(Preliminary; Comments Welcome)

Private Trigger Strategies in the Presence of Concealed Trade Barriers

Jee-Hyeong Park

School of Economics
Seoul National University

First Version: June 2004
This Version: March 2006

ABSTRACT

To analyze the issue of enforcing international trade agreements in the presence of potential deviations of which countries receive *imperfect* and *private* signals, this paper analyzes a repeated bilateral trade relationship where each country can secretly raise its protection level through concealed trade barriers. In particular, it explores the possibility that countries adopt *private trigger strategies* (*PTS*) under which each country triggers an *explicit* tariff war based on its privately observed imperfect signals of the potential use of concealed trade barriers Based on a full characterization of optimal protection sequence that each can take under *PTS*, the analysis establishes that symmetric countries may restrain the use of concealed trade barriers under *symmetric PTS* as long as their private signals are sensitive enough to concealed protection. The analysis on *symmetric PTS* also reveals that it is not optimal to push down the cooperative protection level to its minimum attainable level. The paper identifies two factors that may limit the use of *PTS*; one is a reduction in each country's time lag to adjust its protection level in response to the other country's initiation of an explicit tariff war, and the other is asymmetry among countries. Both of these factors may limit the level of cooperation attainable under *PTS* by reducing the length of a tariff war phase that countries can employ against potential deviations.

Corresponding Author: Address: School of Economics, Seoul National University, San 56, Sillim-Dong, Kwanak-Ku, Seoul, 151-746, Korea; tel: +82-2-880-6329; fax: +82-2-886-4231; email: j-hpark@snu.ac.kr

JEL Classification Code: F02; F13

Keywords: Concealed Trade Barriers; Imperfect Private Information; Trigger Strategies

1. Introduction

Enforcing international trade agreements often involve disputes with countries presenting different opinions about potential deviations from agreements. Differences in opinions may take various forms, such as disagreement over the existence of *concealed trade barriers* in disputes between the U.S and Japan during 1980s or disagreement over legitimacy of antidumping duties, a frequent theme in the dispute settlement procedure of the World Trade Organization (WTO). These disagreements reflect imperfectness of information about deviations from trade agreements. In addition to being *imperfect*, each country's opinion of potential deviations can be *private* in the sense that its true opinion is not known to other countries. For example, when the U.S. Trade Representative (USTR) engages in a negotiation with China to curtail piracy and counterfeiting that impede the U.S. intellectual property rights, China and the USTR may not know each other's true belief regarding Chinese government's effort level to curtail such practices, which in turn may contribute to a breakdown in the negotiation.[1]

To analyze the issue of enforcing international trade agreements in the presence of potential deviations of which countries receive imperfect and private signals, this paper analyzes a repeated bilateral trade relationship where each country can secretly raise its protection level through concealed trade barriers. In particular, it explores the possibility that countries adopt *private trigger strategies* (*PTS*) under which each country triggers an *explicit* tariff war based on its privately observed imperfect signals of the potential use of concealed trade barriers.[2] The analysis specifies the condition under which countries can restrain deviations based on *PTS*, and characterizes an optimal symmetric *PTS* that maximizes symmetric countries' expected payoffs under *PTS*. This paper also identifies factors that may limit the use of *PTS* in restraining deviations from trade agreements.

[1] The signals that the USTR receives regarding potential deviations from trade agreements often come from the US companies whose interests are affected by deviations. Such signals may involve companies' private information of which public revelation can be costly for those companies, forcing the signals to be private.

[2] While this paper focuses on the enforcement of trade agreement in the presence of concealed trade barriers, the analysis of *PTS* in this paper is applicable to a broad range of repeated gamed where players privately observe imperfect signals of potential deviations, as discussed later.

This paper follows the well-established tradition of analyzing the enforcement issue of trade agreements using trigger strategies in a repeated game setup. With regard to observable actions, such as tariff protection, many studies model international trade agreements as a subgame perfect equilibrium in a repeated game. For example, Dixit (1987) establishes that countries can sustain the equilibrium with zero tariffs by restraining their unilateral incentives to impose tariffs based on a threat of invoking tariff wars against positive imposing tariffs. [3] To address the issue of enforcing trade agreements in the presence of concealed trade barriers, Riezman (1991) modifies "*trigger-price strategies*" of Green and Porter (1984) on collusion among firms into "*import trigger strategies*" where countries start a trade war phase when the level of imports falls below a critical level. Because the import level is negatively correlated with countries' protection levels, countries have an incentive to hold down their concealed protection levels to reduce the probability of triggering a costly tariff war. In contrast to import trigger strategies where countries coordinate their punishments through *imperfect public information* of potential deviations, such as the import levels, each country unilaterally triggers a punishment phase based on its own *imperfect private information* of potential deviations under *PTS*. This paper differs from previous studies by focusing on how the private nature of signals about deviations may limit the use of trigger strategies in enforcing trade agreements. [4]

In establishing that countries can restrict the use of concealed protection based on *PTS*, an analytical challenge emerges from the necessity to check not only one-time deviations from the specified strategy, but whole deviation paths that each country may take in order to ensure that proposed

---

[3] Bagwell and Staiger (1990) show that countries need to have high as well as low protection periods as a cooperative equilibrium to relax higher deviation incentives during high trade volume periods. More recently, Maggi (1999) extends the repeated game analysis beyond a bilateral trade setting to study the role of multilateral institutions, such as the WTO. Bond and Park (2002) show that gradual tariff reductions may emerge as a way to relax incentive constraints for asymmetric countries by inter-temporally shifting their payoffs along a time-varying trade agreement. One may find a more comprehensive review of studies that take this approach towards international trade agreements in Staiger (1995) and in Bagwell and Staiger (2002).

[4] Bagwell and Staiger (2005) analyze the issue of implementing trade agreements when each government is privately informed about its domestic political pressure for protection. Their analysis differs from this paper's analysis because it focuses on the structure of trade agreements that can induce the truthful revelation of private political pressure rather than analyzing the enforcement of trade agreements when countries privately observe imperfect signals of potential deviations.

PTS can serve as a *supergame equilibrium* of the repeated protection-setting game.[5] To solve this issue, I provide a full characterization of an optimal (possibly deviatory) protection sequence that each country may take under *PTS* in Section 2. In the same section, I establish that there exists a stationary protection level that each country may sustain as a cooperative protection level as long as the countries' private information are sensitive enough to concealed protection.

In addition to establishing that symmetric countries may restrain the use of concealed trade barriers with *symmetric PTS*, the analysis in Section 3 characterizes *optimal symmetric PTS* under which countries maximize their expected discounted payoffs. The analysis shows that it is not optimal to push down the cooperative protection level to its minimum level attainable under symmetric *PTS* due to the cost associated with increasing the probability of costly tariff wars.

A potential limitation of *PTS* comes from the private nature of signals utilized under *PTS* because it limits the lengths of tariff war phases that countries can employ. Note that each country may misrepresent its private signal either by initiating a tariff war when its private signal does not belong to the range under which it is supposed to trigger a tariff war or by not initiating a tariff war when its private signal does belong to such a range. On the one hand, if the tariff war phase is too long so that its expected payoff is higher when it ignores its private signals to trigger a tariff war, then each country will never initiate a tariff war. On the other hand, each country will always initiate a tariff war by imposing its static optimal (explicit) tariff if the following war is too short.[6] In contrast to repeated games with public information where countries can choose any length for their tariff war phases, the private nature of signals imposes restrictions on the lengths of tariff war phases employable under *PTS*!

[5] As discussed in more details in Section 2, if private signals are triggering tariff wars as under *PTS*, any deviatory action that each country might have taken in a previous period can influence its optimal deviatory action in a current period. This in turn prohibits us to apply the logic of the well-known "one-stage-deviation principle" for a subgame perfect equilibrium. If the private information is almost perfect as assumed by Park (2002), however, there will be no need to fully characterize an optimal (deviatory) protection sequence because countries will simply set their static optimal protection levels when they deviate.

[6] Each country benefits in the period that it unilaterally initiates a tariff war phase because it imposes its static optimal tariff. If there is no actual tariff war phase to be followed, then imposing the static optimal tariff becomes a dominant strategy for each country.

This paper identifies two factors that may limit the effectiveness of *PTS*; one is a reduction in each country's time lag to adjust its protection levels in response to the other country's initiation of an explicit tariff war, discussed in Section 4.1 and the other is asymmetry among countries, analyzed in Section 4.2. Both of these factors may limit the level of cooperation attainable under *PTS* by reducing the length of a tariff war phase that countries can employ against potential deviations from the cooperative behaviors. One of the factors that determine the length of a tariff war phase that a country can initiate under *PTS* is the one-period gain that the country can realize in the period that it initiates a tariff war phase. If there is a reduction in each country's time lag to adjust protection levels in response to the other country's initiation of an explicit tariff war, the tariff-war-initiating country's one-period gain by imposing its static optimal tariff decreases as the other country will react more quickly by its own static optimal tariff. Such a reduction in the gain from initiating a tariff war decreases the length of the tariff war phase, which in turn reduces the level of cooperation that countries can sustain under *PTS*. Asymmetry among countries can reduce the length of a tariff war phase that a small country can initiate against a large country in a similar manner. As asymmetry in countries' relative market size increases, the small country's ability to change the terms of trade in its favor by imposing tariffs decreases, reducing the one-period gain that it can realize by imposing its static optimal tariff. This in turn shortens the length of a tariff war phase that the small country can initiate against the large country's potential use of concealed protection.

The analysis of *PTS* provides useful insights on the evolution of an aggressive unilateral approach of the U.S. toward enforcing international trade agreements. According to the analysis, the fact that the U.S. is the largest trading economy in the world make her to be a country most capable of using *PTS* to deter its trading partners' use of concealed trade barriers. Indeed, the U.S. is the only country in the world that has the legislation, Section 301, authorizing its government to invoke a tariff war based on its own unilateral judgment of potential deviations from trade agreements. As emphasized in the analysis, the credibility of invoking a tariff war is crucial for the success of such a unilateral approach. To raise the credibility of a punitive tariff war, the U.S. Congress has modified section 301 in 1988 by shifting the authority to retaliate from president to the U.S. Trade Representatives (USTR) and mandating retaliation against unjustifiable practices. Note also that the USTR has often taken its Section 301 investigation cases to the WTO panel investigation.[7] Such an action seemingly respecting the multilateral enforcement mechanism of the WTO, can be an attempt to make the threat of invoking a tariff war more credible by delegating the judgment of deviations to a third party panel who would presumably care less about the cost of a tariff war that may result from the judgment.

While this paper focuses on the issue of enforcing international agreements, the analysis of *PTS* is applicable to a more broad range of problems. The protection-setting game analyzed in this paper belongs to repeated games with *imperfect private monitoring*. It is well known in the game theory literature that analyzing repeated games with imperfect private monitoring is difficult because utilization of privately observed signals in determining continuation plays can destroy the recursive structure of repeated games.[8] As a way to overcome this problem in repeated games with imperfect private monitoring, Kandori and Matsushima (1998) and Compte (1998) allow players to communicate their privately observed information regarding potential deviations. Such communication serves as imperfect *public* information (in the sense that every player can observe the communication), thus, restoring a recursive structure to the repeated game.[9] *PTS* considered in this paper show an alternative way to restore a recursive structure to a repeated game with imperfect private monitoring. Under *PTS*, each country initiates a tariff war phase by imposing *explicit* tariffs if it receives private signals that are highly correlated with other countries' defective behaviors. Because all trading partners can perfectly observe explicit tariffs, countries can avoid potential confusion between punishment phases and non-punishment phases, which ensures a "recursive" structure of the repeated game along the equilibrium path. In the context of collusion among firms that can engage in secret-price cuttings, firms can employ *advertised* (thus *public*) sales to initiate a punishment phase against potential defections from collusive

[7]. See Bayard and Elliott (1992) for a detailed discussion of Section 301 cases.
[8] See Kandori and Matsushima (1998) for a more detailed discussion on this point.

pricing as a way to coordinate their punishments. According to the analysis of *PTS* in this paper, the expansion of internet commerce can negatively affect collusive behaviors based on such *PTS* because it reduces each firm's time lag to effectively advertise its sales over the internet in response to the other firm's initiation of advertised sales.

The paper is organized as follows. Section 2.1 develops a bilateral trade model where each country receives imperfect private signals of each other's use of concealed barriers and specifies *PTS* that countries employ to deter such protection. Section 2.2 describes unconventional incentive constraints under *PTS*, providing conditions under which those incentive constraints can be satisfied. Section 3 proves the existence of symmetric *PTS* as a supergame equilibrium of the repeated protection setting game (Section 3.1) and characterizes optimal symmetric *PTS* under which countries maximize their joint expected discounted payoffs (Section 3.2). Section 4.1 analyzes how a reduction in the time lag to adjust protection levels in response to an initiation of an explicit tariff war affects effectiveness of *PTS*, and Section 4.2 provides an analysis of the effect of introducing asymmetry among countries on *PTS*. Section 5 concludes by providing a summary of the results together with a discussion about a possible extension of this paper's analysis toward understanding the workings of dispute settlement procedures of the WTO.

2. Private Trigger Strategies

To explore the possibility of using *private trigger strategies* (*PTS*) to restrain the use of concealed protection, I analyze an infinitely repeated bilateral trade relationship where each country can control its import protection level either through non-tariff barriers that is not observable to the other country or through explicit tariffs. Section 2.1 lays out a bilateral trade model where each country receives imperfect private signals of each other's use of concealed barriers and specifies *PTS* that countries

[9] In these studies, the communication among players entails no cost (so that it is "cheap talk") and each country's revealed private information does not affect its own continuation payoff in order to ensure truthful revelation of private information.

employ to deter such protection. Section 2.2, describes the incentive constraints for *PTS* to be a supergame equilibrium in the repeated protection-setting game, providing conditions for those incentive constraints to be satisfied.

2.1. A Trade Model with Concealed Trade Barriers and Private Trigger Strategies

The basic bilateral trade model comes from Dixit (1987) with concealed trade barriers being introduced in a similar way as in Riezman (1991). There exist two countries, home (H) and foreign (F), producing and trading two products, good 1 and good 2, under perfect competition. H imports good 2 and F imports good 1. In each period, H and F simultaneously choose their explicit tariff levels, e and e^* and their (total) import protection levels, τ and τ^*, respectively, having $\tau - e$ and $\tau^* - e^*$ represent the concealed protection levels of H and F (an asterisk denotes F's variables). Then, the local prices, p_1, p_2, p_1^*, and p_2^* are related as follows: $p_2 = p_2^*(1+\tau)$ and $p_1^* = p_1(1+\tau^*)$. Given the assumption of perfect competition, I can define each country's one-period payoff function as a function of the terms of trade, denoted by $\pi\ (\equiv p_1 / p_2^*)$, and its own protection level. Such a payoff function, represented by $w(\pi,\tau)$ and $w^*(\pi,\tau^*)$, induces a corresponding import demand function for each country, denoted by $m(\pi,\tau)$ and $m^*(\pi,\tau^*)$. If there exists no uncertainty (random elements) in this world, each country's amount of imports is a deterministic function of each country's protection level and the term of trade. This implies that each country may figure out the exact level of the other country's protection based on the information about the terms of trade and the amount of imports, even in the presence of concealed trade barriers.

