Signaling, Trade, and Alliance Commitment in Peacetime*

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Abstract

Alliance treaties survive when allies can successfully coordinate security policies to cope with changes in external strategic environments. However, since allies do not always have the same preference over the level of alliance commitment, an uncertainty about their partners' resolve can be an obstacle to achieving an agreement among allies. I explore when and how allies can use intra-alliance trade cooperation to overcome the uncertainty problem, resulting in the maintenance of the treaty. I present a negotiation model where leaders confront both domestic and international risks arising from intra-alliance trade cooperation. In the equilibrium, trade signaling can change leaders' beliefs and in turn reinforce alliance ties. The logic of trade signaling illuminates the importance of intra-alliance trade cooperation as a policy instrument to maintain the survival of alliance treaties and provides new insights for the trade-security linkage.

1 Introduction

At the end of World War II, military alliances such as the North Atlantic Treaty Organization (NATO) and the U.S.-Japan Security Treaty were formed to contain the expansion of communist influence. The primary objective of these alliances was to deter the Soviet challenge and to maintain peace (Skålnes 2000, Chapter 6). Throughout the Cold War, these alliances were tested both by intra-alliance conflicts, such as the Suez Crisis, and inter-alliance crises, such as the Taiwan Straits crisis, the Vietnam War and the Falklands War, which produced disagreements among the allies. The security environment in which these alliances operated also changed over time with events such as decolonization, French withdrawal from NATO, and the military expansion of the USSR. The strength of these alliances was also challenged by changes in the international economy, such as the rapid growth of international markets, which led to the collapse of the Bretton Woods system, and the oil crisis of the 1970s. Although these exogenous shocks tested alliance ties, the western alliances persisted.

After the collapse of the USSR, some international relations scholars predicted that western alliances would disappear because those alliances had lost their principal purpose, the containment of communist influence.[1] However, they have endured far beyond their original objectives as the alliances have come to focus more on resolving regional disputes. In effect, the members have used their alliances to deal with new issues in international relations.[2] Why have these alliances survived, while others, such as the Southeast Asia Collective Defense Treaty (1954–1977) and the United Arab Republic-Jordan Defense Agreement (1967–1979), have dissolved? What determines the durability of alliances?

To explain the life-span of an alliance treaty, scholars in international relations focus on political attributes of alliance treaties such as the power distribution within each alliance and polity types of the members. Morrow (1991) argues that asymmetric alliances between major and minor powers are more likely to persist than symmetric alliances. In an asymmetric

[1] Waltz (1993) doubted the endurance of NATO immediately after the Cold War. Cumings (1992) also doubted the raison d'etre of the U.S.-Japan alliance treaty immediately after the Cold War.

[2] The NATO has been used for maintaining regional peace since the end of the Cold War.

alliance, a major power provides the security while a minor power gives legitimacy to the major power's challenge to the status quo. Although the risk of war and the loss of policy autonomy are political costs for a major and a minor power, respectively, an asymmetric alliance can produce reciprocal interests through the exchange of security and legitimacy. Thus, an asymmetric alliance is more likely to survive longer than a symmetric alliance.

Regime type is also often argued to affect the durability of alliance treaties. In democracies, voters can punish a government for its failed foreign policy in the elections. Leaders in a democracy are less likely to sign alliance treaties if they cannot comply with their obligations. Since a system of checks and balance do not allow democratic leaders to easily change their policy stances, an alliance populated by democracies is more likely to remain over time than an alliance with non-democracies (Gaubatz 1996; Leeds 1999; Reed 1997).

A few of case studies, however, have examined intra-alliance economic interdependence as a determinant of alliance durability. Two historical cases illuminate the utility of foreign economic policy to enhance alliance ties in peacetime. George Washington and Alexander Hamilton blocked Secretary of State Thomas Jefferson's efforts for a U.S.-France reciprocal trade agreement and as a result, the 1778 Franco-American security treaty collapsed (DeConde 1958, Chapter 5). In 1910 the Diet of Japan accepted lower tariffs on British goods to avoid potential challenges to alliance relationships, and in 1911 the Anglo-Japanese Alliance was successfully renewed (Davis 2009). Thus, intra-alliance trade conflict and cooperation can spill over the fate of an alliance.

This study advances current research on the durability of alliance treaties by focusing on the utility of intra-alliance trade policy in peacetime alliance politics. I investigate the decision to maintain an alliance as the result of a series of negotiations over how to cope with unexpected changes in the political environment such as exogenous threats and domestic opposition to the treaty. Since allies can have different preferences on policy solutions due to geopolitical and national interests, I argue that the uncertainty about policy preferences presents an obstacle to successful policy coordination in alliance treaties. I show the strategic use of intra-alliance trade cooperation as a policy instrument of signaling policy preferences to alliance partners. The game theoretic analysis and the empirical analysis of alliance durability in the period 1950-2001 produces new microfoundation for the trade-security linkage.

2 Foreign Economic Policies as Strategic Instruments

A literature focusing on foreign economic policies as strategic instruments provides some guidance to understanding how policy makers can use or manipulate structural (especially economic) constraints to pursue strategic purposes. Hirschman (1980) explores trade interdependence as a policy tool to strengthen political influence, while others such as Baldwin (1985) address the use of economic sanctions as instruments of statecraft. Kirshner (1995) offers a theory that concerns the coercive manipulation of international monetary relations for security and non-economic purposes. In the context of alliance politics, Gowa (1994) investigates why allies use discriminative trade policy to strengthen alliance ties. She argues that intra-alliance trade enhances allies' economic welfare, which in turn increases their potential military power. Discriminative trade policies can have a positive effect on the security of intra-alliance trade partners because they can give rise to so-called security externalities. Her argument is helpful for understanding the difference between inter-alliance and intra-alliance trade policy choices. However, the literature has thus far never posited an explanation for the variance of intra-alliance trade flows as the result of political manipulation.

Skålnes (2000) and Papayoanou (1999) discuss the nature of intra-alliance trade cooperation from the perspective of policy instruments to pursue national interests. Skålnes (2000) argues that leaders can use intra-alliance trade liberalization to strengthen domestic support for the alliance treaty in the partner country, making abrogation by their partners more difficult. In contrast, Papayoanou (1999) considers how interest groups constrain leaders to seek grand strategies or alliance cooperation if national security concerns are conflicting with socio-economic interests.

Together, Skålnes (2000) and Papayoanou (1999) address the signaling role of intra-alliance trade cooperation based on their views about the nature of intra-alliance trade policy. Skålnes (2000) suggests that intra-alliance trade liberalization is recognized as the outcomes of security concerns and enhances the confidence of alliance partnerships. Nevertheless, Papayoanou's (1999) view suggests that deeper economic ties reflect strong domestic support for alliance relationships, such that leaders can more readily rely on their alliance partners. Thus, the exchange of intra-foreign economic policy can enhance alliance ties by means of conveying intentions central to the life-span of an alliance treaty.

I address both views of Skålnes (2000) and Papayoanou (1999) in the analysis and assume that policy makers pursue alliance cooperation while confronting the dilemma between security concerns and economic interests. I explore when and how intra-alliance trade cooperation enables allies to enhance the durability of alliances by conveying their intentions to each other.

3 The Model

In this section, I formalize trade politics and peacetime alliance politics separately and then combine them to construct the signaling logic of trade. In peacetime, whenever leaders face strategic changes in domestic and international environments, they are required to coordinate their security policies. Also, leaders are uncertain about their partners' preferences on the level of commitment to the alliance treaty in a given issue. When the uncertainty problem prevails, allies are more likely to fail to coordinate their security policies, resulting in treaty abrogation.

However, the strategic use of foreign economic policies can be a solution for the uncertainty problem. Foreign economic policies often serve as instruments to enhance national security even though the implementation of these policies can sometimes be inconsistent with the preferences of the private sector. When a foreign economic policy based on security concerns is not helpful for the interests of the private sector, leaders confront the loss of domestic support from the sectors exposed to import-competition. Thus, only when politicians recognize the importance of further alliance cooperation will they isolate foreign economic policy from socio-economic interests. Leaders can convey the significance of strategic needs to their partners using cooperative foreign economic policies without domestic support. Here, I explore the role of intra-alliance cooperation as policy instruments to overcome the uncertainty problem and to enhance alliance durability.

