machine learning allows us to make prediction on out-of-sample data from the patterns identified from existing data. The WTO's regional trade agreements (RTAs) and prefer-ential trade agreements (PTAs) database, for example, lists the membership and status for each RTA/PTA and sort them by coverage (i.e., goods, services, or both). One can use "in force" RTAs/PTAs as "training set" and take advantage of the variances in their memberships and coverage to improve the generalizability of the estimate on ongoing or newly launched free trade negotiations.[23] The learning process should help identify key initiator countries and potential non-cooperators in existing RTAs/PTAs as well as issue areas most (least) likely to engender cooperation, and such information would lend useful insights on each country' propensity to cooperate and types of FTA initiatives most likely to succeed. This potential extension is currently being explored by us.

Appendix

By (1), (2), and (3), a central node of type C or D of the D_{kl} set with degree k and l defecting neighbors engages in a PD game with its neighbors and obtain a payoff

[23] This is logically akin to cross-validation in statistical model selection in which the iterative validation of the analysis of one subset of data partitioned from the sample data on another subset of the data maximizes the validity of the predictive model on any unknown datasets.

$$\begin{cases} P_C | D_{kl} = 1 \cdot \frac{2N_{CC}}{N_C} + 0 \cdot \frac{N_{CD}}{N_C} \\ P_D | D_{kl} = (k-l) \cdot (1+u) + l \cdot u \end{cases} .$$

While the computation for P_D is straightforward, the first line is so because we do not have information about the neighbors of the center node's C neighbors and can only approximate their utility by averaging the total payoff across all C nodes. Substituting P_C and P_D into (3), we obtain

$$\phi_{kl}^D(D \to C) = \frac{1}{1+\exp[\beta(P_D - P_C)]},$$

as shown in (5) and (6).

Likewise, for the C_{kl} set,

$$\begin{cases} P_C | C_{kl} = l \cdot 0 + (k-l) \cdot 1 \\ P_D | C_{kl} = (1+u) \cdot \frac{N_{CD}}{N_D} + u \cdot \frac{2N_{DD}}{N_D} \end{cases} ,$$

and

$$\phi_{kl}^C(C \to D) = \frac{1}{1+\exp[\beta(P_C - P_D)]}.$$

Following Gleeson (2011: 6-7; 2013: 22), other transition parameters listed in Figure 3 can be defined by first calculating the number of edges of various types (N_{CC}, N_{CD}, and N_{DD}, here we focus on the number of N_{CD} links only) formed by nodes susceptible to state transition realized from the binomial distribution

$$\binom{k}{l} q^l (1-q)^{k-l},$$

then differentiating the resulting expression with respect to time to computing the number of edges switching from their original types to new types in the time interval dt. The probability of each possible type of transition is given by taking the ratio of the former to the latter

$$\beta^C = \frac{\sum_{k,l}(k-l)lC_{k,l}}{\sum_{k,l}(k-l)C_{k,l}}$$

$$\gamma^C = \frac{\sum_{k,l} l^2 C_{k,l}}{\sum_{k,l} lC_{k,l}}$$

$$\beta^D = \frac{\sum_{k,l}(k-l)^2 D_{k,l}}{\sum_{k,l}(k-l)D_{k,l}}$$

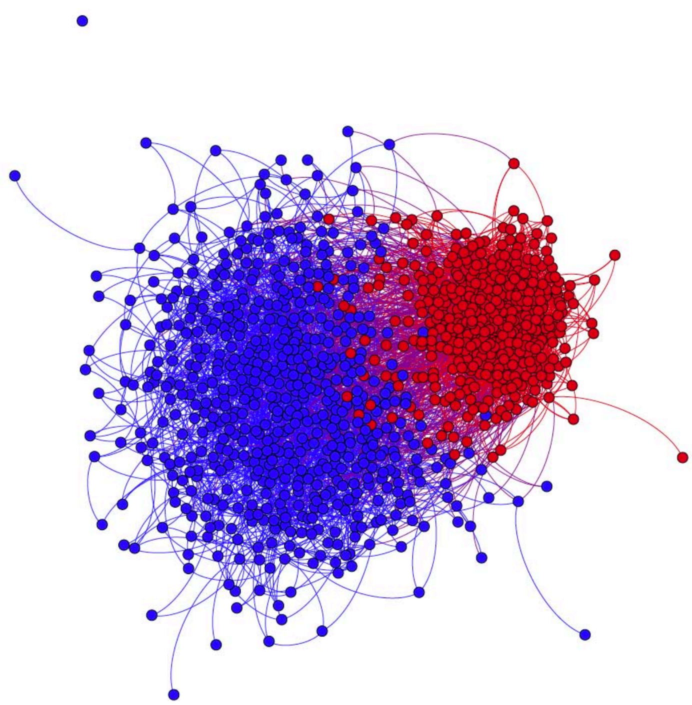
$$\gamma^D = \frac{\sum_{k,l} l^2 D_{k,l}}{\sum_{k,l} lD_{k,l}}.$$

Note that because these transition parameters are expressed as the quotients of the second order moments of C_{kl} and D_{kl} divided by their first order moments (initial (mean) distribution), they are functionally equivalent to the coefficient of variation (CV) that measures the of dispersion of the probability distribution of the C_{kl} and D_{kl} sets, that is, the dispersion of the nodes susceptible to state transition within a given interval. For example, the probability that one defecting type node changes its type to become cooperative means a $D \to C$ transition occurs in the interval $(K - l + 1, l)$

$$\int_{k-l+1}^{l} s\gamma^{C} \mathrm{d}s.$$

When there are more nodes experiencing state transitions, then these transition parameters will impart greater effects on the central nodes' utilities.

Figure A: Visualization of partner-switching prior to stationary state



Note: Simulated at $N = 1000$, $M = 5000$, $u = 0.5$, and $\rho = 0.5$. Cooperative type nodes colored in blue, defecting type nodes colored in red. Note a small number of discordant edges in the middle that exist before full separation is reached.

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