However, when I introduce uncertainty into the model as a way of representing shocks to technology or preferences, the exact derivation of other countries' protection levels based on the amount of imports and the terms of trade may become impossible. Uncertainty caused by random shocks can be modeled into random components in countries' import demand functions as follows:

(1) $$m_t = m(\pi_t, \tau_t, \theta_t) \text{ and } m_t^* = m^*(\pi_t, \tau_t^*, \theta_t^*),$$

where $\theta_t \in \Theta$ and $\theta_t^* \in \Theta^*$ respectively denote each country's random components affecting its import demand at period t (subscript t denotes the variables determined in period t), which follow a joint density function, $f(\theta_t,\theta_t^*)$ that is iid across periods. In equilibrium, the following balance of payment condition should be satisfied:

(2) $$\pi_t \cdot m(\pi_t, \tau_t, \theta_t) = m^*(\pi_t, \tau_t^*, \theta_t^*),$$

which determines the equilibrium values for π_t, m_t, and m_t^* as functions of τ_t, τ_t^*, θ_t, and θ_t^*. Now, each country's one-period expected payoff, denoted by u and u^*, with random shocks realizing after τ and τ^* being determined, is a function of both countries' protection levels:

(3)
$$u(\tau_t, \tau_t^*) = \iint_{(\theta_t,\theta_t^*)\in(\Theta,\Theta^*)} w\left(\pi_t(\tau_t, \tau_t^*, \theta_t, \theta_t^*), \tau_t\right) f(\theta_t, \theta_t^*) d\theta_t d\theta_t^* \text{ for H, and}$$
$$u^*(\tau_t^*, \tau_t) = \iint_{(\theta_t,\theta_t^*)\in(\Theta,\Theta^*)} w^*\left(\pi_t(\tau_t, \tau_t^*, \theta_t, \theta_t^*), \tau_t^*\right) f(\theta_t, \theta_t^*) d\theta_t d\theta_t^* \text{ for F.}$$

Regarding derivatives of $u(\tau, \tau^*)$ and $u^*(\tau^*, \tau)$ with respect to τ and τ^*, I assume that the following standard trade-theoretic results continue to hold in the presence of these random variables: $\partial u/\partial\tau > 0$ at $\tau = 0$ and $\partial u^*/\partial\tau^* > 0$ at $\tau^* = 0$ (each country has an incentive to raise its protection level above zero); $\partial u/\partial\tau^* < 0$ and $\partial u^*/\partial\tau < 0$ (such protection hurts the other country); $\partial u/\partial\tau + \partial u^*/\partial\tau < 0$ and $\partial u/\partial\tau^* + \partial u^*/\partial\tau^* < 0$ (such protection reduces the total payoff of H and F as it creates distortional loss) for (τ, τ^*) that are not trade-prohibitive. For analytical simplicity, I introduce the following additional assumptions: $\partial^2 u/\partial\tau^2 < 0$ and $\partial^2 u^*/\partial\tau^{*2} < 0$ (the marginal gain from protection decreases as the protection level increases); $\partial^2 u/\partial\tau\partial\tau^* = 0$ and $\partial^2 u^*/\partial\tau\partial\tau^* = 0$ (the marginal gain from protection is not affected by the other country's protection level).[10] These additional assumptions guarantee the existence of a unique static optimal protection level for each country which I denote by h (> 0) for H and h^* (> 0) for F. The one-shot protection setting game between H and F then generates a Nash equilibrium where $(\tau, \tau^*) = (h, h^*)$.

At the end of period t, each country privately observes realized values of its own payoff and its random variable, (u_t, θ_t) by H and (u_t^*, θ_t^*) by F, and both countries observe a pair of explicit tariffs, (e_t, e_t^*).[11] Each country cannot infer the exact level of the other country's concealed protection because it does not know the realized value of the other's random variable. However, note that the privately observed information, denoted by $\omega_t = (u_t, \theta_t, \tau_t) \in \Omega$ for H and $\omega_t^* = (u_t^*, \theta_t^*, \tau_t^*) \in \Omega^*$ for F, can serve as a measure for detecting the other country's potential use of concealed protection.[12] More specifically, each country can choose a subset of its possible private signals, denoted by Ω^D and Ω^{D*}, such that $\partial Pr(\omega_t \in \Omega^D)/\partial \tau_t^* > 0$ and $\partial Pr(\omega_t^* \in \Omega^{D*})/\partial \tau_t > 0$ where $Pr(B)$ denotes the probability of event B occurring. For example, H can assign values of u_t that are less than a certain critical value as the payoff part of Ω^D. This can induce $\partial Pr(\omega_t \in \Omega^D)/\partial \tau_t^* > 0$ because $\partial u_t/\partial \tau_t^* < 0$, and the sensitivity of u_t against τ_t^* can improve once it is properly controlled for θ_t and τ_t.

Given the stage game depicted above, I can describe an infinitely repeated protection-setting game between H and F with their privately observed signals serving as measures to detect the potential use of concealed protection as follows. A strategy for each country is defined by $s = (s(t))_{t=1}^{\infty}$ and $s^* = (s^*(t))_{t=1}^{\infty}$ with

(4) $$s(t): A^{t-1} \times \Omega^{t-1} \times (E^*)^{t-1} \rightarrow A \text{ and } s^*(t): (A^*)^{t-1} \times (\Omega^*)^{t-1} \times E^{t-1} \rightarrow A^*$$

where A and A^* denote the sets of possible actions that each country can take in a period with $a \equiv (\tau, e) \in A$ and $a^* \equiv (\tau^*, e^*) \in A^*$, and E and E^* denote the sets of possible explicit tariffs that each country can impose in a period with $e \in E$ and $e^* \in E^*$. $s(t)$, the strategy of H in period t, assigns its action (τ_t, e_t)

[10] These properties of social utility function can be derived from a two good, partial equilibrium model of trade with linear demand and supply curves. See Bond and Park (2002) for derivation of such properties.

[11] Countries may also observe public statistics, like import volumes, that can serve as imperfect public information of concealed protection levels. Riezman (1991) shows that countries can use such *imperfect public information* as a device that triggers tariff wars to discourage the potential use of concealed protections. The focus of this paper is, however, on the possibility of using *imperfect private information*, like (u_t, θ_t, τ_t) for H and $(u_t^*, \theta_t^*, \tau_t)$ for F, as such a triggering device.

based on the history of its own previous actions, $(a_1, \cdots, a_{t-1}) \in A^{t-1}$, the history of its own private information, $(\omega_1, \omega_2, \cdots, \omega_{t-1}) \in \Omega^{t-1}$, and the history of the other country's explicit tariffs, $(e_1^*, e_2^*, \cdots, e_{t-1}^*) \in (E^*)^{t-1}$, while $s^*(t)$ assigns the action for F in a similar manner. If each country conforms to its strategy defined in (4), then the expected discounted payoff is given by:

$$(5) \qquad \begin{aligned} V(s,s^*) &= E\left[\sum_{t=1}^{\infty} u(\tau_t,\tau_t^*)(\delta^C)^{t-1} \middle| (s,s^*)\right] \text{ for H, and} \\ V^*(s,s^*) &= E\left[\sum_{t=1}^{\infty} u^*(\tau_t^*,\tau_t)(\delta^C)^{t-1} \middle| (s,s^*)\right] \text{ for F,} \end{aligned}$$

where $E[\cdot \mid (s, s^*)]$ is the expectation with respect to the probability measure on histories induced by strategy profile (s, s^*); $u(\cdot)$ and $u^*(\cdot)$ are one-period expected payoffs defined in (3); and $\delta^C \in [0, 1)$ denotes the common discount factor. Now, I define a *supergame equilibrium* in this infinitely repeated protection setting game between H and F as follows:

Definition 1. A strategy profile (s, s^*) is a *supergame equilibrium* in the repeated game between H and F, if $V(s,s^*) \geq V(s^{/},s^*)$ and $V^*(s,s^*) \geq V^*(s,s^{*/})$ for all $s^{/} \neq s$ and $s^{*/} \neq s^*$.[13]

To explore the possibility of supporting cooperative protection levels, denoted by l and l^*, that are lower than the one-shot Nash protection levels (h and h^*) as a supergame equilibrium of the repeated game described above, I consider following strategies under which each country uses its private signal, ω and ω^*, as a device to trigger an explicit tariff war against the other country's potential use of concealed protections:[14]

---

[12] Once H observes u_t, θ_t, and τ_t, for example, H can calculate the probability of $\tau_t^* \leq l$ (a certain protection level) by $Pr(\tau_t^* \leq l \mid u_t, \theta_t, \tau_t) = \int_0^l \left(\int_{\theta^* \in \Theta^*(u_t,\theta_t,\tau_t\tau^*)} f(\theta_t,\theta^*)d\theta^* \right) d\tau^*$ where $\Theta^*(u_t, \theta_t, \tau_t, \tau^*) = \{\theta^* \in \Theta^* \mid u(\tau_t, \tau^*, \theta_t, \theta^*) = u_t\}$.

[13] This definition of a *supergame equilibrium* of a repeated game with privately observed signals of other players' actions follows Matsushima (1991).

[14] One trivial supergame equilibrium strategy profile is the one of assigning one-shot Nash protection levels (h, h^*) for all periods because it assigns the static optimal behavior for each country.

(i) Given that period $t-1$ was a "*cooperative*" period with (e_{t-1}, e^*_{t-1}) = (0, 0), H sets (τ_t, e_t) = (l, 0) if $\omega_{t-1} \notin \Omega^D$, and H initiates a tariff war by setting (τ_t, e_t) = (h, h) if $\omega_{t-1} \in \Omega^D$; F sets (τ_t^*, e_t^*) = (l^*, 0) if $\omega^*_{t-1} \notin \Omega^{D*}$, and F initiates a tariff war by setting (τ_t^*, e_t^*) = (h^*, h^*) if $\omega^*_{t-1} \in \Omega^{D*}$.

(ii) Given that a "*tariff war phase*" was initiated in period $t-1$ with $(e_{t-1}, e^*_{t-1}) \neq$ (0,0), H and F set (τ, e) = (h, h) and (τ^*, e^*) = (h^*, h^*) for the following (T – 2) periods and they continue to do so one more period with probability λ if (e_{t-1}, e^*_{t-1}) = (h, 0); H and F set (τ, e) = (h, h) and (τ^*, e^*) = (h^*, h^*) for the following (T^* – 2) periods and they continue to do so one more period with probability λ^* if (e_{t-1}, e^*_{t-1}) = (0, h); H and F set (τ, e) = (h, h) and (τ^*, e^*) = (h^*, h^*) for the following (T^S – 2) periods and they continue to do so one more period with probability λ^S if (e_{t-1}, e^*_{t-1}) = (h, h^*), with T, T^*, and T^S being integer numbers that are greater than or equal to 2, and λ, λ^*, and λ^S belonging to [0, 1].

(iii) In period 1 and other "*initial*" periods right after the end of any tariff war phase, H sets (τ, e) = (l, 0) with probability (1 – Pr) but initiates a tariff war by setting (τ, e) = (h, h) with probability Pr, and F sets (τ^*, e^*) = (l^*, 0) with probability (1 – Pr^*) but initiates a tariff war by setting (τ, e) = (h, h) with probability Pr^*, where $Pr = Pr(\omega_t \in \Omega^D)$ and $Pr^* = Pr(\omega_t^* \in \Omega^{D*})$ with (τ_t, e_t) = (l, 0) and (τ_t^*, e_t^*) = (l, 0).

Note that the absence or presence of explicit tariffs classifies any period into either a "*cooperative*" period (with no explicit tariffs) or a "*tariff war*" period (with some positive tariffs). While H and F cannot observe each other's concealed protection levels, they use their explicit tariffs as public signals to coordinate tariff war phases as described in (i) and (ii). Extending a tariff war phase one more period with a certain probability as specified in (ii) is an instrument to make the length of a tariff war phase to behave as if it were a continuous variable.[15] Also note that the actions for period 1 and other "initial periods" described in (iii) are designed to make them mimic those in a period that immediately follows a "cooperative" one, which in turn simplifies the analysis of the trigger strategies defined above.[16] Finally, note that the sets of private signals that trigger tariff wars (Ω^D, Ω^{D*}) and the lengths of different tariff war phases ($T-1$ if H triggers, T^*-1 if F triggers, and T^S-1 if H and F trigger simultaneously) with corresponding probabilities to extend the tariff war phases one more period (λ, λ^*, λ^S) characterize the strategy profile defined by (i), (ii) and (iii), together with the cooperative protection levels (l, l^*). Thus, I define *private trigger strategies* (*PTS*) as follows:

Definition 2. If (i), (ii), and (iii) describe a strategy profile ($\underline{s}$, $\underline{s}^*$), then, ($\underline{s}$, $\underline{s}^*$) are ***private trigger strategies* (*PTS*)** with ($l, l^*, \Omega^D, \Omega^{D*}, T, T^*, T^S, \lambda, \lambda^*, \lambda^S$) as characterizing parameters.

Given this definition, I can derive the expected discounted payoffs under ($\underline{s}$, $\underline{s}^*$) with ($l, l^*, \Omega^D, \Omega^{D*}, T, T^*, T^S, \lambda, \lambda^*, \lambda^S$), denoted by $V(\underline{s},\underline{s}^*)$ and $V^*(\underline{s},\underline{s}^*)$, as follows:

(6)
$$V(\underline{s},\underline{s}^*)=\frac{u(h,h^*)}{1-\delta^C}+\frac{(1-Pr\cdot Pr^*)[u(l,l^*)-u(h,h^*)]+Pr(1-Pr^*)[u(h,l^*)-u(l,l^*)]+Pr^*(1-Pr)[u(l,h^*)-u(l,l^*)]}{1-\delta^C+Pr(1-Pr^*)(\delta^C-\delta)+Pr^*(1-Pr)(\delta^C-\delta^*)+Pr\cdot Pr^*(\delta^C-\delta^S)},$$
$$V^*(\underline{s},\underline{s}^*)=\frac{u^*(h^*,h)}{1-\delta^C}+\frac{(1-Pr\cdot Pr^*)[u^*(l^*,l)-u^*(h^*,h)]+Pr(1-Pr^*)[u^*(l^*,h)-u^*(l^*,l)]+Pr^*(1-Pr)[u^*(h^*,l)-u^*(l^*,l)]}{1-\delta^C+Pr(1-Pr^*)(\delta^C-\delta)+Pr^*(1-Pr)(\delta^C-\delta^*)+Pr\cdot Pr^*(\delta^C-\delta^S)}$$

[15] For example, $\lambda = 0$ implies that H and F play the one-shot Nash tariff war for ($T-2$) periods, and $\lambda = 1$ implies that they play the one-shot Nash tariff war for ($T-1$) periods, with each $\lambda \in (0,1)$ being equivalent to a case where they play the one-shot Nash tariff war for some intermediate length of periods between ($T-2$) and ($T-1$). This allows the expected discounted payoff from invoking a tariff war phase to vary smoothly (by varying the length of a tariff war phase "*smoothly*") so that it can be set equal to the expected discounted payoff from not invoking a tariff war phase, an important requirement for incentive constraints considered in Section 2.2.1.

[16] If, for example, $Pr = 0 \neq Pr(\omega_t \in \Omega^D)$ with $(\tau_t, e_t) = (l, 0)$ and $(\tau_t^*, e_t^*) = (l, 0)$, then the expected one-period payoffs for period 1 and other initial periods will be different from those for any period immediately following a cooperative one, making the expected discounted payoffs along the equilibrium path more complicated than those in (6). Furthermore, having actions in period 1 and in other initial periods different from those in periods immediately following a cooperative period will make deviation incentives different across these periods, which in turn complicates characterization of the optimal protection sequence in Section 2.2.2.

where $\delta = \lambda(\delta^C)^T + (1-\lambda)(\delta^C)^{T-1}$, $\delta^* = \lambda^*(\delta^C)^{T^*} + (1-\lambda^*)(\delta^C)^{T^*-1}$, and $\delta^S = \lambda^S(\delta^C)^{T^S} + (1-\lambda^S)$ $(\delta^C)^{T^S-1}$, having $(\delta^C - \delta)$, $(\delta^C - \delta^*)$, and $(\delta^C - \delta^S)$ respectively represent the relative length of the tariff war phase initiated by H alone, by F alone, and by H and F simultaneously. Because (T, T^*, T^S, λ, λ^*, λ^S) uniquely defines (δ,δ^*,δ^S) as shown above, I will describe *PTS* using (l, l^*,Ω^D, Ω^{D*}, δ, δ^*, δ^S) instead of using (l, l^*,Ω^D, Ω^{D*}, T, T^*, T^S, λ, λ^*, λ^S) from now on.

2.2. Incentive Constraints under Private Trigger Strategies

In this section, I analyze incentive constraints for PTS to be a supergame equilibrium in the repeated game described in Section 2.1. The private nature of signals that trigger tariff wars under PTS makes such incentive constraints different from the incentive constraints for trigger strategies under which public signals trigger punishment phases in two distinctive ways. First, note that each country may misrepresent its private signal either by initiating a tariff war when its private signal does not belong to the trigger range (Ω^D for H and Ω^{D*} for F) or by not initiating a tariff war when its private signal does belong to such a range because the signal is not observed by the other country. On the one hand, if the tariff war phase is so long such that its expected payoff is higher when it ignores its private signals to trigger a tariff war, then each country will never initiate a tariff war along the equilibrium path under PTS.[17] On the other hand, each country will always initiate a tariff war by imposing its static optimal tariff if the following war is too short, as in the case where $T = T^* = T^S = 2$ and $\lambda = \lambda^* = \lambda^S = 0$ so that no tariff war follows.[18] In contrast to the repeated game with imperfect public information where countries can choose any length for their tariff war phases, the private nature of signals utilized under PTS imposes restrictions on the lengths of tariff war phases. Section 2.2.1 analyzes such limits on the lengths of tariff war phases that PTS can employ.

[17] Along the equilibrium path under *PTS*, each country's private signal is not informative about the other country's potential deviation of raising its concealed protection level because countries set cooperative protection levels in cooperative periods. A realized value of each country's private signal, therefore, does not affect its incentive to initiate a tariff war along the equilibrium path.