3.1 Trade Politics

I begin by presenting a model of intra-alliance trade politics. The standard trade model in international economics explains how the international division of labor can work to improve national welfare of countries (Krugman and Obstfeld 2005). Since each country has a relative advantage of producing goods, any country can specialize in producing extra goods to exchange for other foreign products. Thus, countries have incentives to engage in international trade to realize mutual gains .

However, trade liberalization does not equally provide benefits within a country. Specific groups within a country might struggle against a rapid increase of imports and press their governments for trade protection.[3] Since trade liberalization can lead to the loss of domestic support, political calculation can highly influence trade policy choice.[4] Political leaders' incentives illuminates the strategic interactions among countries. Given trade liberalization by the partner country, the adoption of protection policy allows political leaders to receive political support from both exporters and makers of import-competing goods. Also, since their partners' protection policy induces the loss of exporters' support, political leaders tend to rely on trade protection as well to mitigate further loss of support from makers facing

[3]Trade liberalization can easily politicize and generate domestic political cleavage (Rogowski 1989). According to the level of factor mobility, trade liberalization lead to the class-based or the inter-industrial conflicts (Hiscox 2002).

[4]Several works develop different political support functions to explain trade policy making. They assume that politicians care about their reelection (Grossman and Helpman 1994; Magee, Brock, and Young 1989; Pahre 1998, 2008).

import-competition.

This preference ordering can describe trade politics as the Prisoner's Dilemma (PD). I formalize intra-alliance trade politics as a PD, where two allies, State A and State B, simultaneously choose between Trade Cooperation (TC) and Defection (D). These strategies represent trade liberalization and protection, respectively. The combination of policy choice by two allies can result in four possible outcomes: mutual cooperation (TC, TC), State A's one-sided defection (D, TC), State B's one-sided defection (TC, D), and mutual defection (D, D).

In the model, the adoption of trade liberalization causes costs and benefits. The parameter $a > 0$ captures benefits from trade liberalization such as extra supports from exporters and consumers. I assume that the size of benefits from trade liberalization is proportional to the number of cooperators because mutual trade liberalization stimulates the demand for the exports to foreign countries more than unilateral trade liberalization. I include the parameter $k > 0$ to denote the political costs that a leader confronts as the result of trade liberalization. As the size of cost k increases, the benefits from mutual trade cooperation shrinks.

Two states have the following payoffs for four possible outcomes. Mutual cooperation (TC, TC) generates $2a - k$ for both states. In State A's one-sided defection (D, TC), State A and State B receive a and $a - k$, respectively. In State B's one-sided defection (TC, D), they have the interchanged payoffs of (D, TC). Mutual defection (D, D) produces 0, the normalized values for the status quo, which serves as the benchmark of trade liberalization. Given $a < k < 2a$, intra-alliance politics is described as a PD in Figure 1.[5]

[5] Bagwell and Staiger (2002) present a general equilibrium model with the political objectives. Their model generalizes the results of the median voter and the interest group politics approaches (Mayer 1984; Grossman and Helpman 1994, 1995). To gain a closed form solution, I set the simple payoffs here that are consistent with their results.

		State B	
		TC	D
State A	TC	$2a-k$, $2a-k$	$a-k$, a
	D	a , $a-k$	0 , 0

Figure 1: Prisoner's Dilemma

3.2 Alliance Politics in Peacetime

Alliance politics in peacetime is a series of negotiations to deal with strategic changes in international and domestic environments. Alliance treaties are signed to treat specific issues. As time passes from alliance formation, changes in international and domestic politics make the initial purposes of treaties less meaningful. Whenever allies face these exogenous shocks, they are required to agree with the level of alliance commitment through negotiations. Unless allies can find policy solutions, alliances will become abrogated. Also, allies do not like to reveal their different preferences for dealing with these shocks because potential opponents will doubt the credibility of the alliance if there appears to be disagreement (Snyder 1997, Chapter 6). Thus, an intra-alliance negotiation can be represented by a coordination game.

Suppose that Allies, State A and State B, are required to choose whether to reinforce alliance cooperation (AC) or to maintain the status quo (SQ). This means that two allies have a negotiation over how to adjust alliance policies to exogenous shocks. The combination of these choices leads to four different outcomes: an agreement with further cooperation (AC, AC), an agreement with the status quo (SQ, SQ), and disagreements (AC, SQ) and (SQ, AC). While agreements lead to alliance survival, disagreements result in alliance termination.

When allies agree with AC or SQ, both receive a joint gain equal to 1. When allies disagree, they cannot attain any joint gain because disagreements signal alliance unreliability to potential opponents. When State $i \in \{A, B\}$ chooses AC, it receives $e_i \in [-2, 2]$, which indicates each ally's assessment of strong alliance commitments regardless of the partner's commitment level. e_i reflects how much military and political support from allies is required for national security, which Skålnes (2000) calls *strategic needs*.[6] That is, e_i equals the relative importance of alliance cooperation by comparison with the status quo. An intra-alliance negotiation is summarized by Figure 2.

		State B AC	State B SQ
State A	AC	$1+e_A, 1+e_B$	e_A , 0
	SQ	0 , e_B	1 , 1

Figure 2: Alliance Game

3.3 Signaling, Trade, and Alliance Politics in Peacetime

Here, I incorporate the uncertainty problem into the model to describe an obstacle to successful policy coordination. Since allies can evaluate situations differently, allies cannot completely grasp their partners' preferences. Suppose that e_i is individually drawn from the uniform distribution $[-2, 2]$ and each ally has private information about its own e_i. Now I combine the trade game with the alliance game to construct the signaling logic of trade. I assume that allies can observe the result of trade politics before they negotiate alliance policy. The extensive form game consists of two stages, the trade game and the alliance game. The time-line form is as follows.

1. Nature draws $e_i \sim \text{unif}[-2, 2]$ and e_i is private information for State i.

2. Two states play the Trade Game (Figure 1).

3. Two states play the Alliance Game (Figure 2).

A strategy for each player is a combination of actions in the two stage games. To describe strategies, I define actions in the two stages. Since the value of e_i is private information for State i, it determines State i's type. Let $a^1_{e_i} \in \{TC, D\}$ denote State i's action in the first stage given the type e_i. To describe a strategy precisely, I assume that actions in the

[6]Strategic needs can implies a variety of the common goals such as military strategy, war plans, joint practice for defense, burden sharing in the budget and so on.

second stage depend on the results of the first stage. Let $a^2_{e_i}|_{(a^1_{e_i},a^1_{e_j})} \in \{AC, SQ\}$ denote State i's action in the second stage given the type e_i $(i \neq j)$. I define State i's strategy as $\sigma_{e_i} = \{a^1_{e_i}, a^2_{e_i}\}$.

Payoffs of the total game are additive of the payoffs in the two stages. The parameter $r \in (0, 1)$ discounts the payoffs in the second stage, which reflects the stability of alliance relationship in different structures of the international system (Snyder 1984). For example, a bipolar world does not allow allies to find a new partner outside of the treaty because the other side is the enemy. As the result, this strategic constraint makes alliance relationships more stable in a bipolar world. In stable alliance relationships, expectations for alliance politics are more likely to influence intra-alliance trade politics. A higher value of r reflects the more stable alliance relationship in a bipolar world. In a multipolar world, allies have the opposite situation and do not take expectations for alliance politics into consideration. A lower value of r implies the less stable alliance relationship of a multipolar world.

Let $f_i(a^1_i, a^1_j)$ denote State i's payoffs for the trade game, given the action profile of the two allies. Let $g_i(a^2_i, a^2_j)$ denote State i's payoffs for the alliance game, given the action profile of the two allies. Suppose that a set of all players' strategies is $\sigma = (\sigma_{e_i}, \sigma_{e_j}, e_i, e_j)$. Given State i's type e_i, State i's expected payoffs of this game are described by $E^\sigma[f_i(a^1_i, a^1_j) + rg_i(a^2_i, a^2_j)|e_i]$. Since trade policy does not change the payoff structure of the alliance game, the strategic problem in alliance politics does not change at all.

4 Equilibrium Analysis

I employ perfect Bayesian equilibrium (PBE) as the equilibrium concept to describe how allies rationally learn their partner's types from the results of the trade game. I will present two possible PBEs to describe the signaling logic of trade in peacetime alliance politics. I briefly characterize the effect of trade signaling by comparing the informative with the uninformative equilibria. Proof of propositions is presented in the appendix.

Also, I use contingent strategies to describe a set of equilibrium strategies for convenience. A contingent strategy consists of three components, an action in the trade game, an action in the alliance game after observing the other's TC, and an action in the alliance game after observing the other's D. For example, State A's strategy (TC, AC, SQ) means that State A plays TC and then chooses AC after observing State B's TC and SQ after observing State B's D.[7]

4.1 The Uninformative Equilibrium

A possible PBE shows the possibility of no signaling effect of trade, called the uninformative equilibrium. In the uninformative equilibrium, states cannot update their beliefs about their partner's strategic needs because all types of states choose defection in the trade game. When states cannot learn their partner's private information from trade politics, the uncertainty problem constrains the possibility of agreements in peacetime alliance politics. In Figure 3, a cutoff point along the possible types describes the equilibrium strategies of State i. The equilibrium strategies and beliefs are summarized in proposition 1.

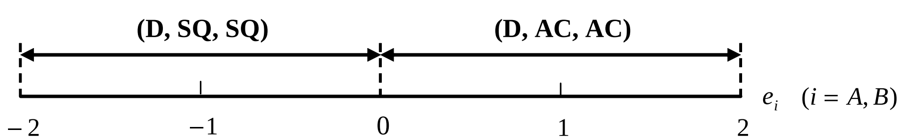

Figure 3: The Equilibrium Strategies in the Uninformative PBE

Proposition 1. The following set of strategies and beliefs constitutes the uninformative PBE.

Strategies. State i plays (D, AC, AC) if $e_i \geq 0$ and (D, SQ, SQ) otherwise.

Beliefs. After the trade game, State i's belief is that State j chooses AC with probability $\frac{1}{2}$.[8]

[7]When State i plays TC, his subsequent actions after playing D do not change State i's payoffs in the alliance game. I reduced strategies with these subsequent actions into a contingent strategy.

[8]In the PBE, we can choose any off-the-equilibrium-path belief such that it supports the on-the

4.2 The Informative Equilibrium

The other possible PBE shows the possibility of trade signaling. In Figure 4, a set of cutoff points along the possible types describe the equilibrium strategies of State i. Let e_T^* denote the critical value that makes State i indifferent between the strategies (TC, AC, AC) and (D, AC, SQ). When $e_i = -1$, State i is indifferent between the strategies (D, AC, SQ) and (D, SQ, SQ). Note that when $-1 \leq e_i < e_T^*$, State i plays D in the trade game but the other's TC can persuade State i to play AC in the alliance game. When political leaders choose trade liberalization, they face the loss of domestic support from protectionists and the risk of the partner's trade protection. These costs allow only states with higher strategic needs to use trade cooperation to convey their intentions. Therefore, intra-alliance trade cooperation serves as a costly signal. The equilibrium strategies and beliefs are summarized in proposition 2.

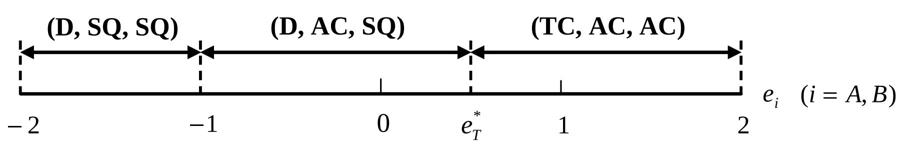

Figure 4: The Equilibrium Strategies in the Informative PBE

Proposition 2. The following set of strategies and beliefs constitutes the informative PBE *if* $e_T^* = -1 + \frac{\sqrt{2r^2 - 4(a-k)r}}{r}$.

Strategies. State i plays (TC, AC, AC) if $e_T^* \leq e_i \leq 2$. State i plays (D, AC, SQ) if $-1 \leq e_i < e_T^*$. State i plays (D, SQ, SQ) if $-2 \leq e_i < -1$.

Beliefs. When State i chooses TC and observes State j's TC, State i's belief is that State j chooses AC with probability 1. When State i chooses TC and observes State j's D, State i's belief is that State j chooses AC with probability $\frac{e_T^*+1}{e_T^*+2}$. When State i chooses D and observes State j's TC, State i's belief is that

equilibrium-path behavior. I assume that in the uninformative equilibrium, states interpret the partner's trade cooperation just as a mistake and cannot update their beliefs by observing the partner's trade cooperation.

State j chooses AC with probability 1. When State i chooses D and observes State j's D, State i's belief is that State j chooses AC with probability 0.

4.3 Summary

Figure 5 provides the summary of the equilibrium path in two equilibria to demonstrate both predicted international outcomes and the probability of an agreement in the alliance game. The shaded area represents the cases where states can successfully agree on either further alliance cooperation or the status quo. For example, the prediction of "$(D, TC) \rightarrow (SQ, AC)$" means that State A's one-sided defection in the trade game results in a failure of policy coordination in the alliance game.

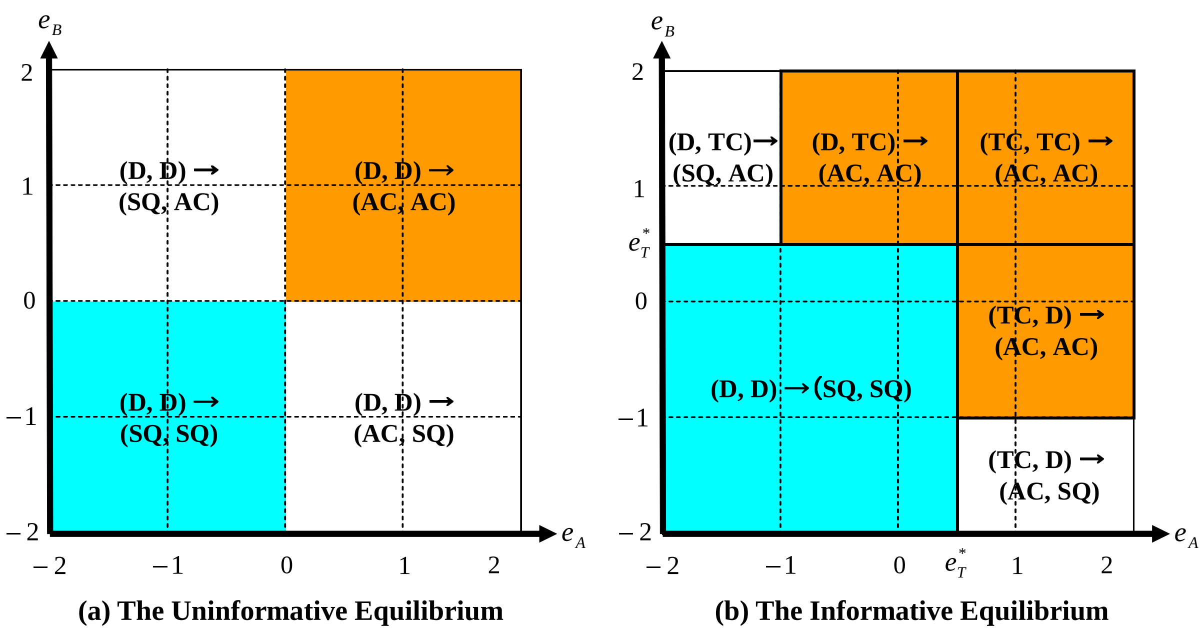

Figure 5: The Equilibrium Path of the Two PBEs

The comparison of the informative with the uninformative equilibria illuminates the signaling effect of trade. In the top-right and bottom-left areas of the informative equilibrium, states mutually convince each other to choose further alliance cooperation and the status quo, respectively. Moreover, when State i has moderate strategic needs within the range $[-1, e_T^*]$, State j's TC can persuade State i to agree with AC. The area of agreement enlarges when states can use trade policy to convey their intentions. Thus, the strategic use of intra-alliance trade cooperation can enhance alliance ties through signaling.