There is another reason why the incentive constraints under *PTS* are different from the case where countries rely on public information in triggering tariff wars. To check the absence of $s^{/}(\neq \underline{s})$ or $s^{*/}(\neq \underline{s}^{*})$ such that $V(s^{/}, \underline{s}^{*}) > V(\underline{s}, \underline{s}^{*})$ and $V^{*}(\underline{s}, s^{*/}) > V^{*}(\underline{s}, \underline{s}^{*})$, I need to check not only *one-time deviations* from the specified strategy, but *whole deviation paths* that each country may take. If a public signal is triggering tariff wars, then checking non-existence of unilateral incentives for one-time defections is enough to guarantee the absence of such strategy profiles.[19] If private signals are triggering tariff wars as under *PTS*, any deviatory action that each country might have taken in a previous period can influence its optimal deviatory action in a current period. This is because the previous period defection may affect the other country's private signal, thus influencing its current period action. For example, a change in $\tau_{t\text{-}1}$ affects $Pr^{*}(\omega_{t-1} \in \Omega^{D})$ as $\partial Pr^{*}(\omega_{t-1} \in \Omega^{D^{*}})/\partial \tau_{t\text{-}1} > 0$, which in turn affects H's optimal protection level in period *t*. This necessitates characterization of an optimal (potentially deviatory) protection sequence that each country may take against $(\underline{s}, \underline{s}^{*})$ in analyzing the incentive constraints for *PTS*. Section 2.2.2 characterizes such a sequence for H under *PTS*, and shows that H's optimal protection sequence can be a stationary one of setting τ at l (the cooperative protection level) in all periods until a tariff war starts, a prerequisite for *PTS* to be a supergame equilibrium of the repeated game between H and F.[20]

2.2.1. Constraints on Lengths of Tariff War Phases

---

[18] Note that each country benefits in the period that it unilaterally initiates a tariff war phase because it imposes its static optimal tariff. If there is no actual tariff war phase to be followed, then imposing the static optimal tariff becomes a dominant strategy for each country.

[19] When a public signal is triggering tariff wars, any deviatory actions that each country might have taken in any previous periods will not affect its optimal deviatory action in the current period for a given history of public signals up to the current period. This is because defections in the previous periods affect the other country's current and future actions only through affecting the history of public signals. Therefore, we can apply the logic of one-stage-deviation principle for subgame perfection equilibrium with observable actions (Theorem 4.1. and Theorem 4.2 in Fudenberg and Tirole, 1991) to perfect public equilibrium with imperfect public information. This independence between an optimal current deviation and previous deviations breaks down under *PTS* which rely on imperfect private signals to trigger tariff war phases.

[20] While Section 2.2.2 focuses on characterizing the optimal protection sequence for H under *PTS*, the same characterization can be applied to the optimal protection sequence for F.

In any period that immediately follows a cooperative period with $(e, e^*) = (0, 0)$ and in any initial periods (period 1 and a period right after the end of any tariff war phase), each country faces the choice of whether to initiate a tariff war phase by imposing its static optimal tariff or not. To eliminate the incentive to misrepresent private signals in such periods, the expected payoff from initiating a tariff war phase should be identical to the expected payoff from not initiating it for each country. Denote such conditions that equate those expected payoffs by *ICP* for H and ICP^* for F. Then,

ICP:

$$(1-Pr^*)[u(l,l^*)+\delta^C V_C)] + Pr^*[u(l,h^*)+(\delta^C-\delta^*)V_N+\delta^* V_C] =$$
$$(1-Pr^*)[u(h,l^*)+(\delta^C-\delta)V_N+\delta V_C] + Pr^*[u(h,h^*)+(\delta^C-\delta^S)V_N+\delta^S V_C],$$

(7) $\boldsymbol{ICP^*}$***:***

$$(1-Pr)[u^*(l^*,l)+\delta^C V_C^*)] + Pr[u^*(l^*,h)+(\delta^C-\delta)V_N^*+\delta V_C^*] =$$
$$(1-Pr)[u^*(h^*,l)+(\delta^C-\delta^*)V_N^*+\delta^* V_C^*] + Pr[u^*(h^*,h)+(\delta^C-\delta^S)V_N^*+\delta^S V_C^*],$$

where $V_C \equiv V(\underline{s}, \underline{s}^*)$, $V_C^* \equiv V^*(\underline{s}, \underline{s}^*)$, $V_N \equiv u(h, h^*)/(1-\delta^C)$, and $V_N^* \equiv u^*(h^*, h)/(1-\delta^C)$. For each country in period t that follows a cooperative period or an initial period, the left side of each equality in (7) represents the expected discounted payoff from not initiating a tariff war phase, thus setting $(\tau_t, e_t) = (l, 0)$ for H and $(\tau_t^*, e_t^*) = (l^*, 0)$ for F. The right side of each equality represents the expected discounted payoff from initiating a tariff war phase, thus setting $(\tau_t, e_t) = (h, h)$ for H and $(\tau_t^*, e_t^*) = (h^*, h^*)$ for F. In calculating these expected discounted payoffs in (7), it is assumed that the other country initiates a tariff war phase with a certain probability that conforms *PTS*, Pr^* by F and Pr by H.

Using $u(l, l^*) - u(l, h^*) = u(h, l^*) - u(h, h^*)$ and $u^*(l^*, l) - u^*(l^*, h) = u^*(h^*, l) - u^*(h^*, h)$ from $\partial^2 u/\partial\tau\partial\tau^* = 0$ and $\partial^2 u^*/\partial\tau\partial\tau^* = 0$, I can simplify (7) into

(ICP) $\quad u(l,l^*)-u(h,l^*)+(\delta^C-\delta)(V_C-V_N) = Pr^*[(\delta^C-\delta^*)-(\delta-\delta^S)](V_C-V_N)$, and

(ICP*) $\quad u^*(l^*,l)-u^*(h^*,l)+(\delta^C-\delta^*)(V_C^*-V_N^*) = Pr[(\delta^C-\delta)-(\delta^*-\delta^S)](V_C^*-V_N^*)$.

For any given cooperative protection levels (l, l^*) and any given ranges of private signals that trigger tariff war phases (Ω^D, Ω^{D*}), I have three variables ($\delta, \delta^*, \delta^S$) to be determined with two equations (*ICP* and *ICP**), potentially having infinite combinations of ($\delta, \delta^*, \delta^S$) that satisfies *ICP* and *ICP**. To have *ICP* and *ICP** satisfied regardless of values that Pr^* and Pr may take, however, $\delta^C + \delta^S$ = $(\delta^* + \delta)$ needs to hold. Then, $\delta^C - \delta$ = $[u(h, l^*) - u(l, l^*)]/(V_C - V_N)$ from *ICP* and $\delta^C - \delta^*$ = $[u^*(h^*, l) - u^*(l^*, l)]/(V_C^* - V_N^*)$ from *ICP**.[21] Therefore, I obtain the following lemma on the sufficient condition for H and F not having any incentive to misrepresent its private signals along the equilibrium path under *PTS*:

Lemma 1.

(a) If $\delta^C - \delta$ = $[u(h, l^*) - u(l, l^*)]/(V_C - V_N)$, $\delta^C - \delta^*$ = $[u^*(h^*, l) - u^*(l^*, l)]/(V_C^* - V_N^*)$, and $\delta^C + \delta^S$ $= (\delta^* + \delta)$, then, *ICP* and *ICP** are satisfied for any values of Pr^* and Pr.

(b) If H and F value their future payoffs high enough (δ^C is close enough to 1) and the probability of a tariff war being triggered along the equilibrium path is low enough (Pr and Pr^* are close enough to 0), then, for any given combination of (l, l^*, Ω^D, Ω^{D*}) with (l, l^*) < (h, h^*) there exists a unique combination of δ, δ^*, and δ^S that satisfies the sufficient condition for *ICP* and *ICP** as defined in *Lemma 1* (a).

Proof) (a) is obvious from simplified *ICP* and *ICP**. See Appendix for the proof of (b).

For a given combination of (l, l^*, Ω^D, Ω^{D*}), note that *ICP* and *ICP** specify the lengths of tariff war phases that countries can employ under *PTS*. Since $\delta = \lambda(\delta^C)^T + (1-\lambda)(\delta^C)^{T-1}$,

[21] Generally speaking, *ICP* and *ICP** need not be satisfied for any values of Pr^* and Pr because $Pr = Pr(\omega_t \in \Omega^D)$ and $Pr^* = Pr(\omega_t^* \in \Omega^{D*})$ with $(\tau_t, e_t) = (l, 0)$ and $(\tau_t^*, e_t^*) = (l, 0)$ along the equilibrium path under *PTS*. As discussed in Section 2.2.2, however, countries may misrepresent private signals along their deviation path under which Pr^* and Pr may not take the same values as those along the equilibrium path. *Lemma 4* (b) in Section 2.2.2 establishes that the sufficient condition in *Lemma 1* (a) indeed guarantees countries have no strict incentives to misrepresent their private signals even along their deviation paths.

$\delta^* = \lambda^*(\delta^C)^{T^*} + (1-\lambda^*)(\delta^C)^{T^*-1}$, and $\delta^S = \lambda^S(\delta^C)^{T^S} + (1-\lambda^S)(\delta^C)^{T^S-1}$, *ICP* limits the length of a tariff war phase that H can initiate unilaterally (T, λ); ICP^* limits the length of a tariff war phase that F can initiate unilaterally (T^*, λ^*); and $\delta^C + \delta^S = (\delta^* + \delta)$ determines the length of a tariff war phase that H and F initiate simultaneously (T^S, λ^S). Part (*b*) of *Lemma 1* establishes that there exists a unique combination of lengths of tariff war phases that satisfy the sufficient condition for *ICP* and ICP^* defined in *Lemma 1* (*a*) if H and F place high enough values for their future payoffs and the possibility of tariff wars is low enough along the equilibrium path.

As the private nature of signals constraints the lengths of tariff war phases under *PTS*, one can ask whether such constraints may become binding constraints for H and F in restraining the use of concealed protection. I will analyze this potential limitation of *PTS* in Section 3 and Section 4.

2.2.2. Optimal Protection Sequence and Existence of a Stationary Protection Level

The first analytical task of this section is to characterize an optimal (potentially deviatory) protection sequence that each country may take given that the other country conforms to *PST*. Because an optimal protection level of a country in any period depends on its protection level set in the previous period as discussed earlier, a complete deviation path needs to be specified to describe an optimal deviation. Once an optimal protection sequence is characterized, then, I address the question of whether a stationary protection sequence exists as an optimal protection choice. The existence of such a stationary protection sequence is a prerequisite for the existence of *PTS* with (l, l^*) < (h, h^*) as a supergame equilibrium of the repeated trade relation between H and F.

To characterize the optimal protection sequence for H, I analyze the dynamic optimization problem for H to maximize its expected discounted payoff by choosing an optimal protection sequence $\{\tau_{d+1}\}_{d=0}^{\infty}$, given that F follows its specified strategy under *PTS*. Then, the dynamic optimization problem for H is

(8) $$\underset{\{\tau_{d+1}\}_{d=0}^{\infty}}{Sup} \sum_{d=0}^{\infty}\left\{(\delta^C)^d \cdot \left[\prod_{i=0}^{d-1}\left[1 - Pr^*(\tau_i)\right]\right] \cdot F(\tau_d, \tau_{d+1})\right\}$$

where $\prod_{i=0}^{d-1}[1-Pr^*(\tau_i)] = [1-Pr^*(\tau_0)]\times[1-Pr^*(\tau_1)]\times\cdots\times[1-Pr^*(\tau_{d-1})]$ with $\prod_{i=0}^{-1}[1-Pr^*(\tau_i)] = 1$, $Pr^*(\tau_i)$ = $Pr(\omega_i^* \in \Omega^{D*})$ given (τ_i, e_i) = $(\tau_i, 0)$ and (τ_i^*, e_i^*) = $(l^*, 0)$, and $\tau_0 = l$; and $F(\tau_d, \tau_{d+1}) = Pr^*(\tau_d)[u(\tau_{d+1}, h^*) + (\delta^C - \delta^*)V_N + \delta^* V_{CO}] + [1-Pr^*(\tau_d)]u(\tau_{d+1}, l^*)$ with $V_{CO} = V_C$. Note that the optimal protection sequence $\{\tau_{d+1}\}_{d=0}^{\infty}$ specifies the protection levels only until F triggers an initial tariff war phase. The optimization problem in (8) also assumes that H will follow its specified strategy under *PTS* once F triggers an initial tariff war phase with V_{CO} = V_C ($\equiv V(\underline{s}, \underline{s}^*)$). The full optimization problem should include the optimal protection sequences after the end of each tariff war phase that may occur in the future periods. If V_{CO} is set to be equal to the maximized expected discounted payoff of the full problem, however, the resulting optimal sequence from (8) will remain the same after each tariff war phase. This is because H will face an identical maximization problem in determining the optimal protection sequence after the end of each tariff war phase. Therefore, characteristics of the optimal protection sequence derived from (8) will be qualitatively identical to those of the full optimization problem as long as the expected discounted payoff of the full problem exists and takes a finite value.[22] Also note that the optimal protection sequence considered in (8) excludes the possibility of using explicit tariffs as a part of its path. As shown later in *Lemma 4* (*b*) of this section, however, once the lengths of tariff war phases satisfy the sufficient condition for *ICP* and *ICP** in *Lemma 1* (a), then, H cannot increase its payoff by using explicit tariffs along its deviation path.

[22] The discounted payoff of the full optimization problem can be obtained by applying the following iterative process to the optimization problem in (8). The optimization described in (8) will generate a discounted payoff as an outcome of the initial optimization problem with V_{CO} being initially set at $V(\underline{s}, \underline{s}^*)$ defined in (6). Then, set the value of V_{CO} in (8) to have the value of this initially generated discounted payoff, supposedly higher than the initial V_{CO}, which redefines the optimization problem in (8). This redefined optimization problem will generate another discounted payoff as an outcome of this second optimization problem. Then, set V_{CO} in (8) to have the value of this newly generated discounted payoff, which once again redefines the optimization problem in (8), and continue this iterative process until the discounted payoff generated through this process reaches its limit. As the sequence of the discounted payoffs generated through this process is monotonically increasing and bounded, there exists such a limit. This limit will be equal to the discounted payoff of the full maximization problem.

Hence, there is no loss of generality in analyzing the optimal protection sequence for H through the optimization problem defined in (8).[23]

Even though the optimization problem in (8) does not take a standard form for which a dynamic programming method is typically applied, *Lemma 2* (*a*) below establishes equivalency between (8) and the following (non-standard) dynamic programming problem:[24]

(9) $$V(\tau_{-1}) = \underset{\tau\in[0,h]}{Sup}\left\{F(\tau_{-1},\tau) + \delta^{C}[1 - Pr^{*}(\tau_{-1})]V(\tau)\right\} \text{ for all } \tau_{-1} \in [0, h],$$

where τ_{-1} and τ, respectively denote a previous-period and a current-period protection level of H. Note that limiting H's protection choice to be equal or less than h as in (9) does not affect the generality of the optimization problem because H has no incentive to raise its protection level above its static optimal protection level, h. Given a solution $V(\cdot)$ to (9), the optimal policy correspondence G: $[0, h] \to [0, h]$ is defined by:

(10) $$G(\tau_{-1}) = \{\tau \in [0, h]: V(\tau_{-1}) = F(\tau_{-1}, \tau) + \delta^{C}[1 - Pr^{*}(\tau_{-1})]\cdot V(\tau)\},$$

which contains values of τ that maximizes $V(\tau_{-1})$ for each $\tau_{-1} \in [0, h]$. Despite the fact that the dynamic optimization problem in (8) and the corresponding dynamic programming problem in (9) take non-standard forms, *Lemma 2* establishes the following standard results on V and G:

Lemma 2.

(*a*) Define $V_S(\tau_0)$ be the supremum function that is generated by (8). Then, (*i*) V_S satisfies (9); (*ii*) the solution to (9) $V(\tau_{-1}) = V_S(\tau_{-1})$; (*iii*) every optimal protection sequence solving (8) is generated from

---

[23] While I focus on characterizing the optimal protection sequence for H under *PTS* in this section, the same characterization can be applied to the optimal protection sequence for F.

[24] (8) is not a standard problem in the sense that the component that corresponds to the return function of a standard problem, $[\prod_{i=0}^{d-1}[1 - Pr^{*}(\tau_i)]]F(\tau_d, \tau_{d+1})$ depends not only on the current choice variable and the choice made in the immediate prior period (as in the case of a usual return function of a typical dynamic programming problem) but also on all the choices made since the initial period. The dynamic programming problem in (9) is not a standard form because the current state variable, τ_{-1}, affects not only the current return function part, $F(\tau_{-1}, \tau)$, but also the future discounted payoff part through $[1 - Pr^{*}(\tau_{-1})]$.

G in (10); (*iv*) any protection sequence generated by G in (10) is an optimal protection sequence that solves (8).

(*b*) There exists a unique continuous function V that satisfies (9).

(*c*) The optimal policy correspondence G defined by (10) is compact-valued and upper- hemi-continuous. (See Appendix for Proof)

Given *Lemma 2*, I can characterize the optimal protection sequence of H by characterizing $G(\cdot)$ in (10) because any protection sequence generated by G with the initial τ being set at l is an optimal protection sequence that solves (8). Utilizing one of generalized envelope theorems of Milgrom and Segal (2002) and a general result of Cotter and Park (2004) on the differentiability of the value function, I can characterize V and G as follows: [25]

Lemma 3.

Assume that the lengths of punishment phases satisfy the conditions in *Lemma 1* (*a*).

(*a*) $V(\tau_{-1})$ is strictly decreasing in $\tau_{-1} \in [0, \text{h}]$.

(*b*) $G(\tau_{-1})$ is strictly increasing in τ_{-1} in the sense that $g(\tau_{-1}^{//}) > g(\tau_{-1}^{/})$ for all $\tau_{-1}^{//} > \tau_{-1}^{/} \in [0, h]$ with $g(\tau_{-1}^{//}) \in G(\tau_{-1}^{//})$ and $g(\tau_{-1}^{/}) \in G(\tau_{-1}^{/})$. (See Appendix for Proof)

Because a higher τ_{-1} (a higher protection level in the cooperative previous period) implies a higher probability that F triggers a tariff war phase in the current period, a higher τ_{-1} implies a more hostile environment for H to maximize its discounted payoff. Therefore, the outcome of the maximization problem, $V(\tau_{-1})$, will get smaller as τ_{-1} increases (*Lemma 3* (*a*)).

[25] In characterizing V and G, I cannot use the well-known result of Benveniste and Scheinkman (1979) on the differentiability of the value function. While Benveniste and Scheinkman established that concavity of the return function on the state and choice variables is sufficient to guarantee the differentiability of the resulting value function of a typical dynamic programming problem, the dynamic problem of choosing the optimal protection sequence analyzed in this paper does not belong the typical dynamic programming problem, as explained earlier. Recently, Milgrom and Segal (2002) developed generalized envelope theorems for arbitrary choice sets, and Cotter and Park (2004) established differentiability of the value function on the range of the optimal policy

To understand *Lemma 3* (*b*), first note that choosing τ (a current-period protection level) is an act to balance the current period's loss from setting the protection level below *h* (the static optimal one) against the future periods' gain from reducing the probability of a tariff war. Figure 1 demonstrates this nature of optimal τ. Given the pervious-period protection level τ_{-1} is equal to $\tau_{-1}^{/}$, the static optimal protection that maximizes the expected current period payoff, $\Pr^*(\tau_{-1}^{/})u(\tau,h^*)+[1-\Pr^*(\tau_{-1}^{/})]u(\tau,l^*)$, is *h*. Setting τ = *h* also maximizes $F(\tau_{-1}^{/},\tau)$ in Figure 1; $F(\tau_{-1}^{/},\tau)=Pr^*(\tau_{-1}^{/})u(\tau,h^*)+[1-Pr^*(\tau_{-1}^{/})]u(\tau,l^*)+Pr^*(\tau_{-1}^{/})[\delta^C-\delta^*)V_N+\delta^*V_C])$ where τ does not affect the future expected discounted payoff contingent upon a tariff war being initiated in the current period, $(\delta^C-\delta^*)V_N+\delta^*V_C$. By reducing τ below *h*, however, H can increase its expected discounted payoff of the current period, $F(\tau_{-1}^{/},\tau)+\delta^C[1-Pr^*(\tau_{-1}^{/})]V(\tau)$ because $V(\tau)$ strictly decreases in τ from *Lemma 3* (*a*). As shown in Figure 1, if H lowers τ from *h*, $\delta^C[1-Pr^*(\tau_{-1}^{/})]V(\tau)$ strictly increases. Therefore, $g(\tau_{-1}^{/})$, the optimal current-period protection with $\tau_{-1}^{/}$ being the previous-period protection level, is lower than *h*.

Given this understanding of the optimal choice over τ as a balancing act between the static incentive to raise τ closer to *h* and the dynamic incentive to avoid a tariff war by reducing τ, I can explain why $G(\tau_{-1})$ strictly increases in τ_{-1} using Figure 1. When τ_{-1} increase from $\tau_{-1}^{/}$ to $\tau_{-1}^{//}$, it may shift $\mathrm{F}(\tau_{-1},\tau)$ upwards as shown in Figure 1 but it will not affect $\partial \mathrm{F}(\tau_{-1},\tau)/\partial\tau$ = $\partial u(\tau,l^*)/\partial\tau$, implying that the static incentive to raise τ closer to *h* stays the same; for example, $\mathrm{F}(\tau_{-1}^{//},h)-F(\tau_{-1}^{//},g(\tau_{-1}^{/}))=\mathrm{F}(\tau_{-1}^{/},h)-F(\tau_{-1}^{/},g(\tau_{-1}^{/}))$ in Figure 1. An increase in τ_{-1}, however, weakens the dynamic incentive for lowering τ to avoid a tariff war in a future period because it increases the likelihood of a tariff war phase starting in the current period. Figure 1, illustrates this by $\delta^C[1-Pr^*(\tau_{-1}^{//})][V(g(\tau_{-1}^{/}))-V(h)]$ < $\delta^C[1-Pr^*(\tau_{-1}^{/})][V(g(\tau_{-1}^{/})-V(h)]$ with $Pr^*(\tau_{-1}^{//})>Pr^*(\tau_{-1}^{/})$; the

correspondence, regardless of the curvature of the return function. I apply these results in characterizing *V* and *G*, dynamic gains from reducing τ from h to $g(\tau'_{-1})$ decreases as τ_{-1} increases from τ'_{-1} to τ''_{-1}. As a result, a higher τ_{-1} moves the balance for choosing an optimal τ towards a higher current period protection level so that $g(\tau''_{-1}) > g(\tau'_{-1})$ as shown in Figure 1. This is because an increased likelihood of a tariff war in the current period (caused by a higher τ_{-1}) reduces the dynamic gains attainable through keeping the protection level low while the static incentive to raise the protection level stays the same.

The fact that $G(\tau_{-1})$ is strictly increasing in τ_{-1} entails both an increasing protection sequence and a decreasing one as shown in Figure 2; if $\tau_0 = l = \tau'_0$, then the optimal protection sequence will be increasing with $\tau'_0 < \tau'_1 < \tau'_2 < \cdots$; and if $\tau_0 = l = \tau''_0$, then the optimal protection sequence will be decreasing with $\tau''_0 > \tau''_1 > \tau''_2 > \cdots$.[26] If $\tau_0 = l = \tau_S$, however, the resulting optimal protection sequence will be stationary with $\tau_0 = \tau_1 = \tau_2 = \cdots$. If there exists such a stationary protection level $\tau_S \in [0, h)$ under *PTS* with $G(\tau_S) = \tau_S$ and $l = \tau_S$, then H would continue to set its protection level at l until a tariff war phase begins. Therefore, the existence of such a stationary protection level τ_S is an important prerequisite for *PTS* to be a supergame equilibrium of the repeated game. An increasing optimal policy correspondence (*Lemma 3* (*b*)) itself, however, does not rule out the possibility that the only stationary protection level of the dynamic problem in (9) is h, as demonstrated by $G'(\tau_{-1})$ in Figure 2.

To address the existence issue of a stationary protection level $\tau_S \in [0, h)$ with $G(\tau_S) = \tau_S$, I analyze a necessary condition for such τ_S. If $V(\tau)$ is differentiable with respect to τ, then τ_S should satisfy the following first order condition for a stationary equilibrium, denoted by *IC*:

(11) ***IC*:** $\partial F(\tau_S, \tau_S)/\partial \tau + \delta^C[1 - Pr^*(\tau_S)]\cdot[\partial V(\tau_S)/\partial \tau] = 0,$

---

as shown in the proof of Lemma 3.

[26] If the cooperative protection level is set too low under *PTS* with $l = \tau_0'$, then H would keep raising the protection level above the cooperative one until it reaches a stationary level, τ_S, and the opposite is true if the cooperative protection level is too high with $l = \tau_0''$. Bruce and Park (2004) identify that a similar dynamic behavior does emerge in the context of an exporting firm's dynamic pricing problem in the presence of antidumping policy; once an exporting firm becomes subject to antidumping duty, it would either continue to decrease its export price (thus, having the duty increase over time) or continue to increase its export price (thus, having the duty lowered over time) depending on whether the initial export pricing is higher or lower than a stationary pricing.

where $\partial F(\tau_S, \tau_S)/\partial\tau = \partial u(\tau_S, l^*)/\partial\tau$ and $\partial V(\tau_S)/\partial\tau = -[\partial Pr^*(\tau_S)/\partial\tau]\{u(\tau_S, l^*) + \delta^C V(\tau_S) - [u(\tau_S, h^*) + (\delta^C - \delta^*)V_N + \delta^* V_C]\}$. While I cannot assume differentiability of $V(\tau)$ on any $\tau \in [0, h]$ as explained earlier, $V(\tau)$ is differentiable on any $\tau \in G(\tau_{-1})$ and $\tau \in (0, h)$ for each $\tau_{-1} \in [0, h]$, according to a generalized differentiability result by Cotter and Park (2004). Therefore, (11) is indeed a necessary condition for any stationary protection level that belongs to $(0, h)$, thus it serves as an incentive constraint (*IC*) for H to sustain the cooperative protection level, l, under *PTS* with $l = \tau_S$.

Using *IC* in (11), *Lemma 4* (*a*) below establishes the existence of a unique stationary protection level, $\tau_S \in (0, h)$ such that $G(\tau_S) = \tau_S$ with some further requirements on the private information. *Lemma 4* (*b*), then shows that H does not have any (strict) incentive to utilize tariffs as part of its deviation path if the cooperative protection level, l, is set to be equal to τ_S.

Lemma 4.

Assume that the lengths of tariff war phases satisfy the conditions in *Lemma 1* (*a*).

(*a*) If $\partial Pr^*(\tau)/\partial\tau = 0$ at $\tau = 0$ and $\partial^2 Pr^*(\tau)/(\partial\tau)^2$ (>0) is high enough to have $[\partial^2 Pr^*(\tau)/(\partial\tau)^2][1 - Pr^*(\tau)] - \{1 + \delta^C[1 - Pr^*(\tau)]\}[\partial Pr^*(\tau)/\partial\tau]^2 > 0$ for all $\tau \in [0, h]$, then there exists a unique stationary equilibrium protection level $\tau_S \in (0, h)$ with $G(\tau_S) = \tau_S$. τ_S is also a globally stable equilibrium with $G(\tau) > \tau$ for $\tau \in [0, \tau_S)$ and $G(\tau) < \tau$ for $\tau \in (\tau_S, h)$.[27]

(*b*) If $l = \tau_S$, then H cannot increase its discounted payoff above $V(\underline{s}, \underline{s}^*)$ by taking any (deviatory) protection sequence that involves initiating tariff wars by imposing tariffs.

(See Appendix for Proof)

A positive $\partial^2 Pr^*(\tau)/(\partial\tau)^2$ implies that the likelihood of a tariff war being triggered increases at an increasing rate as H raises its level of concealed protection, and a higher $\partial^2 Pr^*(\tau)/(\partial\tau)^2$ means that the

[27] This global stability result is an application of Theorem 4 of Cotter and Park (2004), as shown in the proof. τ_S being a globally stable protection level is a contributing factor to the stability of *PTS* as an equilibrium of the repeated game. This is because H will eventually return to its globally stable behavior of setting $\tau = \tau_S$ (= l) after any arbitrary perturbations (possibly caused by errors) in its protection level choices.

increasing rate is higher. Therefore, having a high positive value for $\partial^2 Pr^*(\tau)/(\partial\tau)^2$ implicitly assumes that the sensitivity of F's private information against H's use of concealed trade protection increases rapidly as the magnitude of such protection grows. $\partial Pr^*(\tau)/\partial\tau$ at $\tau = 0$ implies that that the sensitivity of F's private information is very low when there is very little use of concealed trade protection.

Given that F's private information satisfies the properties specified above, with $Pr^*(l)$ being close enough to 0 and δ^C being close to 1, *Lemma 1* and *Lemma 4* together establish that there exist *PTS* from which H does not have any incentive to deviate with $l = \tau_S$. However, it still remains to be shown that there exist *PTS* from which not only H but also F has no incentive to deviate. One obvious candidate is symmetric *PTS* for symmetric countries, which is the focus of Section 3.[28]

3. Optimal Symmetric Private Trigger Strategies for Symmetric Countries

This section establishes that symmetric countries can sustain a symmetric cooperative protection level based on *PTS* as long as their private information satisfies certain conditions. After proving the existence of symmetric *PTS* as a supergame equilibrium of the repeated protection-setting game between H and F in Section 3.1, I characterize optimal symmetric *PTS* under which H and F maximize their joint expected discounted payoffs in Section 3.2.

3.1. Symmetric Private Trigger Strategies

To analyze the case where H and F are symmetric, this section assumes that $u(\tau^1,\tau^2) = u^*(\tau^1,\tau^2)$ for all τ^1 and $\tau^2 \in [0, h]$ and that $Pr(\omega_t \in \Omega^D) = Pr^*(\omega_t^* \in \Omega^{D*})$ for all $(\tau_t, e_t) = (\tau_t^*, e_t^*)$ and $\Omega^D = \Omega^{D*}$. This section focuses on symmetric *PTS* with $l = l^*$, $\Omega^D = \Omega^{D*}$, and $\delta = \delta^*$. If symmetric *PTS* satisfy *ICP* and

[28] While an obvious candidate is symmetric *PTS* ($l = l^*, \Omega^D = \Omega^{D*}$, $\delta = \delta^*$, δ^S) for symmetric H and F, showing the existence of such *PTS* as an equilibrium of the repeated game is not a trivial matter. To prove the existence, I need to show that there exists ($l = l^*, \Omega^D = \Omega^{D*}$, $\delta = \delta^*, \delta^S$) that satisfies *ICP*, *ICP**, *IC*, and *IC** simultaneously.

IC for H, such *PTS* will also satisfy ICP^* and IC^* for F by symmetry. Without loss of generality, the following analysis focuses on proving the existence of symmetric *PTS* that satisfy *ICP* and *IC*.[29]

Assume that there exists τ_S that satisfies *IC* in (11) with $\tau_S = l$. This implies that $V(\tau_S) = V_C$. Then, I can rewrite *IC* in (11) as follows:

$$(12)\qquad \partial u(\tau_S, l^*)/\partial\tau = \delta^C[\partial Pr^*(\tau_S)/\partial\tau][1 - Pr^*(\tau_S)][u(\tau_S, l^*) - u(\tau_S, h^*) + (\delta^C - \delta^*)(V_C - V_N)].$$

The left-hand side of the equality in (12) represents H's current period gain from raising its protection level above the cooperative one ($l = \tau_S$) and the right-hand side denotes H's expected loss from raising the probability of a tariff war being triggered by F in the following period. As discussed in the previous section, (12) is a necessary condition for H to have no incentive to change its protection level away from the cooperative one until a tariff war phase starts.

To guarantee that *PTS* satisfy *ICP* (and ICP^*), I assume that the lengths of tariff phases are determined by the sufficient condition for *ICP* and ICP^* in *Lemma* 1 (*a*); $\delta^C - \delta = [u(h, l^*) - u(l, l^*)]/(V_C - V_N) = \delta^C - \delta^* = [u^*(h^*, l) - u^*(l^*, l)]/(V_C^* - V_N^*)$ by symmetry and $\delta^C + \delta^S = (\delta^* + \delta)$. By denoting the symmetric cooperative protection level under symmetry *PTS* by l^c (= $l = l^*$), *IC* in (12) can then be rewritten into the following implicit function, $I(l^c)$:

$$(13)\qquad I(l^c) \equiv \partial u(l^c, l^c)/\partial\tau - \delta^C[\partial Pr^*(l^c)/\partial\tau][1 - Pr^*(l^c)][u(h, l^c) - u(l^c, h^*)] = 0.$$

If there exists $l^c \in [0, h)$ that satisfies the above implicit function, $I(l^c)$, then symmetric *PTS* with $l = l^* = l^c$, $\Omega^D = \Omega^{D*}$, $\delta = \delta^* = \delta^C - [u(h, l^c) - u(l^c, l^c)]/(V_C - V_N)$, and $\delta^S = \delta + \delta^* - \delta^C$ can be a supergame equilibrium of the repeated protection setting game between H and F. *Proposition 1* provides a sufficient condition for the existence of such symmetric *PTS*,

***Proposition 1*.**

[29] In contrast to the analysis in Section 2.2 where $\underline{s}^*$ is assumed to be fixed in specifying *IC*, to prove the existence of symmetric *PTS* that satisfy *ICP*, ICP^*, *IC*, and IC^* simultaneously, I vary the variables, l^*(= l), δ^* (=δ), and δ^S to satisfy ICP^*(*ICP*) in characterizing *IC* in this section.