The main concern of this paper is to investigate how trade signaling promotes allies' agreements on further cooperation or the status quo in peacetime. I calculate the probability of agreement in both equilibria to analyze the net-effect of intra-alliance trade policy.

Let A denote the probability of agreements in the informative PBE. The probability of agreement is: $A = 1 - 2\left(\frac{1}{4}\right)\left(\frac{2-e_T^*}{4}\right) = \frac{3}{4} + \frac{e_T^*}{8}$. In contrast, the probability of agreement in the uninformative PBE is half because allies successfully coordinate security policies on AC with probability $\frac{1}{4}$ and on SQ with probability $\frac{1}{4}$. Since $A > \frac{3}{4}$ and $0 < e_T^* < 1$, trade signaling strongly promotes agreements with further alliance cooperation and the status quo. That is, intra-alliance trade policy serves as a strategic instrument to solve the uncertainty problem in peacetime alliance politics. At the same time, an opportunity of possible coordination in the future makes it possible to take mutually beneficial trade policy today. The effect of trade signaling is summarized by the following corollary.

Corollary 1. Without signaling, the probability of coordination is 50 percent. In contrast, with signaling, the probability of coordination is at least 75 percent.

5 Comparative Statics

The informative PBE describes the signaling logic of intra-alliance trade policy and the size of the signaling effect can be measured by the probability of agreement. In the equilibrium, the probability of agreement is the function of the parameters, the political benefits from trade liberalization a, the political costs of trade liberalization k, and the discount factor based on the polarity of the international system r. That is, the costliness of trade cooperation determines the effectiveness of trade signaling. Here, I present the results of comparative statics to grasp when the strategic use of intra-alliance cooperation works.

First, I consider the relationship among the political benefits from trade liberalization and both the threshold of trade cooperation e_T^* and the probability of agreement A. The partial derivative of e_T^* with regard to a is: $\frac{\partial e_T^*}{\partial a} = \frac{-2}{\sqrt{2r^2-4(a-k)r}} < 0$. Also, the partial derivative of A with regard to a is: $\frac{\partial A}{\partial a} = \frac{\partial A}{\partial e_T^*}\frac{\partial e_T^*}{\partial a} = \frac{1}{8}\left(\frac{-2}{\sqrt{2r^2-4(a-k)r}}\right) < 0$. The first result means that when political leaders gain more benefits from trade liberalization, they face relatively less domestic opposition for free trade and the broader type of e_i is able to use trade cooperation as a strategic instrument, making trade signaling less reliable. The second result implies that less costly trade cooperation constrains the possibilities of agreements in peacetime alliance politics.

> *Proposition 3.* As the benefits from trade liberalization increases, the use of trade cooperation becomes less costly, in turn making the signals of trade policy less credible. Less credible trade signaling decreases the probability of agreement.

Second, I explore the relationship between the costs of trade liberalization and both the threshold of trade cooperation e_T^* and the probability of agreement A. The partial derivative of e_T^* with regard to k is: $\frac{\partial e_T^*}{\partial k} = \frac{2}{\sqrt{2r^2-4(a-k)r}} > 0$. Also, the partial derivative of A with regard to k is: $\frac{\partial A}{\partial k} = \frac{\partial A}{\partial e_T^*}\frac{\partial e_T^*}{\partial k} = \frac{1}{8}\left(\frac{2}{\sqrt{2r^2-4(a-k)r}}\right) > 0$. The first result shows that when the costs of trade liberalization are higher, political leaders face more domestic opposition for free trade and only the narrow type of higher e_i can use trade cooperation as a strategic instrument. The second result indicates that more costly trade signaling increases the possibility of agreements in peacetime alliance politics.

> *Proposition 4.* As the costs of trade liberalization increases, the use of trade cooperation becomes more costly, in turn making the signal of trade policy more credible. More credible trade signaling increases the probability of agreement.

Third, I investigate the relationship between the discount factor based on the polarity of the international system and both the threshold e_T^* and the probability of agreement A. The partial derivative of e_T^* with regard to r is: $\frac{\partial e_T^*}{\partial r} = \frac{2(a-k)}{r\sqrt{2r^2-4(a-k)r}} < 0$. Also, the partial derivative of A with regard to r is: $\frac{\partial A}{\partial r} = \frac{\partial A}{\partial e_T^*}\frac{\partial e_T^*}{\partial r} = \frac{1}{8}\left(\frac{2(a-k)}{r\sqrt{2r^2-4(a-k)r}}\right) < 0$. The first result notes that when the international system changes from multipolar to bipolar and the discount factor increases, the adoption of trade cooperation becomes costless and the broader type of e_i becomes able to use trade cooperation as a strategic instrument. The second result implies that less costly trade cooperation decreases the probability of agreements in peacetime alliance politics.

> *Proposition 5.* As the international system changes from multipolarity to bipolarity and the discount factor increases, the use of trade cooperation become less costly, thus making the signal of trade policy less credible. Less credible trade signaling decreases the probability of agreement.

These results show that political leaders have a tradeoff between the effectiveness and the availability of trade cooperation. When political leaders confront strong political opposition and are in a multipolar world, the adoption of intra-alliance trade cooperation is too risky and costly, making trade signaling more credible. If political leaders can change trade patterns from conflicting to complementary over the long-term, they will become able to use trade cooperation as a strategic instrument, making trade signaling less credible. Thus, understanding the signaling logic of trade is helpful for controlling the effectiveness of trade signaling according to changes in international politics and market.

6 Empirical Analysis

In this section, I present a statistical model to test hypotheses about the signaling effect of trade in peacetime alliance politics. In peacetime, whenever leaders confronts unexpected situational changes domestically and internationally, they have a negotiation over the level of alliance commitment captured by the game theoretic model above. The fate of an alliance treaty depends on the results of a series of negotiations and successful policy coordination can prolong the life-span of an alliance treaty. Here, I analyze the timing of alliance termination to examine the relationship between trade signaling and alliance durability.

6.1 The Statistical Model

To model alliance durability, I adopt an accelerated failure time (AFT) model that describes survival times as a function of covariates. The AFT model estimates the risk of alliance over time as a positive random variable T. I employ a log-logistic specification to construct a linear model for $\ln(T)$. A benefit of using the log-logistic model is in capturing the institutional inertia of alliance treaties with regard to the hazard rate, $h(t)$, which is is a *conditional* failure rate at some year t. This provides the rate at which an alliance experiences termination or a member's withdrawal by t, given that the alliance had survived until t. The log-logistic hazard rate monotonically decreases if $\gamma \geq 1$, but increases and then decreases if $\gamma < 1$. Here, I assume $\tau_{i,t} = exp(-\beta' X)t_i$. The model implies that the actual survival time of an alliance treaty t_i is explained by observations of time-varying covariates X in the previous year $t-1$.[9]

$$\begin{aligned}
&\ln(t_i) = \beta' X_{t-1} + \ln(\tau_{i,t}) \\
&\beta' X_{t-1} = \beta_1 x_{1i,t-1} + \beta_2 x_{2i,t-1} + \ldots + \beta_k x_{ki,t-1} \\
&\tau_{i,t} \sim \text{Log-logistic}(\beta_0, \gamma)
\end{aligned}$$

The rules and informal interactions in the treaty can allow allies to reduce transaction costs and facilitate information exchange over time, in turn, reducing the hazard rate (Keohane 1984, pp.100–103). However, alliance treaties might also be more likely to experience failures before they mature. The log-logistic model reveals the details of alliance durability by estimating the shape of the hazard rate.

The dependent variable observes the duration of alliance treaties. I use the Alliance

[9]This model is equivalent to the following model: $\ln(t_i) = \beta_0 + \beta' X_{t-1} + u_i$ with $u_i \sim \text{logistic}(0, \frac{\pi\gamma}{\sqrt{3}})$. See Cleves, Gould, Gutierrez, and Marchenko (2010, p. 273).

Treaty Obligations and Provisions (ATOP) dataset to record the duration of alliance treaties.[10] The ATOP dataset captures the beginning year of each treaty as the signature rather than the ratification year. After signing an alliance treaty, political leaders are assumed to "behave as if the alliance is in force" (Leeds 2005, p.33).[11] The end year of each treaty is the termination year regardless of the reason.

There are four ways that an alliance can be terminated. Actions unrelated to the alliance sometimes cause the loss of one or more members' independence, resulting in the termination of the alliance treaty. The alliance relationship can also end when its specified provisions are achieved or if those provisions are violated. There is also the case where an alliance terminates because it is replaced with the new treaty (Leeds 2005; Leeds and Savun 2007). The practical meaning of the treaty might also terminate due to withdrawal of some of its members because it can cause significant changes in the security context. In this case, the members' withdrawal will change the current terms of the agreement and a new relationship will implicitly form among the remaining members. That is, an alliance treaty can have multiple phases. Therefore, I assume that the withdrawal of any member from the alliance is counted as an indication of alliance termination, a failure event in the duration analysis here. The duration of each alliance is calculated as the period between the beginning and the end year.

The independent variables consist of policy choice in intra-alliance trade, the political costs and benefits of trade liberalization, and the polarity of the international system. Policy choice in intra-alliance trade account for the value of the signal sent by engaging in trade. The latter three are political economic factors determining the effectiveness of trade signaling.

First, political leaders choose intra-alliance trade cooperation to convey their strategic needs to their partners. When leaders choose intra-alliance trade liberalization to enhance alliance ties, cooperative policy can cause a trade diversion effect and discriminate non-

[10] Leeds et al. (2002) explain the characteristics of the ATOP dataset. Their coding scheme allows us to investigate institutional differences of alliance treaties more than the alliance data by the Correlates of War project.

[11] If an alliance is signed but *not* ratified, this alliance is never included in the ATOP dataset.

members (Gowa 1994; Gowa and Mansfield 1993). As such, I measure intra-alliance trade cooperation by using intra-alliance trade share as the ratio of members' intra-alliance trade to their total trade.[12] When the strategic use of trade cooperation produces higher intra-alliance trade share, an alliance treaty is more likely to survive.

Next, the availability of intra-alliance trade cooperation can determine the effectiveness of trade signaling. When trade liberalization enhance more political support from exporters and consumers than the loss of support from import-competitors, intra-alliance trade cooperation can become an easier policy alternative. When the members' economies are complementary, their intra-alliance trade has a huge impact on their national welfare and promote support from exporters and consumers. Since joint gains from intra-alliance trade positively correlate with support from exporters and consumers, I measure political benefits by using intra-alliance trade dependency as the ratio of the members' intra-alliance trade to their total GDP.[13] When higher intra-alliance trade dependency makes trade signaling less effective, an alliance is less likely to survive.

Also, when allies' economies are more open, further trade liberalization often causes severe domestic protectionist pressures. Since tariffs and non-tariff barriers as the result of protectionist pressure can dampen openness of the markets, trade openness positively correlates with political costs that leaders have paid to choose trade liberalization.[14] Thus, allies' trade openness is an indicator for the political costs that accrue to a leader. Trade openness is defined as the total volume of each member's trade in an alliance.[15] The larger

[12] To calculate intra-alliance trade share, I calculate the sum of bilateral trade between alliance members i and j, BT_{ij}, and the sum of member i's total trade, TT_i. Then, I divide the former by the latter, $\frac{\Sigma BT_{ij}}{\Sigma TT_i}$ for $i \neq j$. The data of trade is based on Gleditsch (2002).

[13] To calculate intra-alliance trade dependency, I calculate the sum of bilateral trade between alliance members i and j, BT_{ij}, and the sum of member i's total GDP, GDP_i. Then, I divide the former by the latter, $\frac{\Sigma BT_{ij}}{\Sigma GDP_i}$ for $i \neq j$. The data on trade and GDP is based on Gleditsch (2002).

[14] Hiscox and Kastner (2008) measure trade protection by using the gravity model with the country-year dummy variable. They estimate the country-year trade barrier index for 82 countries in the period 1960-1992. They show that the level of trade barrier negatively correlates with total trade as a percentage of GDP. Pahre (2008) uses openness to measure the level of protection and shows that average tariff correlates with openness in the nineteenth century Europe.

[15] Here, I do not use the ratio of the total trade volume to the total GDP volume of alliance members because this ratio is the function of intra-alliance trade share and dependency and the correlation among these variables can cause multi-collinearity. The data on trade is based on Gleditsch (2002).

the total volume of all members' trade is, the more trade signaling is enhanced, making an alliance more likely to survive.

Finally, political leaders care about the instability of alliance relationships, which is described as the discount factor in the formal model. Allies in a bipolar world have greater difficulty switching to the opposing side than those in a multipolar world because alliance relationships are consolidated. In a multipolar world, allies worry about the instability of alliance relationships and intra-alliance trade cooperation is an investment with a huge risk. The polarity of the international system can measure political costs based on the instability of alliance relationship. Since the data covers the period 1950–2001, I use a dummy variable for the Cold War to describe the bipolar world. If the year $t_i - 1$ is within the period 1950–1990, the dummy variable equals 1, and otherwise 0. This coding is based on the number of great powers by the Correlates of War project.[16] Since bipolarity reduces political costs and makes trade signaling less effective, an alliance is less likely to survive in the Cold War.

Of course, the durability of alliances can be explained by other variables that the game theoretic model does not capture. Here, I control for the influence of a set of variables that are frequently discussed in the literature. These include types of alliance treaties, the power distribution in each alliance, types of political regimes, any member's use of force or participation in a war, and the number of members in a treaty.

Types of alliance treaties consist of defense, offense, neutrality, non-aggression, and consultation pacts in the ATOP dataset (Leeds 2005, pp.20-21), while the COW dataset categorizes alliances by defense pact, neutrality and non-aggression pact, and entente (Gibler and Sarkees 2004). Both coding schemes assume that defense and offense pacts require members to fulfill more serious commitments than other treaties. I employ a binary variable to indicate types of alliance treaties, which is equal to 1 if an alliance is an defense and/or offense

[16] I used the software, *EUGene*, to extract the data on the number of great powers(Bennett and Stam 2000). From 1950 to 1990, great powers were the members of the United Nations security council. The number of great powers increased to seven after 1991 because Germany and Japan become coded as great powers. Using the dummy variable is appropriate because the number of great powers does not have enough variances in the period 1950–2001.

pact, and 0 otherwise. I posit that states which sign a defense or offense pact will be more likely to show a strong commitment to the alliance.

Because the power distribution within each alliance can affect the life-span of an alliance treaty (Morrow 1991), I account for whether or not the alliance is symmetric. If a major power forms an alliance with a minor power, the major power acquires policy autonomy to change the status quo, while the minor power strengthens its protection based on security support by the partner. I use Smith's power index to measure the proportional asymmetry of GDP within the alliance.[17] This index takes any value between 0 and 1. As asymmetry grows, the value of the index approaches 1.[18] When power asymmetry is high, an alliance should be more likely to survive.

Because different political regimes can also determine the durability of alliance treaties (Gaubatz 1996; Leeds 1999; Reed 1997), I measure the level of democracy in each alliance. I calculate the mean of each member's value on the Polity IV democracy scale.[19] When an alliance has a high average level of democracy, it is more likely to survive.