If $\partial Pr^*(l^c)/\partial l^c = 0$ at $l^c = 0$ and $\partial^2 Pr^*(l^c)/(\partial l^c)^2$ (>0) is high enough to have $[\partial^2 Pr^*(l^c)/(\partial l^c)^2][1 - Pr^*(l^c)] - \{1 + \delta^C[1 - Pr^*(l^c)]\}[\partial Pr^*(l^c)/\partial l^c]^2 > 0$ for all $l^c \in [0, h]$, and there exists a unique protection level, $l_S^c < h$ with $I(l_S^c) \equiv 0$, then, symmetric H and F can employ symmetric *PTS* with $l^c = l_S^c$ as a supergame equilibrium of the repeated protection setting game. (See Appendix for Proof)

If the private information is sensitive enough to meet the condition specified in the above proposition, then symmetric countries can restrain the use of concealed trade barriers based on symmetric *PTS* with $l^c = l_S^c$. The sufficient condition in *Proposition 1* is stronger than the one in *Lemma 4* (*a*) because it additionally requires $I(l^c) = 0$ for a unique value of $l^c < h$.[30] One can relax the sufficient condition to allow multiple l^c to satisfy $I(l^c) = 0$ as illustrated in Figure 3; $l^c = l_{\max}$ as well as $l^c = l_{min}$ satisfy $I(l^c) = 0$. Denoting the minimum of such l^c by l_{min}, symmetric *PTS* with $l^c = l_{min}$ will Pareto-dominate the others when $Pr^*(\ l_c)$ is small enough.[31]

Up to this point, I have assumed that the range of private signals that trigger a tariff war phase (Ω^D for H and Ω^{D*} for F) is fixed. Note that symmetric countries can change the cooperative protection level l_c under symmetric *PTS* by changing the range of tariff-war-triggering private signals, $\Omega^D = \Omega^{D*}$, because it affects the probability of a tariff war being triggered. The following section characterizes optimal symmetric *PTS*, focusing its analysis on the choice of Ω^D (= Ω^{D*}) that maximizes the expected discounted payoff under *PTS*.

3.2 Optimal Symmetric Private Trigger Strategy

---

[30] The sufficient condition in *Lemma 4* (*a*) does not imply the existence of a unique l^c (< h) with $I(l^c) = 0$ because $\partial \text{©}[\partial Pr^*(l)/\partial l][1 - Pr^*(l)][u(h, l) - u(l, h^*)]\prod/\partial l_c = \text{©}[\partial^2 Pr^*(l)/(\partial l)^2][1 - Pr^*(l)] - \{1 + \delta^C[1 - Pr^*(l)]\}[\partial Pr^*(l)/\partial l]^2\prod[u(h, l) - u(l, h^*)] + [\partial Pr^*(l)/\partial l][1 - Pr^*(l)]\text{©}\partial[u(h, l) - u(l, h^*)]/\partial l\prod$ with $[\partial Pr^*(l)/\partial l][1 - Pr^*(l)]\text{©}\partial[u(h, l) - u(l, h^*)]/\partial l\prod < 0$.

[31] Note that $u(l_{min}, l_{min}) > u(l_{max}, l_{max})$ and $Pr^*(l_{min}) < Pr^*(l_{max})$ imply a higher cooperative-period payoff and a lower probability of tariff wars with $l^c = l_{min}$ than with $l^c = l_{max}$. While the lengths of tariff war phases may be longer with $l^c = l_{min}$ than with $l^c = l_{max}$, an increase in l^c will lower the expected discounted payoff under symmetric *PTS* if $Pr^*(l^c)$ is close enough to 0, as shown in (15) of the following section.

The private signal $\omega \in \Omega$ has two distinctive quality dimensions as a measure that detects the potential use of concealed protection. One is the sensitivity of the signal in detecting possible defections, which links a higher protection to a higher probability of a tariff war. The other is the stability of the signal that rewards the cooperative behavior with a lower probability of a tariff war. I can represent the sensitivity by $Pr'(\tau^*) \equiv \partial Pr(\tau^*)/\partial\tau^* > 0$ and the stability by $1 - Pr(\tau^*)$ at $\tau^* = l^c$ for H's private signal, with corresponding expressions for F.

A change in the range of private signals that trigger a tariff war phase affects these qualities of signals. In particular, H may raise the sensitivity by properly expanding the range of tariff-war-triggering private signals, Ω^D, but at the cost of undermining the stability. By denoting the degree of such expansion with a parameter ω^D (namely, a *trigger control variable*), I can formalize this trade-off that H faces in choosing ω^D by assuming $\partial Pr'(\tau^*)/\partial\omega^D > 0$ and $\partial Pr(\tau^*)/\partial\omega^D > 0$. I can represent the same type of trade-off for F by $\partial Pr^{*\prime}(\tau)/\partial\omega^{D*} > 0$ and $\partial Pr^*(\tau)/\partial\omega^{D*} > 0$.

The analysis of optimality in this section constrains itself to the symmetric *PTS* identified in *Proposition 1* with the cooperative protection level being determined by a choice over ω^D. Assuming that ω^D uniquely determines l_S^c with $I(l_S^c) \equiv 0$ (or equivalently, assuming that the sufficient condition in *Proposition 1* holds for any ω^D), I can represents l_S^c as a function of ω^D; $l_S^c = l_S^c(\omega^D)$. Using $\delta^C - \delta$ = $\delta^C - \delta^*$ = $[u(h, l_S^c) - u(l_S^c, l_S^c)]/(V_C - V_N)$, $\delta^C + \delta^S$ = $(\delta^* + \delta)$ and $Pr^*(l_S^c) = Pr(l_S^c)$ by symmetry, I can derive H's expected discounted payoff under the symmetric *PTS* from (6) as follows:

$$V_C \equiv V(\underline{s}, \underline{s}^*) = \frac{u(l_S^c, l_S^c)}{1-\delta^C} - Pr(l_S^c)\frac{\{[u(l_S^c, l_S^c) - u(l_S^c, h^*)] + [u(h, h^*) - u(l_S^c, h^*)]\}}{1-\delta^C} \tag{14}$$

Note that the expected discounted payoff in (14) is no longer depending on the lengths of the tariff war phases. Therefore, I can describe the optimal choice for ω^D (=ω^{D*}), denoted by $\underline{\omega}^D \equiv \underset{\omega^D}{Aug\max} V(\underline{s}, \underline{s}^*)$, as ω^D that satisfies the following first order condition:

(15) $$\frac{dV_C}{d\omega^D} = \frac{\partial V_C}{\partial l_S^c}\frac{\partial l_S^c(\omega^D)}{\partial \omega^D} + \frac{\partial V_C}{\partial \omega^D} = 0, \text{ with}$$

$$\frac{\partial V_C}{\partial l_S^c} = \frac{\partial u(l_S^c, l_S^c)}{\partial l_S^c}\frac{1}{1-\delta^C} - Pr^{/}(l_S^c)\frac{\{[u(l_S^c, l_S^c) - u(l_S^c, h^*)] + [u(h,h^*) - u(l_S^c, h^*)]\}}{1-\delta^C}$$

$$- Pr(l_S^c)\frac{\{\partial u(l_S^c, l_S^c)/\partial \tau^* - \partial u(l_S^c, l_S^c)/\partial \tau\}}{1-\delta^C} < 0 \text{ for } \Pr(l_S^c) \text{ being close to 0,}$$

$$\frac{\partial l_S^c(\omega^D)}{\partial \omega^D} = -\frac{\partial I/\partial \omega^D}{\partial I/\partial l_S^c} < 0 \text{ iff } \frac{\partial Pr^{/}(l_S^c)}{\partial \omega^D}[1 - Pr(l_S^c)] - \frac{\partial Pr(l_S^c)}{\partial \omega^D}Pr^{/}(l_S^c) > 0, \text{ and}$$

$$\frac{\partial V_C}{\partial \omega^D} = -Pr\frac{\partial Pr(l_S^c)}{\partial \omega^D}\frac{\{[u(l_S^c, l_S^c) - u(l_S^c, h^*)] + [u(h,h^*) - u(l_S^c, h^*)]\}}{1-\delta^C} < 0,$$

where $I = I(l_S^c)$ is the implicit function defined in (13). The first order condition is informative about the trade-off that the countries face in choosing an optimal ω^D. Raising the trigger control variable (ω^D) will have a positive effect on the expected discounted payoff (V_C) by lowering the cooperative protection level (l_S^c) if $\partial l_S^c/\partial \omega^D < 0$ and $\partial V_C/\partial l_S^c < 0$, but it also has a negative effect on the expected payoff by increasing the probability of a tariff war phase being invoked as shown by $\partial V_C/\partial \omega^D < 0$ in (15). Thus, the optimal ω^D should balance the gain from raising the sensitivity of the private signal (thus achieving a lower l_S^c) against the loss from reducing the stability of the cooperative equilibrium with a higher tariff war probability.

When the initial ω^D is at a very low level, then, it is generally possible to lower the cooperative protection level by raising the trigger control variable. For example, if $\Omega^D = \varnothing$, then $l_S^c = h$, $Pr(l_S^c) = Pr^{/}(l_S^c) = 0$, implying $\partial l_S^c/\partial \omega^D < 0$ with $\partial Pr^{/}(l_S^c)/\partial \omega^D > 0$ from (15). If countries continue to raise ω^D, the marginal increase in the sensitivity of private signals in response to an increase in ω^D is likely to get smaller. To formalize this decreasing return to raising the trigger control variable, I assume that $\partial^2 Pr^{/}(l_S^c)/\partial(\omega^D)^2 < 0$ and $\partial^2 Pr(l_S^c)/\partial(\omega^D)^2 = 0$, with the latter assumption making the effect of a higher ω^D on $Pr(l_S^c)$ to be constant. Then, it is possible to have $\partial^2 l_S^c/\partial(\omega^D)^2 > 0$ and $\partial l_S^c/\partial \omega^D = 0$ for a high enough ω^D. While it is possible to raise ω^D to such a point that the countries would no longer be able to lower the cooperative protection level any further ($\partial l_S^c / \partial \omega^D = 0$), note that it is never optimal to do so. If it does, then the first order condition for the optimal ω^D in (15) will be violated as $dV_C / d\omega^D = \partial V_C / \partial \omega^D < 0$, implying that countries can increase their payoffs by lowering the trigger control variable. When ω^D is high enough to make $\partial l_S^c / \partial \omega^D = 0$, then the gain associated with a higher ω^D (to be realized through reducing l_S^c) becomes negligible, but the cost associated with a higher ω^D (of increasing the probability of a costly tariff war) remains significant. I summarize these characterizations of optimal symmetric *PTS* in the following proposition.

Proposition 2.

The choice over the trigger control variable ω^D is a balancing act between raising the sensitivity of the private signal (thus achieving lower cooperative protection levels) and reducing the stability of the cooperative equilibrium (by a higher tariff war probability). As a result, optimal symmetric *PTS* do not raise the trigger control variable to the level that pushes down the cooperative protection level to its minimum attainable level with $\partial l_S^c / \partial \omega^D = 0$.[32]

Note that $\partial l_S^c / \partial \omega^D = 0$ for $l_S^c = 0$ because $Pr'(l_S^c) = 0$ for $l_S^c = 0$ as assumed in *Proposition 1*. *Proposition 2*, thus implies that choosing ω^D so that l_S^c gets arbitrarily close to 0 is not optimal; optimal symmetric *PTS* subject to imperfect information will not entail zero tolerance against concealed protection. If countries can detect deviations even when there is almost no deviation ($Pr'(l_S^c) > 0$ even at $l_S^c = 0$), then this anti zero-tolerance result is no longer necessarily true.

4. Limitations of Private Trigger Strategies

[32] While the above proposition focuses on strategies that trigger tariff war phases based on imperfect private signals, a similar characterization can be drawn for optimal strategies that trigger tariff phases based on imperfect public information. For example, see Porter (1983) on optimal cartel trigger price strategies.

In this section, I consider factors that may limit the effectiveness of *PTS* in restraining the use of concealed protection. Section 4.1 analyzes how a reduction in the time lag to adjust protection levels in response to an initiation of an explicit tariff war affects effectiveness of *PTS*. Section 4.2 analyzes the effect of introducing asymmetry among countries on *PTS*.

4.1. A Faster Response to an Initiation of an Explicit Tariff War

The analyses in previous sections assume that H and F simultaneously set their concealed and explicit protection levels at the beginning of each period and cannot adjust those protection levels until that period is over. While this is a standard assumption in the literature that analyzes self-enforcing trade agreements in a repeated game setup, the time lag (one period) for countries to readjust their protection levels plays an important role in determining the effectiveness of *PTS* as shown below. In particular, I analyze how reducing the time lag in adjusting protection levels in response to an initiation of an explicit tariff war affects the level of cooperation attainable under *PTS*.

To analyze the effect of such a reduction in the time lag in adjusting protection levels without changing the basic structure of the model, I represent one-period payoffs for a period when F initiates a tariff war by imposing its static optimal tariff by $u(l, h^*)/n + (n-1)u(h, h^*)/n$ for H and $u^*(h^*, l)/n + (n-1)u^*(h^*, h)/n$ for F, with $n \in [1, \infty)$ denoting how fast each country can readjust its protection level in response to an initiation of a tariff war phase by the other country.[33] Note that $n = 1$ implies no reduction in the time lag to adjust protection levels and $n \to \infty$ means instantaneous adjustment (no lag). For a period when H initiates a tariff war, one-period payoffs are $u(h, l^*)/n + (n-1)u(h, h^*)/n$ for H and $u^*(l^*, h)/n + (n-1)u(h^*, h)/n$ for F.

[33] Note that the time-lag reduction considered in this section does not applies to the general time lags in adjusting protection levels, like the speed of adjusting concealed protection levels, but only to the time lags in adjusting protection levels in response to an initiation of an explicit tariff war. If the speed of adjusting concealed protection levels changes, it will affect countries' optimal protection sequence, thus, the whole optimization problem under *PTS*. While fixing the speed of adjusting concealed protection levels, one may still consider a reduction in the time lags in adjusting protection levels by allowing countries to adjust their explicit tariff levels faster. In comparison with controlling concealed protections, which may require non-explicit and customary arrangements

As in Section 3, I continue to focus on symmetric *PTS* for symmetric countries. Then, a change in the speed that each country can readjust its protection level, denoted by n, affects the cooperative protection level that countries can attain under *PTS*, l^c, by affecting the incentive constraint, *IC* in (11) and the lengths of tariff war phases that satisfy *ICP* and *ICP**. First, I analyze its effect on *IC*. Using $F(\tau_d, \tau_{d+1}) = Pr^*(\tau_d)[u(\tau_{d+1}, h^*)/n + (n-1)u(\tau_{d+1}, h^*)/n + (\delta^C - \delta^*)V_N + \delta^* V_C] + [1 - Pr^*(\tau_d)]u(\tau_{d+1}, l^*)$, I can rewrite *IC* in (11) into

(16) $$\partial u(l^c, l^c)/\partial\tau = \delta^C[\partial Pr^*(l^c)/\partial\tau][1 - Pr^*(l_c)][u(l^c, l^c) - u(l^c, h^*) + (\delta^C - \delta^*)(V_C - V_N)]$$
$$+ [(n-1)/n]\{Pr^*(l^c)[\partial u(l^c, l^c)/\partial\tau] - \delta^C[\partial Pr^*(l^c)/\partial\tau][1 - Pr^*(l^c)][u(h, h^*) - u(l^c, h^*)]\}.$$

Note that *IC* in (16) takes the same form as the one in (12), *IC* under symmetry with $n = 1$, except for the last term on the right-hand side of the equality. This last term on the right-hand side will take on a negative value when it is measured at $l^c = l_S^c$ with $I(l_S^c) \equiv 0$ in (13) as long as $Pr^*(l_S^c)$ is significantly less than 1/2; (13) implies that $\partial u(l_S^c, l_S^c)/\partial\tau = \delta^C[\partial Pr^*(l_S^c)/\partial\tau][1 - Pr^*(l_S^c)][u(h, l_S^c) - u(h, h^*) + u(h, h^*) - u(l_S^c, h^*)] \approx 2\delta^C[\partial Pr^*(l_S^c)/\partial\tau][1 - Pr^*(l_S^c)][u(h, h) - u(l_S^c, h^*)]$ from $[u(h, h^*) - u(l_S^c, h^*)] \approx [u(h, l_S^c) - u(h, h^*)]$. Given that the lengths of tariff war phases that satisfy *ICP* and *ICP** are held constant (thus, $\delta^C - \delta^*$ is held constant), this implies that an increase in the speed of adjustment (a higher n) will increase the incentive to deviate from a cooperative equilibrium. The cost associated with raising the concealed protection level, represented by the right-hand side of equality in (16), decreases in n as an increase in n raises $[(n-1)/n]$, making the last negative term in (16) to have a larger absolute value. For the case where F initiates a tariff war in the current period, H's gain from raising concealed protection decreases as n increases because H would react faster to such a case by setting its static optimal tariff during that period. This is represented by $Pr^*(l^c)[\partial u(l^c, l^c)/\partial\tau]$ in the last term of (16). As n increases, however, the cost associated with raising the current protection level decreases because H can react faster to F's initiation of a tariff war in the following period by imposing its static optimal tariff. This

with various players in the market, changing the explicit tariff levels in response to a foreign initiation of a tariff increase in the incentive to raise the concealed protection, represented by $-\delta^C[\partial Pr^*(l^c)/\partial\tau][1 - Pr^*(l^c)][u(h, h^*) - u(l, h^*)]$ in the last term of (16), dominates the reduction in the incentive to deviate, represented by $Pr^*(l^c)[\partial u(l^c, l^c)/\partial\tau]$ in the same last term, as long as $Pr^*(l^c)$ is significantly less than 1/2. As a result, H will have a higher incentive to raise its concealed protection when it can react faster to F's initiation of a tariff war phase, implying a reduction in countries' ability to reduce concealed protections under *PST*.