Since violations of a treaty's obligations can cause the termination of an alliance (Leeds and Savun 2007), I use a binary variable for disputes to indicate cases where an alliance is in a crisis. This variable is equal to 1 if one or more members use force or participate in a war in the year, and 0 otherwise. When an alliance is in a crisis, it is less likely to survive. The number of members can influence the durability of alliances. As the number of members increases, allies face a burden-sharing problem and must solve the free-rider problem(Olson and Zeckhauser 1966; Sandler and Hartley 1999). The larger number of members also increases transaction cost to reach an agreement. Therefore, a multilateral alliance is more likely to fail than a bilateral alliance.

[17] Smith (2000) calculates the proportional asymmetry of GDP within each regional trade agreement by $P = \Sigma x_i^2 - 1/N$ for all i where x_i is each member's share of total pact GDP such that $\Sigma x_i = 1$. Since the upper bound (MAX) of P varies with the number of members, he controls for the difference in the maximum value of P by using P/MAX where MAX is equivalent to $1 - 1/N$.

[18] The GDP data is based on Gleditsch's (2002) data.

[19] Each member's value on the Polity IV democracy scale is calculated by subtracting the polity autocracy score from the polity democracy score. See Marshall and Jaggers (2009) for the Polity IV data.

Finally, the dataset covers 388 alliances that were formed in the period 1950-2000. The durability of alliances is examined in the period 1950-2001, during which 161 of the alliances were terminated or experienced one or more members' withdrawal.[20] A unit of analysis is an annual record of an alliance's survival or termination. Since individual observations are no longer independent within an alliance, I cluster the standard errors on each treaty to correct the size of the standard error. I employ the Breslow method to accounts for ties in duration data (Box-Steffensmeier and Jones 2004, pp.54-55) and log-transform the trade variables (intra-alliance trade share, intra-alliance trade dependency, and the total volume of trade within each alliance) to mitigate their skewed distributions.[21]

6.2 Results

Table 1 shows both the estimated coefficients and the time ratio for the log-logistic model of alliance durability. I interpret time ratio for each result, which indicates the percentage of actual survival times a one-unit increase in the variable of interest X_k increases or decreases. If the time ratio is greater than one, then a one-unit increase in X_k increases actual survival times. If the time ratio is less than one, then a one-unit increase in X_k decreases actual survival times. When, for example, the time ratio is 1.25, increasing the independent variable by one-unit increases actual survival times by 25 percent. If, on the other hand, the time ratio is 0.8, then a one-unit increase in the variable decrease actual survival times by 20 percent.

The results are broadly consistent with the signaling theory of trade and the independent variables are shown to significantly affect the actual survival times of alliance treaties. In contrast, none of the control variables have any statistically significant effect on actual

[20] Alliances that survived less than one year are omitted from the analysis because the statistical model explains how the covariates in the previous year affect the fate of the alliance treaty in the current year.

[21] When allies have no intra-alliance trade, the values of intra-alliance trade share and dependency are zero. The log-transformation of these variables generated 218 missing values in each variable because zero cannot be log-transformed. I use list-wise deletion to estimate the coefficients because the game theoretic model does not suppose that there is no trade flow among allies.

Table 1: Log-Logistic Model of Alliance Durability

Variable	Hypothesis	Coefficient (Robust S.E.)	Time Ratio
ln(Intra-alliance Trade Share)	+	0.200**	**1.221**
		(0.088)	
ln(Intra-alliance Trade Dependency)	–	–0.194*	**0.824**
		(0.104)	
ln(Total Trade)	+	0.161***	**1.174**
		(0.055)	
Cold War	–	–0.542***	**0.581**
		(0.198)	
Defense and/or Offense Pact	+	–0.244	0.784
		(0.151)	
Power Asymmetry	+	–0.143	0.867
		(0.256)	
Democracy	+	–0.019	0.981
		(0.014)	
Dispute	–	0.086	1.089
		(0.124)	
Number of Members	–	–0.006	0.994
		(0.017)	
Constant		–0.009	
		(1.403)	
γ		0.519***	
		(0.040)	
Log Pseudo-likelihood		–297.215	
Wald chi-squared		30.760	
Prob > chi-squared		< 0.001	
Number of Observations		4833	
Number of Alliance Treaties		388	

Note: *** = $p < 0.01$; ** = $p < 0.05$; * = $p < 0.1$

survival times.[22]

A one-percent increase in intra-alliance trade share generates a 22.1 percent increase in actual survival times and its effect is statistically significant at the 0.05 level. This suggests that political leaders can communicate through the strategic use of intra-alliance trade cooperation to enhance alliance ties. A one-percent increase in intra-alliance trade dependency generates a 17.6 percent decrease in actual survival times and its effect is statistically significant at the 0.1 level. This corroborates the hypothesis from the game theoretic model that as trade becomes more complementary, the use of trade cooperation becomes less costly,

[22] As an additional robustness check, I estimate the same model using the Cox proportional hazard model, a semi-parametric model, that makes no assumption about the shape of the baseline hazard function. The signs of the coefficients shown in Table 1 are consistent with those derived from the Cox proportional hazard model, though there are some minor differences in the statistical significance of several control variables that are not relevant to this study. The Cox model estimates are available upon request.

thus making trade policy a less credible signal. Less credible trade signaling in turn weakens the durability of alliances. A one-percent increase in the total trade volume within an alliance generates a 17.4 percent increase in actual survival times and its effect is statistically significant at the 0.01 level. This implies that severe domestic pressures from the result of trade liberalization constrains the availability of intra-alliance trade cooperation as a policy instrument. As the level of market openness increases, the use of trade cooperation becomes more costly, in turn making the signal of trade policy more credible. More credible trade signaling prolongs the life-span of an alliance treaty. Finally, if an alliance treaty is in the Cold War period, actual survival times decreases by 41.9 percent. Its effect is statistically significant at the 0.01 level. This shows that the polarity of the international system highly influence political calculations in peacetime alliance politics. As the international system changes from bipolarity to multipolarity, the use of trade cooperation becomes more costly, thus making the signal of trade policy more credible. More credible trade signaling reinforces the durability of alliances.

Note that the effects of the independent variables are not constant over time because the change in the hazard rate is not proportional to the baseline hazard but to the odds ratio over time. The impact of intra-alliance trade cooperation is provided by calculating a hazard rate. Suppose $\lambda = \exp(-\beta' X)$. For the log-logistic parameterization, the hazard rate is calculated by the following function (Box-Steffensmeier and Jones 2004, p. 32).

$$h(t) = \frac{\lambda^{\frac{1}{\gamma}} (\lambda t)^{\frac{1}{\gamma}-1}}{1 + (\lambda t)^{\frac{1}{\gamma}}}.$$

For the Cold War and the post Cold War periods, I estimate the hazard rate of the alliance treaties that require strong commitments. Figure 6 shows changes in the hazard rate overtime and the impact of trade signaling. The solid line represents the hazard rate of defense and/or offense pacts when the independent variables are fixed at the mean. In contrast, the dashed line denotes the hazard rate of defense and/or offense pacts when a one-percent increase in trade share affects the hazard rate.

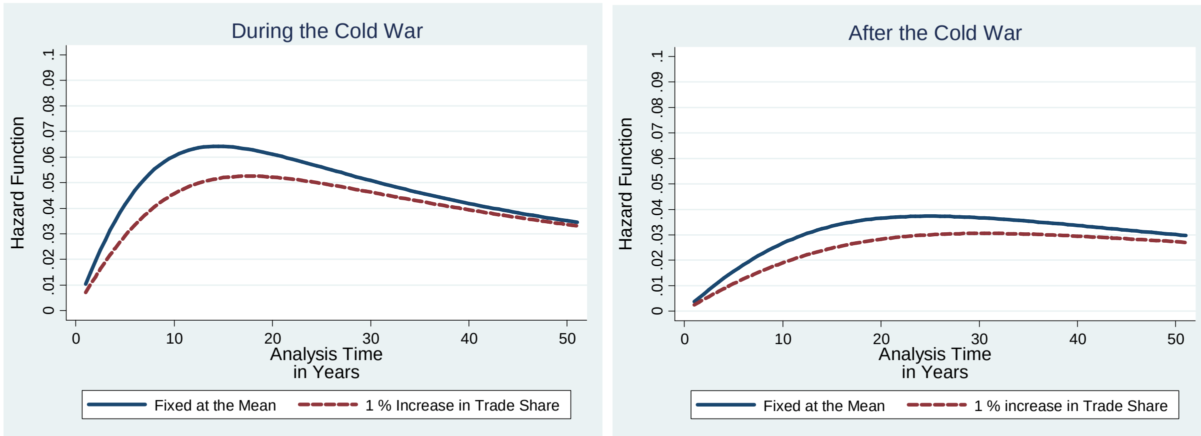

Figure 6: Hazard Function

Findings are summarized in the three points. First, the impact of intra-alliance cooperation is maximum for both periods when the hazard is the highest. Second, with the comparison of the Cold War with the post Cold War periods, the hazard rate is much lower after than during the Cold War. This reflect political costs based on alliance stability. As the international system changes from bipolar to multipolar, the use of intra-alliance cooperation becomes costly, making trade signaling credible. More credible trade signaling reduces the hazard rate. Third, alliance treaties get matured faster in the bipolar world than in the multipolar world. During the Cold War, the hazard rate stops increasing at almost fifteen years after alliance formation. On the other hand, the hazard rate after the Cold War stops increasing at almost twenty five years after alliance formation.

Alliance stability based on the polarity of the international system can affect the timing of alliance consolidation. This implies that we might observe different strategic interaction problems among allies after alliance are consolidated. Does this mean it takes roughly fifteen years to twenty five years for a security community, as described by Deutsch et al. (1957), to form? The interpretation of this result is that not only outsiders but also the members themselves doubt the alliance treaty in the first fifteen to twenty five years. The credibility of an alliance treaty is more likely to be tested by outsiders and environmental changes.

In contrast, once members believe their alliance relationship will endure, outsiders take this fact into account in their strategic calculation. An alliance treaty is less likely to be tested after its fifteenth to twenty-fifth year. This implies that alliance relationships become incorporated into social norms around fifteen to twenty five years after their formation. This result provides an opportunity to reconsider alliance politics from both the institutional and constructivist approaches.

7 Conclusion

Alliance treaties survive when allies can successfully coordinate security policies to cope with changes in external strategic environments. However, since allies do not always have the same preference over the level of alliance commitment, an uncertainty about their partners' resolve can be an obstacle for achieving an agreement among allies. I explored when and how allies can use intra-alliance cooperation to overcome the uncertainty problem, resulting in the survival of the treaty. I presented a negotiation model where leaders confront both domestic and international risks arising from intra-alliance trade liberalization. The equilibrium analysis shows that trade signaling can change leaders' beliefs and in turn reinforce alliance ties because only resolved leaders can overcome political costs for adopting intra-alliance trade cooperation. The logic of trade signaling illuminates the importance of intra-alliance trade cooperation as a policy instrument to maintain the survival of alliance treaties.

Formal analysis of intra-alliance trade policy provides some insightful implications for alliance politics in peacetime. According to a story of security externalities, allies prefer discriminative trade policy in favor of their partners because extra gains from intra-alliance trade liberalization can be used for enhancing their security positions in relation to potential opponents (Gowa 1994). Note that leaders need a long time to change the international structure with trade policy to realize security externalities. However, the strategic use of intra-alliance trade cooperation has an immediate effect on alliance politics and significantly enhance alliance durability.

The result of the empirical analysis is consistent with the signaling theory of trade and provides policy implications. The comparison of the Cold War period with the post Cold War period shows that alliances are more likely to experience failures in a bipolar world than in a multipolar world. This finding is inconsistent with the conventional wisdom. However, the theory of trade signaling explains how intra-alliance trade policy enhances the durability of alliances even in a multipolar world. The empirical analysis suggests that the consolidation of alliance treaties is realized much earlier in a bipolar world than in a multipolar world, which is consistent with the conventional wisdom. When the the timing of alliance termination is taken into consideration, I find the new characteristics of alliance durability with regard to the uncertainty problem.

In this paper, I explored the utility of foreign economic policy as a strategic instrument. I attribute the durability of alliance treaties to a series of negotiations in peace time alliance politics, not the polarity of the international system. The uncertainty problem is a significant obstacle to agreements in alliance politics. I developed the signaling theory of intra-alliance trade and showed that intra-alliance trade cooperation significantly mitigates the uncertainty problem. The results of the formal analysis complement the view of the existing literature and provide a microfoundation of foreign economic policies as strategic instruments. The results of the empirical analysis confirm the theory's hypotheses and illuminate the complexities of alliance durability. The theory of trade signaling is helpful for understanding better the dynamics in peacetime alliance politics.

8 Appendix

To derive the two PBE, I begin by specifying the best responses of each state by working backwards from the alliance game to the trade game. Let Xj denote the probability that

State j plays AC in the alliance game. State i's expected payoffs for playing AC and SQ are described by $EU_i(AC) = X_j(1 + e_i) + (1 - X_j)(e_i) = X_j + e_i$ and $EU_i(SQ) = X_j(0) + (1 - X_j)(1) = 1 - X_j$. The difference between these expected payoffs is $EU_i(AC) - EU_i(SQ) = e_i - 1 + 2X_j$. State i plays AC if $e_i \geq 1 - 2X_j$ and otherwise plays SQ. Thus, only State i's belief about State j's playing AC determines State i's best response after different outcomes of the trade game.

The Proof of Proposition 1

Suppose that all types of State i play D in the trade game. Since we can choose any off-the-equilibrium-path belief in the PBE to support the on-the equilibrium-path behavior, I assume that in the uninformative equilibrium, states interpret the partner's trade cooperation just as a mistake and cannot update their beliefs by observing the partner's trade cooperation. That is, State i is supposed not to update its belief after the trade game.

State i is indifferent between AC and SQ when $e_i = 1 - 2X_j = e^*$. Since the alliance game has the symmetric payoffs, State j also has the same critical value e^*. State j chooses AC with probability $\frac{1}{4}(2 - e^*)$ because $e_j \sim \text{unif}[-2, 2]$. Since $e^* = 1 - 2\left(\frac{1}{4}(2 - e^*)\right)$, $e^* = 0$. Hence, State i plays AC regardless of the trade game outcomes if $e_i \geq 0$, otherwise SQ. Formally, the best responses are $(\bullet, AC, AC)$ for $e_i \geq 0$ and $(\bullet, SQ, SQ)$ for $e_i < 0$.

For $e_i \geq 0$, the expected payoff for choosing (TC, AC, AC) is $Pr(e_j \geq 0)[f_i(TC, D) + rg_i(AC, AC)] + Pr(e_j < 0)[f_i(TC, D) + rg_i(AC, SQ)]$, while that for choosing (D, AC, AC) is $Pr(e_j \geq 0)[f_i(D, D) + rg_i(AC, AC)] + Pr(e_j < 0)[f_i(D, D) + rg_i(AC, SQ)]$. The difference is $EU_i(TC, AC, AC) - EU_i(D, AC, AC) = f_i(TC, D) - f_i(D, D) = a - k < 0$. Hence, the best response for $e_i \geq 0$ is D in the trade game. Similarly, the best response for $e_i < 0$ is D in the trade game. These best responses constitute the equilibrium strategies. These sets of the equilibrium strategies with beliefs constitute the uninformative equilibrium. (Q.E.D.)

The Proof of Proposition 2

Suppose that State j plays (TC, AC, AC) if $e_T^* \leq e_j \leq 2$, (D, AC, SQ) if $-1 \leq e_j < e_T^*$, and (D, SQ, SQ) if $-2 \leq e_j < -1$. Also suppose that there exists e_T^* between 0 and 1 for both states, making them indifferent between TC and D. Below, I specify State i's best responses given State j's strategies.

At information sets on the equilibrium path, State i's beliefs are determined by Bayes' rule and State j's strategies. Let TC_i and D_i denote State i's cooperation and defection in the trade game. Also, let AC_i and SQ_i denote State i's policy choice of cooperation and the status quo in the alliance game.