The above discussion about the effect of a faster reaction to an initiation of a tariff war on the incentive to deviate using (16), however, assumes that an increase in n does not affect the lengths of tariff war phases. In fact, a higher n does affect the lengths of tariff war phases in a direction that weakens the punishments against potential deviations. Under *PTS*, recall that the expected payoff from initiating a tariff war phase should be the same as the expected payoff from not initiating one, as represented by *ICP* and ICP^* in Section 2.2.1. Imposing an explicit tariff starts a tariff war in the following period(s) that is costly for the initiating country in the sense that its one-period payoff under a tariff war is lower than its payoff under a cooperative period. However, *ICP* and ICP^* can still be satisfied because the country who initiates a tariff war enjoys a higher payoff in the initial period of a tariff war phase during which it imposes its static optimal tariff while the other country still keeps a cooperative protection level. This observation reveals that the time lag in adjusting an explicit tariff in response to an initiation of an explicit tariff war is crucial for the countries to have an incentive to trigger a tariff war phase.

To analyze how a faster response to an initiation of a tariff war affects the lengths of tariff war phases under symmetric *PTS*, I rewrite *ICP* in (7) as follows:

$$(17)\quad \begin{aligned}&(1-Pr^*)[u(l,l^*)+\delta^C V_C]+Pr^*[\frac{u(l,h^*)}{n}+\frac{(n-1)u(h,h^*)}{n}+(\delta^C-\delta^*)V_N+\delta^* V_C]=\\&(1-Pr^*)[\frac{u(h,l^*)}{n}+\frac{(n-1)u(h,h^*)}{n}+(\delta^C-\delta)V_N+\delta V_C]+Pr^*[u(h,h^*)+(\delta^C-\delta^S)V_N+\delta^S V_C],\end{aligned}$$

or equivalently,

war may take much less time, like issuing an executive order.

$$u(l,l^*)+\delta^C V_C - Pr^*\{\frac{u(l,l^*)-u(l,h^*)}{n}+\frac{(n-1)[u(l,l^*)-u(h,h^*)]}{n}+(\delta^C-\delta^*)(V_C-V_N)\}=$$
$$\frac{u(h,l^*)}{n}+\frac{(n-1)u(h,h^*)}{n}+(\delta^C-\delta)V_N+\delta V_C - Pr^*[\frac{u(h,l^*)-u(h,h^*)}{n}+(\delta-\delta^S)(V_C-V_N)].$$

To have the above *ICP* satisfied for all $Pr^* \in [0, 1]$, $\delta = \delta^*$ and δ^S need to satisfy

(18)
$$(\delta^C-\delta)(V_C-V_N)=[u(h,l^*)-u(l,h^*)]+\frac{(n-1)[u(h,l^*)-u(h,h^*)]}{n},\text{ and}$$
$$[(\delta-\delta^S)-(\delta^C-\delta^*)](V_C-V_N)=\frac{(n-1)[u(l,l^*)-u(h,h^*)]}{n},$$

which becomes the same sufficient condition for *ICP* and *ICP** specified in *Lemma 1*(a) if $n = 1$. With these conditions in (18) defining the lengths of tariff war phases under symmetric *PTS*, *IC* in (16) changes into

(19) $$\partial u(l^c, l^c)/\partial\tau = \delta^C[\partial Pr^*(l^c)/\partial\tau][1 - Pr^*(l^c)][u(h, l^c) - u(l^c, h^*)]$$
$$+ [(n-1)/n]\{Pr^*(l^c)[\partial u(l^c, l^c)/\partial\tau] - \delta^C[\partial Pr^*(l^c)/\partial\tau][1 - Pr^*(l^c)][u(h, l^c) - u(l^c, h^*)]\}.$$

Comparing with (16), note that the last term in (19) will have a larger (in absolute value) negative value because $[u(h, l^c) - u(l^c, h^*)] > [u(h, h^*) - u(l^c, h^*)]$, implying that H has a higher incentive to deviate from a cooperative protection level once the speed of protection readjustment affects the lengths of tariff war phases. An increase in n induces $\delta\,(=\delta^*)$ and δ^S to have lower values, as implied by (18), thus resulting in shorter lengths of tariff war phases. This decrease in the severity of punishments against potential deviations manifests itself as a higher incentive to deviate in (19). When the speed of protection readjustment gets high enough, it becomes impossible to support any level of cooperation under *PTS* regardless of the sensitivity of private signals in detecting potential deviations. The following proposition summarizes the above observation about the effect of a faster reaction to an initiation of a tariff war on the cooperative protection level attainable under symmetric *PTS*.

Proposition 3.

As each country readjusts its protection level faster in response to the other country's initiation of a tariff war phase (a higher *n*), the cooperative protection level attainable under symmetric *PTS* increases as long as $Pr^*(l_S^c) = Pr(l_S^c)$ is significantly less than 1/2. In particular, an increase in the speed of protection readjustment can decrease the lengths of tariff war phases to the degree that it is impossible to sustain any level of cooperative protection ($l^c < h$) regardless of the accuracy of imperfect private signals in detecting potential deviations. (See Appendix for Proof.)

This finding on the effect of a faster response to an initiation of a tariff war on *PTS* contrasts with how the same increase in the speed of protection readjustment would affect the cooperative protection level attainable under trigger strategies based on public signals, namely *public trigger strategies*. As *public trigger strategies* embody simultaneous imposition of explicit tariffs in the initial period of any tariff war phases, a faster response to an initiation of a tariff war would not affect the cooperative protection level attainable under *public trigger strategies*. When countries can readjust their protection levels quickly, *Proposition 3* implies that *public trigger strategies* are more likely to be successful than *private trigger strategies* in restraining the use of concealed protection.

To illustrate that a change in the time lag in adjusting the protection level matters in enforcing the international trade agreements, one may discuss the WTO's amendment of GATT Article XIX; Article XIX, known as the "escape clause," allows a government to temporarily suspend a concession agreed upon in a previous negotiation if its import-competing industry is injured as a consequence of a temporary surge in import volume.[34] To encourage the use of Article XIX as opposed to the use of managed-trade policies (such as Voluntary Export Restraints), the WTO's amendment prohibits the retaliatory responses by affected partners for a three-year period following the original imposition of Article XIX-based tariffs. Even though the escape clause is not about imposing tariffs to punish other countries' use of concealed protection, this amendment does reflect the WTO member countries' concern that the lack of time lag in imposing retaliatory tariffs in response to the imposition of Article

XIX-motivated tariffs may discourage the use of Article XIX tariffs. This recent amendment of Article XIX indicates that the fast retaliatory reaction to an imposition of tariffs can undermine the effectiveness of *PTS*, as suggested by *Proposition 3*.

4.2. Asymmetry among Countries

In this section, I analyze how asymmetry among countries affects the cooperative protection levels sustainable under *PTS*. To introduce asymmetry among countries, I analyze the following partial equilibrium trade model where H exports good 1 and F exports good 2, with $\sigma \in [1, \infty)$ denoting the size of H's markets relative to F's. Demand for good *i* in H is $D_i = \sigma(A - Bp_i)$ and the supply of good *i* in H is $X_i = \sigma(\alpha_i + \beta p_i)$, where p_i is the price of good *i* in H with *i* = 1 or 2. For F, demand and supply are given by $D_i^* = A - Bp_i^*$ and $X_i^* = \alpha_i^* + \beta p_i^*$. To ensure that H will export good 1 and import good 2 and that the countries will be symmetric when $\sigma = 1$, I assume $\alpha_1 - \alpha_1^* = \alpha_2^* - \alpha_2 > 0$ and $\alpha_1 = \alpha_2^*$. By varying σ on $[1, \infty)$, I can consider the range of relative country sizes from symmetric countries to the case where F is a price taker in world market ($\sigma \to \infty$). This partial equilibrium trade model between asymmetric countries with linear demands and supplies originates from Bond and Park (2002).

Given that each country sets its protection level on its imports (equivalent to a specific tariff), denoted by τ for H and τ^* for F, domestic prices are $p_2 = p_2^* + \tau$ and $p_1^* = p_1 + \tau^*$, and each country's one-period payoff function can be expressed as

(20) $$w^j(\tau^j, \tau^k) = \sum_{i=1,2}\left[\int_{p_i^j}^{A/B} D_i^j(u)du + \int_{-\alpha_i^j/\beta}^{p_i^j} X_i^j(u)du\right] + \tau^j\left(D_m^j(p_m^j) - X_m^j(p_m^j)\right)$$

where *j*, *k* = * or none with $j \neq k$ and *m* = 1 (2) when *j* = * (none).[35] The above trade model does not incorporate uncertainties in the economy. For analytical simplicity, however, I assume that

[34] Bagwell and Staiger (Section 6.2.1, 2002) provide a more detailed discussion on Article XIX and its amendment.

uncertainties in the economy are such that one-period payoff functions under uncertainties defined by (3) in Section 2 are the same as those in (20); $u(\tau, \tau^*) = w(\tau, \tau^*)$ and $u^*(\tau^*, \tau) = w^*(\tau^*, \tau)$. Then, I can show that all the assumptions about derivatives of u and u^* with respect to τ and τ^* in Section 2 are satisfied; $\partial u/\partial\tau > 0$ at $\tau = 0$ and $\partial u^*/\partial\tau^* > 0$ at $\tau^* = 0$; $\partial u/\partial\tau^* < 0$, $\partial u^*/\partial\tau < 0$, $\partial u/\partial\tau + \partial u^*/\partial\tau < 0$, and $\partial u/\partial\tau^* + \partial u^*/\partial\tau^* < 0$ for (τ, τ^*) that are not trade-prohibitive; $\partial^2 u/\partial\tau^2 < 0$ and $\partial^2 u^*/\partial\tau^{*2} < 0$; $\partial^2 u/\partial\tau\partial\tau^* = 0$ and $\partial^2 u^*/\partial\tau\partial\tau^* = 0$.

To analyze the effect of asymmetry among countries on *PTS*, I focus on how the asymmetry, represented by σ, affects the following *IC* and IC^*:

(21) ***IC*:** $u(l, l^*)/\partial\tau = \delta^C[\partial Pr^*(l)/\partial\tau][1 - Pr^*(l)][u(l, l^*) - u(l, h^*) + (\delta^C - \delta^*)(V_C - V_N)]$,

***IC**:** $u^*(l^*, l)/\partial\tau^* = \delta^C[\partial Pr(l^*)/\partial\tau^*][1 - Pr(l^*)][u^*(l^*, l) - u^*(l^*, h) + (\delta^C - \delta)(V_C^* - V_N^*)]$,

where $(\delta^C - \delta^*) = [u^*(h^*, l) - u^*(l^*, l)]/(V_C^* - V_N^*)$ and $(\delta^C - \delta) = [u(h, l^*) - u(l, l^*)]/(V_C - V_N)$ with $\delta^C + \delta^S = (\delta^* + \delta)$ to satisfy the sufficient condition for *ICP* and ICP^* defined in *Lemma 1* (*a*).

Having formal proofs given in the appendix, here I provide an intuitive explanation of the effect of asymmetry on *PTS* using Figure 4, which shows *IC* and IC^* in the space of (l^*, l). First, I discuss the properties of *IC* and IC^* for the case where H and F are symmetric ($\sigma = 1$; $IC_{\sigma=1}$ and $IC^*_{\sigma=1}$ in Figure 4), then I explain how an increase in the relative size of H affects *IC* and IC^* ($\sigma > 1$; $IC_{\sigma>1}$ and $IC^*_{\sigma>1}$ in Figure 4), thus the cooperative protection levels sustainable under *PTS*.

For the case where H and F are symmetric ($\sigma = 1$), I assume that the private information of H and F satisfies the sufficient condition for the existence of symmetric *PTS* with $l^c < h$, specified in *Proposition 1*. Then, there exists a unique cooperative protection level, l_S^c, which H and F can sustain under symmetric *PTS* as a supergame equilibrium of the repeated protection setting game. This cooperative protection level is denoted by $l_{\sigma=1} = l^*_{\sigma=1}$ in Figure 4. $IC_{\sigma=1}$ and $IC^*_{\sigma=1}$ represent the combinations of (l^*,

[35] The protection levels enter in the form that is equivalent to specific tariffs in this trade model. While being different from the ad valorem tariffs modeled in Section 2, it does not make any difference in the following

l) that satisfy IC and IC^* in (21), respectively, given σ = 1. Note that only $(l^*_{\sigma=1}, l_{\sigma=1})$ satisfies $IC_{\sigma=1}$ and $IC^*_{\sigma=1}$ simultaneously in Figure 4, confirming that $E_{\sigma=1}$ is the unique combination of protection levels that symmetric H and F can sustain under symmetric *PTS*.

Another notable point in Figure 4 is that $IC_{\sigma=1}$ and $IC^*_{\sigma=1}$ are positively sloped, implying that each country's cooperative protection level needs to increase in response to an increase in the other country's cooperative protection level in order to satisfy its own incentive constraint in (21). To prove this point, I need to show that $dl/dl^*\big|_{IC} > 0$ and $dl/dl^*\big|_{IC^*} > 0$ from totally differentiating IC and IC^* in (21) with respect to l and l^*. To satisfy the sufficient condition for ICP and ICP^*, note that the lengths of tariff war phases (thus, δ, δ^*, and δ^C) will change in responses to changes in l and l^*, which in turn affects V_C and V_C^*. This makes the job of signing $dl/dl^*\big|_{IC}$ and $dl/dl^*\big|_{IC^*}$ a complicated one. To make this analysis more tractable, I can rewrite IC in (22) into:

$$\textbf{\textit{IC}}: \quad \partial u(l,l^*)/\partial\tau = \delta^C[\partial Pr^*(l)][1-Pr^*(l)]\{[u(l,l^*)-u(l,h^*)]+[u^*(h^*,l)-u^*(l^*,l)]\frac{V_C-V_N}{V_C^*-V_C^*}\}$$

(22)

$$\text{with} \quad \frac{V_C-V_N}{V_C^*-V_N^*} = \frac{[u(l,l^*)-u(h,h^*)]+Pr(l^*)[u(h,l^*)-u(l,l^*)]-Pr^*(l)[u(l,l^*)-u(l,h^*)]}{[u^*(l^*,l)-u^*(h^*,h)]+Pr^*(l)[u^*(h^*,l)-u^*(l^*,l)]-Pr(l^*)[u^*(l^*,l)-u(l^*,h)]},$$

using ICP and ICP^* in (7) together with the sufficient condition for them to hold in *Lemma 1* (*a*). Given this expression for IC in (22), I can show that $dl/dl^*\big|_{IC} > 0$ using the signs of the following derivatives; $\partial^2 u(l, l^*)/(\partial l)^2 < 0$, $\partial\{\delta^C[\partial Pr^*(l)/\partial l][1 - Pr^*(l)]\}/\partial l > 0$, $\partial[(V_C - V_N)/(V_C^* - V_N^*)]/\partial l > 0$, $\partial u(l, l^*)/\partial l^* < 0$, $\partial u^*(l^*, l)/\partial l^* > 0$, and $\partial[(V_C - V_N)/(V_C^* - V_N^*)]/\partial l^* < 0$. I can also show that $dl/dl^*\big|_{IC^*} > 0$ using a similar expression for IC^*.[36]

---

analysis.

[36] IC is flatter than the 45 degree line and IC^* is steeper than the 45 degree line in Figure 4. While this is not a crucial point in analyzing the effects of σ on *PTS*, one can link this fact to the stability of the cooperative equilibrium under *PTS* in the following sense. Even when the cooperative protection combination $E_{\sigma=1}$ is perturbed by some shocks (possibly random errors in setting protection levels), the relative slopes of IC and IC^* ensure that countries' self-correction incentives (to change its protection level back to its payoff-maximizing level)

Having established that IC and IC^* are positively sloped in Figure 4, I can now illustrate the effect of an increase in the size of H relative to F ($\sigma > 1$) by analyzing its effect on IC in (22) and on a corresponding expression for IC^*.[37] I explain why a higher σ shifts IC upwards as shown in Figure 4 by discussing how a higher σ leads to a higher incentive for H to raise its protection level under *PTS*. Then, I can apply to the same logic to explain why a higher σ shifts IC^* to the left (reflecting a decrease in F's incentive to raise its protection level).