After observing (TC_i, TC_j) in the trade game, State i's belief about State j's AC is: $Pr(AC_j \mid TC_j) = \frac{Pr(AC_j)Pr(TC_j|AC_j)}{Pr(AC_j)Pr(TC_j|AC_j)+Pr(SQ_j)Pr(TC_j|SQ_j)} = \frac{\left(\frac{2-(-1)}{4}\right)\left(\frac{2-e_T^*}{2-(-1)}\right)}{\left(\frac{2-(-1)}{4}\right)\left(\frac{2-e_T^*}{2-(-1)}\right)+\left(\frac{-1-(-2)}{4}\right)(0)} = 1.$ (Note that State j plays AC after observing State i's TC if $-1 \leq e_j \leq 2$ and State j also plays TC if $e_T^* \leq e_j \leq 2$.) That is, State i's belief after observing (TC_i, TC_j) is that State j plays AC with probability 1. Hence, the difference between expected payoffs for playing AC and SQ is $EU_i(AC) - EU_i(SQ) = e_i - 1 + 2(1) = e_i + 1$. State i plays AC if $e_i \geq -1$ and otherwise plays SQ. Since $e_i \in [e_T^*, 2]$, State i plays AC after (TC_i, TC_j).

After observing (TC_i, D_j) in the trade game, State i's belief about State j's AC is: $Pr(AC_j \mid D_j) = \frac{Pr(AC_j)Pr(D_j|AC_j)}{Pr(AC_j)Pr(D_j|AC_j)+Pr(SQ_j)Pr(D_j|SQ_j)} = \frac{\left(\frac{2-(-1)}{4}\right)\left(\frac{e_T^*-(-1)}{2-(-1)}\right)}{\left(\frac{2-(-1)}{4}\right)\left(\frac{e_T^*-(-1)}{2-(-1)}\right)+\left(\frac{-1-(-2)}{4}\right)(1)} = \frac{e_T^*+1}{e_T^*+2}.$ (Note that State j plays AC after observing State i's TC if $-1 \leq e_j \leq 2$ and State j also plays D if $-1 \leq e_j < e_T^*$. Also note that State j plays SQ after observing State i's TC if $-2 \leq e_j < -1$ and State j also plays D within this range.) That is, State i's belief after observing (TC_i, D_j) is that State j plays AC with probability $\frac{e_T^*+1}{e_T^*+2}$ and otherwise plays SQ. Hence, the difference between expected payoffs for playing AC and SQ is $EU_i(AC) - EU_i(SQ) = e_i - 1 + 2\left(\frac{e_T^*+1}{e_T^*+2}\right) = e_i + \frac{e_T^*}{e_T^*+2}$. State i plays AC if $e_i \geq -\frac{e_T^*}{e_T^*+2}$ and otherwise plays SQ. Since $e_i \in [e_T^*, 2]$, State i plays AC after (TC_i, D_j).

After observing (D_i, TC_j) in the trade game, State i's belief about State j's AC is:

$Pr(AC_j \mid TC_j) = \frac{Pr(AC_j)Pr(TC_j|AC_j)}{Pr(AC_j)Pr(TC_j|AC_j)+Pr(SQ_j)Pr(TC_j|SQ_j)} = \frac{\left(\frac{2-e_T^*}{4}\right)(1)}{\left(\frac{2-e_T^*}{4}\right)(1)+\left(\frac{e_T^*-(-2)}{4}\right)(0)} = 1$. (Note that State j plays AC after observing State i's D if $e_T^* \leq e_j \leq 2$ and State j also plays TC within this range. Also note that State j plays SQ after observing State i's D if $-2 \leq e_j < e_T^*$ and State j never plays TC within this range.) That is, State i's belief after observing (D_i, TC_j) is that State j plays AC with probability 1. Hence the difference between expected payoffs for playing AC and SQ is $EU_i(AC) - EU_i(SQ) = e_i - 1 + 2(1) = e_i + 1$. State i plays AC if $e_i \geq -1$ and otherwise plays SQ after (D_i, TC_j).

After observing (D_i, D_j) in the trade game, State i's belief about State j's AC is: $Pr(AC_j \mid D_j) = \frac{Pr(AC_j)Pr(D_j|AC_j)}{Pr(AC_j)Pr(D_j|AC_j)+Pr(SQ_j)Pr(D_j|SQ_j)} = \frac{\left(\frac{2-e_T^*}{4}\right)(0)}{\left(\frac{2-e_T^*}{4}\right)(0)+\left(\frac{e_T^*-(-2)}{4}\right)(1)} = 0$. (Note that State j plays AC after observing State i's D if $e_T^* \leq e_j \leq 2$ and State j never plays D within this range. Also note that State j plays SQ after observing State i's D if $-2 \leq e_j < e_T^*$ and State j plays D within this range.) That is, State i's belief after observing (D_i, D_j) is that State j plays AC with probability 0. Hence, the difference between expected payoffs for playing AC and SQ is $EU_i(AC) - EU_i(SQ) = e_i - 1 + 2(0) = e_i - 1$. State i plays AC if $e_i \geq 1$ and otherwise plays SQ. Since $e_i < e_T^* < 1$, State i plays SQ after (D_i, D_j).

Combining the best responses construct a set of the following strategies: State i plays (TC, AC, AC) if $e_T^* \leq e_i \leq 2$, (D, AC, SQ) if $-1 \leq e_i < e_T^*$, and (D, SQ, SQ) if $-2 \leq e_i < -1$. In order to examine State i's best response in the trade game, I show that there exists e_T^* making State i indifferent between the strategies (TC, AC, AC) and (D, AC, SQ). State i's expected payoffs for these strategies are described by $EU_i(TC, AC, AC) = Pr(e_T^* \leq e_j \leq 2)[f_i(TC, TC) + rg_i(AC, AC)|e_T^*] + Pr(-1 \leq e_j < e_T^*)[f_i(TC, D) + rg_i(AC, AC)|e_T^*] + Pr(-2 \leq e_j < -1)[f_i(TC, D) + rg_i(AC, SQ)|e_T^*] = \left(\frac{2-e_T^*}{4}\right)(2a - k + r(1 + e_T^*)) + \left(\frac{e_T^*+1}{4}\right)(a - k + r(1 + e_T^*)) + \left(\frac{1}{4}\right)(a - k + re_T^*)$ and $EU_i(D, AC, D) = Pr(e_T^* \leq e_j \leq 2)[f_i(D, TC) + rg_i(AC, AC)|e_T^*] + Pr(-1 \leq e_j < e_T^*)[f_i(D, D) + rg_i(SQ, SQ)|e_T^*] + Pr(-2 \leq e_i < -1)[f_i(D, D) + rg_i(SQ, SQ)|e_T^*]$ $= \left(\frac{2-e_T^*}{4}\right)(a + r(1 + e_T^*)) + \left(\frac{e_T^*+2}{4}\right)(r)$. The difference between these expected payoffs is $EU_i(TC, AC, AC) - EU_i(D, AC, SQ) = \left(\frac{2-e_T^*}{4}\right)(a - k) + \left(\frac{e_T^*+2}{4}\right)(a - k) + \left(\frac{e_T^*+1}{4}\right)(re_T^*) +$

$\left(\frac{1}{4}\right)(re_T^* - r) = a - k + \left(\frac{e_T^*+2}{4}\right)(re_T^*) - \frac{r}{4}$. This difference must be zero when $e_i = e_T^*$.

$$a - k + \left(\frac{e_T^* + 2}{4}\right)(re_T^*) - \frac{r}{4} = 0$$
$$\Rightarrow \qquad re_T^{*2} + 2re_T^* - \{r - 4(a-k)\} = 0.$$
$$e_T^* = -1 + \frac{\sqrt{2r^2 - 4(a-k)r}}{r} \qquad (\because 0 < e_T^* < 1).$$

The equilibrium strategies and the beliefs constitute the informative equilibrium. (Q.E.D.)

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