First, note that a higher σ leads to a higher value for the left-hand side of the equality in (22) because $\partial^2 u(l, l^*)/\partial l \partial \sigma > 0$, implying a higher incentive for H to raise its protection level above the cooperative one. This reflects H's enhanced ability to change the terms of trade in its favor by raising its protection level as it gets larger relative to F.[38] An increase in σ also makes the value of the right hand side of the equality in (22) smaller, representing a decrease in the cost associated with raising the current protection level for H. Two factors contribute to this reduction in the cost of raising the protection level. One of them is F's reduced ability to decrease H's one-period payoff by initiating an explicit tariff war, reflected by $\partial[u(l, l^*) - u(l, h^*)]/\partial\sigma < 0$. As F gets smaller relative to H, its static optimal protection will entail a smaller change in the terms of trade, thus a smaller decrease in H's one-period payoff in the period that F initiates a tariff war phase. The other factor comes from a decrease in the damage that H needs to endure during the tariff war that follows F's imposition of its static optimal tariff. As H gets larger, the damage that H needs to endure during the tariff war that F initiates, represented by $[u^*(h^*, l) - u^*(l^*, l)](V_C - V_N)/(V_C^* - V_N^*)$ in the right-hand side of the equality in (22), decreases because $\partial[u^*(h^*, l) - u^*(l^*, l)]/\partial\sigma < 0$ and $\partial[(V_C - V_N)/(V_C^* - V_N^*)]/\partial\sigma < 0$. The level of such

---

move the protection combination back to $E_{\sigma=1}$. The proof for these properties of IC and IC^* is provided in *Proofs* for *Proposition 4* in the appendix.

[37] Note that IC in (22) applies not only to the case with $\sigma = 1$ but also to the cases with any $\sigma > 1$. This implies that the result on the positive slopes of IC and IC^* is a general result. This also implies that I can use IC in (22) to analyze the effect of an increase in σ on IC.

[38] It is well known in the trade literature that a country's ability to change the terms of trade in its favor by imposing tariffs strengthens as it gets relatively larger than its trading partner. Kennan and Riezman (1988), McLaren (1997), and Park (2000) analyze how such an asymmetry in countries' ability to influence the terms of trade affects the cooperation attainable among asymmetric countries.

damage depends on both the length of a tariff war phase that F initiates ($\delta^C - \delta^*$) and H's loss of its expected discounted payoff that it could have earned in a non-tariff war period ($V_C - V_N$). Note that ($\delta^C - \delta^*$) = $[u^*(h^*, l) - u^*(l^*, l)]/(V_C^* - V_N^*)$ decreases with a lower value for $u^*(h^*, l) - u^*(l^*, l)$ and with a higher value for $(V_C^* - V_N^*)$.[39] As F gets smaller relative to H, F can obtain a less increase in its one-period payoff from imposing its static optimal tariff (a lower value for $u^*(h^*, l) - u^*(l^*, l)$) while it can attain more gains from trading with a bigger H in a non-tariff war period (a higher value for $V_C^* - V_N^*$). This implies that the length of a tariff war phase that F can employ against H's potential deviation gets shorter with a higher σ. In addition, H's loss of its expected discounted payoff that it could have earned in a non-tariff war period ($V_C - V_N$) gets smaller as H can obtain smaller gains from trade with a smaller F.[40]

In summary, an increase in σ induces H to have a higher incentive to raise its protection level in a cooperative period (a larger value for the left-hand side of the equality in (22)) while the cost associated with such a deviatory behavior gets smaller for H (a smaller value for the right-hand side of the equality in (22)). This leads to an overall increase in H's incentive to raise its protection level under *PTS*. As a result, a higher σ shifts *IC* upward in Figure 4. One can apply the same type of logic to explain how a higher σ shifts IC^* to the left by lowering F's incentive to raise its protection level under *PTS*. These shifts in *IC* and IC^* together imply that a larger country (H) ends up using more concealed protection

[39] If F can obtain a smaller one-period gain from initiating a tariff war phase (a lower value for $u^*(h^*, l) - u^*(l^*, l)$), its expected discounted payoff from initiating a tariff war phase will remain at the same level only with a shorter tariff phase to follow. If F needs to endure more damage to its payoff under a tariff war (a higher value for $V_C^* - V_N^*$), once again F's expected discounted payoff from initiating a tariff war will remain the same only with a shorter tariff war phase to follow.

[40] In a bilateral trade relationship, the terms of trade under free trade gets closer to (further away from) a larger country's (smaller country's) autarky price ratio as the larger country become larger relative to the smaller one. This implies that the large (small) country can realize smaller (larger) gains from the bilateral trade. This discussion about the size of gains from free trade does not directly translate into a higher value for $V_C^* - V_N^*$ and a lower value for $V_C - V_N$ under *PTS* because the changes in the lengths of tariff war phases may also affect V_C^* and V_C. However, $\partial[(V_C - V_N)/(V_C^* - V_N^*)]/\partial\sigma < 0$ ensures the damage that H needs to endure during the tariff war that F initiates gets smaller under *PTS* as H gets larger relative to F.

than a smaller country under *PTS* as indicated by $l_{\sigma>1} > l_{\sigma=1} = l^*_{\sigma=1} > l^*_{\sigma>1}$. *Proposition 4* summarizes these findings as follows:

Proposition 4.

If there is an increase in H's market size relative to F's (an increase in H's relative ability to influence the terms of trade through protection), then the cooperative protection levels that H and F sustain under *PTS*, (l, l^*), change into a direction where l gets higher and l^* gets lower. A decrease (increase) in the length of a tariff war phase that F (H) can initiate against H's (F's) potential deviations under *PTS*, as well as an increase (decrease) in H's (F's) ability to change the terms of trade through protection, contributes to this change. (See Appendix for Proof.)

According to *Proposition 4*, the asymmetry among countries may severely limit the small country's ability to restrain the large country's use of concealed protection under *PTS*. In the above analysis, I assume that H and F do not change their trigger control variables ($\omega^D = \omega^{D*}$ defined in Section 3) when the asymmetry in their size affects the cooperative protection levels they sustain under *PTS*. This implies that the smaller country F will initiate tariff wars more often than the larger country H as $Pr^*(l) > Pr(l^*)$ with $l > l^*$ and $\omega^D = \omega^{D*}$. However, this result may change as H and F change their trigger control variables in response to an increase in the size of H relative to F. For example, if H increases its trigger control variable and F decreases its own in response to a higher σ, it is possible to have a case where F initiates tariff wars less often than H even when H uses concealed protection more intensely than F.[41]

[41] When one considers the case with asymmetric countries, defining "*optimal*" *PTS* regarding the choice over the trigger control variables becomes a less obvious matter because maximizing the simple sum of the two countries' expected discounted payoffs under *PTS* may entail a gain for one country at the expense of the other. This opens up the question of how each country will change its trigger control variable in response to an increase in the asymmetry among countries, possibly to maximize its expected discounted payoff under *PTS*. While this potential game between H and F of setting trigger control variables is an interesting issue, it remains to be pursued, possibly in a future work.

5. Concluding Remarks

The analysis in this paper establishes that symmetric countries may restrain the use of concealed trade barriers with symmetric *PTS* (*private trigger strategies*) as long as their private signals are sensitive enough to such barriers. The analysis also reveals that it is not optimal to push down the cooperative protection level to its minimum level attainable under symmetric *PTS* due to the cost associated with increasing the probability of costly tariff wars. This paper identifies two factors that may limit the effectiveness of *PTS*. One is a reduction in each country's time lag to adjust protection levels in response to the other country's initiation of an explicit tariff war and the other is asymmetry among countries. Both of these factors may limit the level of cooperation attainable under *PTS* by reducing the lengths of tariff war phases that countries can employ against potential deviations from the cooperative behavior.

A major potential limitation of *PTS* is that the private nature of signals that trigger tariff wars constraints the lengths of tariff war phases. In contrast, countries can employ a tariff war phase of any length under *public trigger strategies* where a public signal (that is correlated with concealed protection levels) triggers tariff wars. While *PTS* may enable countries to utilize more accurate information about concealed trade barriers than public signals, such as volumes of trade, the limitation on the lengths of tariff war phases under *PTS* may induce countries to prefer *public trigger strategies* over *PTS* in restraining the use of such barriers. In this regard, one may perceive Trade Policy Reviews of the WTO as an effort to generate (potentially better) public signals of trade barriers, especially of those barriers that are not directly observable.

Regarding the general issue of enforcing international trade agreements, this paper emphasizes a point that the trade literature has not fully explored; countries may have different opinions about potential violations of trade agreements. Private signals of other countries' concealed trade barriers represent one possible source for such disagreements over potential violations. There are, of course, other ways that countries may disagree. For example, trade disputes can be over explicit trade barriers, like imposition of explicit tariffs as a legitimate safeguard policy. As demonstrated through the recent U.S. safeguard action on its steel industry, countries may disagree on whether the economic environment is severe enough to justify such a safeguard action. Bagwell and Staiger (1990) provide a model that explains the necessity of safeguard actions; in the presence of random shocks to the economy, high protection periods (*safeguard-action* periods) should be allowed to avoid unnecessary tariff wars when realized shocks increase countries' incentive to use protective trade policies. Bagwell and Staiger, however, do not consider potential disputes among countries over legitimacy of safeguard actions. If countries can form different opinions about legitimacy of potential safeguard actions, a proper working of safeguard policy need to overcome two distinctive but related problems.[42] One comes from the possibility that countries may pretend to believe in a strong safeguard case just to abuse the safeguard policy. The other comes from the possibility that countries may not challenge a safeguard action (even when they believe that it is a weak safeguard case) just to avoid potentially costly tariff wars.[43] A dispute settlement procedure involving a third party panel investigation which either legitimizes a safeguard action or grants the right for using retaliatory measures against it, like that of the WTO, may help countries overcome these problems. Formally analyzing the role of such a dispute settlement procedure in the presence of potential misrepresentations of private signals or beliefs about protective trade policies would be a challenging but worthy extension of this paper.

[42] Athey and Bagwell (2001) and Athey et al. (2004) consider similar issues in the context of collusion among firms. They analyze possible collusive pricing schemes in an infinitely repeated Bertrand game in which prices are perfectly observed and each firm receives a privately-observed i.i.d. cost shock in each period.
[43] Section 2.2.1 addresses the same type issue in the context of modeling *private trigger strategies* against the potential use of concealed protection.

Appendix

Proof for Lemma 1 **(b)**

If $Pr = Pr^* = 0$, then $\delta = \delta^C - (1 - \delta^C)\,[u(h, l^*) - u(l, l^*)]/[u(l, l^*) - u(h, h^*)]$ and $\delta^* = \delta^C - (1 - \delta^C)\,[u^*(h^*, l) - u^*(l^*, l)]/[u^*(l^*, l) - u^*(h, h^*)]$ with such δ, δ^*, and $\delta^S = \delta + \delta^* - \delta^C$ all belonging to $(0, \delta^C)$ if δ^C is close enough to 1. This proves (b) for the case of $Pr = Pr^* = 0$ with δ^C being close enough to 1.

Now, it remains to prove (b) for the case that Pr and Pr^* are close to 0 with δ^C being close enough to 1. To prove this, I first rewrite the sufficient condition in (a) as $\delta = \delta^C - (1-\delta^C)k$, $\delta^* = \delta^C - (1-\delta^C)k^*$, and $\delta^S = (\delta^* + \delta) - \delta^C$, where $k = [u(h, l^*) - u(l, l^*)]/[(1 - \delta^C)V_C - u(h, h^*)]$ and $k^* = [u^*(h^*, l) - u^*(l^*, l)]/[(1 - \delta^C)V_C^* - u^*(h^*, h)]$. Note that $\partial k/\partial\delta = -Pr(1 - Pr^*)C$, $\partial k/\partial\delta^* = -Pr^*(1 - Pr)C$, $\partial k/\partial\delta^S = -PrPr^*C$, $\partial k^*/\partial\delta = -Pr(1 - Pr^*)C^*$, $\partial k^*/\partial\delta^* = -Pr^*(1 - Pr)C^*$, and $\partial k^*/\partial\delta^S = -PrPr^*C^*$ with $C = (1 - \delta^C)\,[u(h, l^*) - u(l, l^*)]\{(1 - PrPr^*)[u(l, l^*) - u(h, h^*)] + Pr(1 - Pr^*)[u(h, l^*) - u(l, l^*)] + Pr^*(1 - Pr)[u(l, h^*) - u(l, l^*)]\}/\{[(1 - \delta^C)V - u(h, h^*)]\,[1 - \delta^C + Pr(1 - Pr^*)(\delta^C - \delta) + Pr^*(1 - Pr)(\delta^C - \delta^*) + PrPr^*(\delta^C - \delta^S)]^2\} > 0$, and $C^* = (1 - \delta^C)\,[u^*(h^*, l) - u^*(l^*, l)]\{(1 - PrPr^*)[u^*(l^*, l) - u^*(h^*, h)] + Pr(1 - Pr^*)[u^*(l^*, h) - u^*(l^*, l)] + Pr^*(1 - Pr)[u^*(h^*, l) - u^*(l^*, l)]\}/\{[(1 - \delta^C)V^* - u^*(h^*, h)]\,[1 - \delta^C + Pr(1 - Pr^*)(\delta^C - \delta) + Pr^*(1 - Pr)(\delta^C - \delta^*) + PrPr^*(\delta^C - \delta^S)]^2\} > 0$. Let $\delta(\delta^*)$ to be the implicit function from $\delta - \delta^C + (1 - \delta^C)k^* = 0$ and $\delta^*(\delta)$ to be the implicit function from $\delta^* - \delta^C + (1 - \delta^C)k^* = 0$ with $\delta^S = \delta + \delta^* - \delta^C$. Then, $\partial\delta(\delta^*)/\partial\delta^* = [Pr^*(1 - \delta^C)C]/[1 - Pr(1 - \delta^C)C]$ and $\partial\delta^*(\delta)/\partial\delta = [Pr(1 - \delta^C)C^*]/[1 - Pr^*(1 - \delta^C)C^*]$. Note that $\partial\delta(\delta^*)/\partial\delta^* \in (0,1)$ and $\partial\delta^*(\delta)/\partial\delta \in (0,1)$ with $\delta(\delta^* = 0) \approx \delta^C - (1 - \delta^C)\,[u(h, l^*) - u(l, l^*)]/[u(l, l^*) - u(h, h^*)] > 0$ and $\delta^*(\delta = 0) \approx \delta^C - (1 - \delta^C)\,[u^*(h^*, l) - u^*(l^*, l)]/[u^*(l^*, l) - u^*(h, h^*)] > 0$ for Pr and Pr^* being close enough to 0 and δ^C is close enough to 1. Because $\partial\delta(\delta^*)/\partial\delta^* \to 0$ and $\partial\delta^*(\delta)/\partial\delta \to 0$ as $\delta^C \to 1$ with $\delta(\delta^* = 0) > 0$ and $\delta^*(\delta = 0)$, this implies that there exists a unique combination of $(\delta, \delta^*, \delta^S)$ that satisfies $\delta = \delta^C - (1-\delta^C)k$, $\delta^* = \delta^C - (1-\delta^C)k^*$, and $\delta^S = (\delta^* + \delta) - \delta^C$, with such δ, δ^*, and δ^S all belonging to $(0, \delta^C)$ as δ^C is close enough to 1.

Proof for Lemma 2

Proofs for the results in *Lemma 2* follow the same logics as the proofs for the corresponding results in Stokey and Lucas (1989). More specifically, Theorem 4.2, 4.3, 4.4, and 4.5 in Stokey and Lucas correspond to (i), (ii), (iii), and (iv) of *Lemma 2* (a), respectively. One may also find corresponding proofs for *Lemma 2* (b) and *Lemma 2* (c) in Theorem 4.6 in Stokey and Lucus. To save the space, I discuss how one can adjust the corresponding proofs in Stockey and Lucas to prove the results in *Lemma 2*. A complete proof for Lemma 2 is available upon request.

***For Lemma 2* (*a*):**

Let Γ: $X \rightarrow X$ denote the correspondence describing the feasibility constraints with X =[0, h]. Given $x_0 \in X$, let $\Pi(x_0)$ ={ $\{x_t\}_{t=0}^{\infty}$: $x_{t+1} \in \Gamma(x_t)$, t = 0, 1, …} be the set of plan that are feasible from x_0. Define $F(x_t, x_{t+1})$ as $F(\cdot)$ in (8). Then, Assumption 4.1 in Stokey and Lucas is satisfied. I modify Assumption 4.2 with $\lim_{n\to\infty} \sum_{t=0}^{n} (\delta^C)^t [\prod_{i=0}^{t-1} (1 - Pr^*(x_i))] F(x_t, x_{t+1})$ existing for all $x_0 \in X$ and $\underline{x} \in \prod(x_0)$, then it is also satisfied. For each n = 0, 1, ···, define u_n: $\Pi(x_0) \rightarrow R$ by $u_n(\underline{x}) = \sum_{t=0}^{n} (\delta^C)^t [\prod_{i=0}^{t-1} (1 - Pr^*(x_i))] F(x_t, x_{t+1})$.

Define u: $\prod(x_0) \rightarrow \overline{R}$ by $u(\underline{x}) = \lim_{n\to\infty} u_n(\underline{x})$. Then, it is easy to show that Lemma 4.1 in Stocky and Lucas holds when one replaces $u(\underline{x}) = F(x_0, x_1) + \delta^C u(\underline{x}^/)$ with $u(\underline{x}) = F(x_0, x_1) + \delta^C (1 - Pr^*(x_0)) u(\underline{x}^/)$. Having v^* and v in Stocky and Lucas represent V_S and V in *Lemma 2*, I can also show that Theorem 4.2, 4.3, 4.4, and 4.5 hold for these newly defined variables, replacing $v^*(x_t^*) = F(x_t^*, x_{t+1}^*) + \delta^C v(x_{t+1}^*)$ of (9) in Stocky and Lucas with $v^*(x_t^*) = F(x_t^*, x_{t+1}^*) + \delta^C (1 - Pr^*(x_i)) v(x_{t+1}^*)$. While one needs to modify some lines of proofs in Stocky and Lucas, it is a pretty straightforward extension of the logics of their proofs, as mentioned earlier.

***For Lemma 2* (*b*) and (*c*):**

First note that *Lemma 2* (*b*) and *Lemma 2* (*c*) correspond to Theorem 4.6 of Stocky and Lucas. Also note that Theorem 4.6 basically uses the Contraction Mapping Theorem (Theorem 3.2) and the Theorem of Maximum (Theorem 3.6) to prove the results. To show that the proof in Theorem 4.6 works for proving *Lemma 2* (*b*) and *Lemma 2* (*c*), I establish that the following result. Define an operator T by $(Tv)(x) = \underset{y\in[0,h]}{Max} \{F(x,y) + \delta^C[1 - Pr^*(x)]v(y)\}$. T satisfies Blackwell's sufficient condition for contraction mapping as it satisfies both "Monotonicity" and "Discounting" criteria:

(Monotonicity)

If $v(y) \leq w(y)$ for all values of y, then $Tv(y) \leq Tw(y)$ because $[1 - Pr^*(x)] \geq 0$ by definition.

(Discounting)

$T(v + a)(x) = \underset{y\in[0,h]}{Max} \{F(x,y) + \delta^C[1 - Pr^*(x)][v(y) + a]\} = \underset{y\in[0,h]}{Max} \{F(x,y) + \delta^C[1 - Pr^*(x)]v(y) + \delta^C[1 - Pr^*(x)]a\}\} = (Tv)(x) + \delta^C[1 - Pr^*(x)]a \leq (Tv)(x) + \delta^C a$ because $[1 - Pr^*(x)] \in [0,1]$.

In addition, T: $C(X) \rightarrow C(X)$ from the Theorem of Maximum with $C(X)$ denoting the set of bounded continuous functions f: $X \rightarrow R$. Thus, T: $C(X) \rightarrow C(X)$ is a contraction mapping with modulus δ^C, implying that I can apply the Contraction Mapping Theorem to T. Thus, I can show that Lemma 2 (*b*) and (*c*) hold using the Theorem of Maximum as in Theorem 4.6.

Proof for Lemma 3

For Lemma 3 (a):

Define $f(\tau_{-1}, \tau) \equiv F(\tau_{-1}, \tau) + \delta^C[1 - Pr^*(\tau_{-1})]V(\tau)$. Note that $f(\tau_{-1}, \tau)$ is everywhere differentiable w.r.t. τ_{-1} for all $\tau \in [0, h]$ and $\partial f(\tau_{-1}, \tau)/\partial\tau_{-1} = -[\partial Pr^*(\tau_{-1})/\partial\tau_{-1}]\{u(\tau, l^*) + \delta^C V(\tau) - u(\tau, h^*) - (\delta^C - \delta^*) V_N - \delta^* V_C\}$ is bounded for all $\tau \in [0, h]$. This implies that $f(\tau_{-1}, \tau)$ is absolutely continuous w.r.t. τ_{-1} for all $\tau \in [0, h]$. Therefore, I can use Theorem 2 of Milgrom and Segal (2002) in deriving the following expression

(A1) $$V(\tau_{-1}) = V(0) + \int_0^{\tau_{-1}} [\partial f(m, g(m))/\partial m] dm,$$

where $g(m) \in G(m)$ and $\partial f(m,g(m))/\partial m = -[\partial Pr^*(m)/\partial m]\{u(g(m), l^*) + \delta^C V(g(m)) - u(g(m), h^*) - (\delta^C - \delta^*)V_N - \delta^* V_C\}$.

(A1) implies that $V(\tau_{-1})$ will be strictly decreasing in $\tau_{-1} \in [0, h]$, if $u[g(m), l^*] + \delta^C V(g(m)) - u(g(m), h^*) - (\delta^C - \delta^*)V_N - \delta^* V_C > 0$ for all $m \in [0, h]$, because $\partial Pr^*(m)/\partial m > 0$ by assumption. To show that $u(g(m), l^*) + \delta^C V(g(m)) - u(g(m), h^*) - (\delta^C - \delta^*)V_N - \delta^* V_C > 0$ for all $m \in [0, h] > 0$, I first establish that the inequality holds for any $g(m) \leq l$, and then show that the inequality holds for any $g(m) > l$.

First, assume that $g(m) \leq l$. To have $u(g(m), l^*) + \delta^C V(g(m)) \leq u(g(m), h^*) + (\delta^C - \delta^*) V_N + \delta^* V_C$, $V_C > V(g(m))$ because $u(g(m), l^*) > u(g(m), h^*)$ with $l^* < h^*$ and $V(g(m)) \geq V_N$. The last inequality is obvious because the strategy of always setting $\tau = h$ will generate a discounted expected payoff at least as good as V_N, regardless of $g(m)$ taking any feasible values. $V(g(m)) \geq [1 - Pr^*(g(m))][u(l, l^*) + \delta^C V_C] + Pr^*(g(m))[u(l, h^*) + (\delta^C - \delta^*) V_N + \delta^* V_C] \geq [1 - Pr^*(l)][u(l, l^*) + \delta^C V_C] + Pr^*(l)[u(l, h^*) + (\delta^C - \delta^*) V_N + \delta^* V_C]$, where the last inequality comes from $g(m) \leq l$ and $[u(l, l^*) + \delta^C V_C] \geq [u(l, h^*) + (\delta^C - \delta^*) V_N + \delta^* V_C]$, and the first inequality comes from the fact that $[1 - Pr^*(g(m))][u(l, l^*) + \delta^C V_C] + Pr^*(g(m))[u(l, h^*) + (\delta^C - \delta^*) V_N + \delta^* V_C]$ represents a discounted expected payoff of playing a potentially suboptimal strategy of setting $\tau = l$ with $\tau_{-1} = g(m)$. From *ICP*, $V_C = [1 - Pr^*(l)][u(l, l^*) + \delta^C V_C] + Pr^*(l)[u(l, h^*) + (\delta^C - \delta^*)V_N + \delta^* V_C]$, which implies that $V_C \leq V(g(m))$, thus a contradiction. Therefore, $u(g(m), l^*) + \delta^C V(g(m)) > u(g(m), h^*) + (\delta^C - \delta^*)V_N + \delta^* V_C$ if $g(m) \leq l$.

Now, I will show that $u(g(m), l^*) + \delta^C V(g(m)) > u(g(m), h^*) + (\delta^C - \delta^*) V_N + \delta^* V_C$ if $g(m) > l$. Define $K \equiv u(g(m), h^*) + (\delta^C - \delta^*)V_N + \delta^* V_C$. Then, $V(g(m)) \geq [1 - Pr^*(g(m))]u(g(m), l^*)/\{1 - \delta^C[1 - Pr^*(g(m))]\} + Pr^*(g(m))K/\{1 - \delta^C[1 - Pr^*(g(m))]\}$ because the right-hand side of the inequality represents a discounted expected payoff from playing a potentially suboptimal strategy of setting the current and all the future protection level at $g(m)$ with $\tau_{-1} = g(m)$. This implies that $u(g(m), l^*) + \delta^C V(g(m)) - K \geq u(\delta(m), l^*) + \delta^C[1 - Pr^*(g(m))]u(g(m), l^*)/\{1 - \delta^C[1 - Pr^*(g(m))]\} + \delta^C Pr^*(g(m))K/\{1 - \delta^C[1 - Pr^*(g(m))]\} - K = (1 - \delta^C)\{u(g(m), l^*)/(1 - \delta^C) - [u(g(m), h^*) + (\delta^C - \delta^*) V_N + \delta^* V_C]\}/\{1 - \delta^C[1 - Pr^*(g(m))]\}$. Note that the last term has a positive sign because $u(g(m), l^*)/(1 - \delta^C) > [u(g(m), h^*) + (\delta^C - \delta^*) V_N + \delta^* V_C]$ with $u(g(m), l^*)/(1 - \delta^C) > V_C$ as $g(m) > l$. This implies that $u(g(m), l^*) + \delta^C V(g(m)) > K$.

***For Lemma 3* (*b*):**

To prove that $G(\tau_{-1})$ is strictly increasing in τ_{-1}, I first show that $\tau^{//} \geq \tau^{/}$ for all $\tau^{//}_{-1} > \tau^{/}_{-1} \in [0, h]$ with $\tau^{//} \in G(\tau^{//}_{-1})$ and $\tau^{/} \in G(\tau^{/}_{-1})$. Then, I show that $\tau^{//} = \tau^{/}$ will lead to a contradiction using a result in Cotter and Park (2004). Consider $\tau^{//}_{-1} > \tau^{/}_{-1}$, having $V(\tau^{/}_{-1}) = F(\tau^{/}_{-1}, \tau^{/}) + \delta^C[1 - Pr^*(\tau^{/}_{-1})]V(\tau^{/})$ and $V(\tau^{//}_{-1}) = F(\tau^{//}_{-1}, \tau^{//}) + \delta^C[1 - Pr^*(\tau^{//}_{-1})]V(\tau^{//})$. Then, $F(\tau^{/}_{-1}, \tau^{/}) + \delta^C[1 - Pr^*(\tau^{/}_{-1})]V(\tau^{/}) \geq F(\tau^{/}_{-1}, \tau^{//}) + \delta^C[1 - Pr^*(\tau^{/}_{-1})]V(\tau^{//})$ and $F(\tau^{//}_{-1}, \tau^{//}) + \delta^C[1 - Pr^*(\tau^{//}_{-1})]V(\tau^{//}) \geq F(\tau^{//}_{-1}, \tau^{/}) + \delta^C[1 - Pr^*(\tau^{//}_{-1})]V(\tau^{/})$ because the terms of the right-hand sides of these inequalities represent discounted expected payoffs from playing potentially suboptimal strategies. These two inequalities together imply that

(A2) $[F(\tau^{/}_{-1}, \tau^{/}) - F(\tau^{//}_{-1}, \tau^{/})] - [F(\tau^{/}_{-1}, \tau^{//}) - F(\tau^{//}_{-1}, \tau^{//})] \geq \delta^C[Pr^*(\tau^{//}_{-1}) - Pr^*(\tau^{/}_{-1})][V(\tau^{//}) - V(\tau^{/})]$.

Define $E(\tau^{/}; \tau^{/}_{-1}, \tau^{//}_{-1}) = F(\tau^{/}_{-1}, \tau^{/}) - F(\tau^{//}_{-1}, \tau^{/})$. According to the mean value theorem (using the fact that $E(\tau^{/}; \tau^{/}_{-1}, \tau^{//}_{-1})$ is continuous and differentiable w.r.t. τ, then $\exists\ \bar{\tau} \in [\mathrm{Min}(\tau^{/}, \tau^{//}), \mathrm{Max}(\tau^{/}, \tau^{//})]$ such that

(A3)
$$\begin{aligned} &E(\tau^{/}; \tau^{/}_{-1}, \tau^{//}_{-1}) - E(\tau^{//}; \tau^{/}_{-1}, \tau^{//}_{-1}) = (\tau^{/} - \tau^{//})[\partial E(\bar{\tau}; \tau^{/}_{-1}, \tau^{//}_{-1}) / \partial \tau] \\ &\geq \delta^C [Pr^*(\tau^{//}_{-1}) - Pr^*(\tau^{/}_{-1})][V(\tau^{//}) - V(\tau^{/})] \end{aligned}$$

with the inequality coming from (A2). Note that $[\partial E(\bar{\tau}; \tau^{/}_{-1}, \tau^{//}_{-1})/\partial \tau] = [\partial u(\bar{\tau}, l^*)/\partial \tau - \partial u(\bar{\tau}, l^*)/\partial \tau] = 0$ as $\partial^2 u(\tau, \tau^*)/\partial \tau\, \partial \tau^* = 0$. Now, I will show that $\tau^{//} < \tau^{/}$ leads to a contradiction. If $\tau^{//} < \tau^{/}$, $\delta^C[Pr^*(\tau^{//}_{-1}) - Pr^*(\tau^{/}_{-1})][V(\tau^{//}) - V(\tau^{/})] > 0$ because $Pr^*(\tau^{//}_{-1}) - Pr^*(\tau^{/}_{-1})) > 0$ and $[V(\tau^{//}) - V(\tau^{/})] > 0$ from *Lemma 3* (*a*). This contradicts $\delta^C[Pr^*(\tau^{//}_{-1}) - Pr^*(\tau^{/}_{-1})][V(\tau^{//}) - V(\tau^{/})] \leq 0$ in (A3), thus $\tau^{//} \geq \tau^{/}$ for all $\tau^{//}_{-1} > \tau^{/}_{-1} \in [0, h]$.

Now, it remains to prove that $\tau^{//} = \tau^{/}$ leads to a contraction. From Theorem 2 of Cotter and Park (2004), $V(\tau)$ is differentiable for $\tau \in G(\tau_{-1})$ for all $\tau_{-1} \in [0, h]$. Therefore,

(A4) $$\partial F(\tau^{/}_{-1}, \tau^{/}) / \partial\tau + \delta^{C}[1 - Pr^{*}(\tau^{/}_{-1})][\partial V(\tau^{/}) / \partial\tau] = 0 \text{ and}$$
$$\partial F(\tau^{//}_{-1}, \tau^{//}) / \partial\tau + \delta^{C}[1 - Pr^{*}(\tau^{//}_{-1})][\partial V(\tau^{//}) / \partial\tau] = 0.$$

If $\tau^{//} = \tau^{/}$, $\partial F(\tau^{/}_{-1}, \tau^{/}) / \partial\tau - \partial F(\tau^{//}_{-1}, \tau^{/}) / \partial\tau = -\delta^{C}[Pr^{*}(\tau^{//}_{-1}) - Pr^{*}(\tau^{/}_{-1})][\partial V(\tau^{/}) / \partial\tau]$ from (A4), contradicting $\partial[F(\tau^{/}_{-1}, \tau^{/}) - F(\tau^{//}_{-1}, \tau^{/})] / \partial\tau = 0$, $[Pr^{*}(\tau^{//}_{-1}) - Pr^{*}(\tau^{/}_{-1})] > 0$, and $\partial V(\tau^{/}) / \partial\tau > 0$.

<u>Proof for Lemma 4</u>

For Lemma 4 (a):

In proving *Lemma 4* (*a*), I use Theorem 4 in Cotter and Park (2004). According to the theorem, if there exists a unique $\tau_S \in (0, h)$ that satisfies *IC* defined in (11): $\partial F(\tau_S, \tau_S)/\partial\tau + \delta^C[1 - Pr^*(\tau_S)]\cdot[\partial V(\tau_S)/\partial\tau] = 0$ and $\tau \in (0, \text{h})$ for every $\tau_{-1} \in [0, h]$ and $\tau \in G(\tau_{-1})$, then $G(\tau_S) = \{\tau_S\}$ and τ_S is a strongly stable protection level in the sense that for every $\tau_{-1} > \tau_S$ and $\tau \in G(\tau_{-1}), \tau < \tau_{-1}$, and for every $\tau_{-1} < \tau_S$ and $\tau \in G(\tau_{-1})$, $\tau > \tau_{-1}$. To prove *Lemma 4* (*a*), therefore, I first show that there exists a unique $\tau_S \in (0, h)$ such that $\partial F(\tau_S, \tau_S)/\partial\tau + \delta^C[1 - Pr^*(\tau_S)]\cdot[\partial V(\tau_S)/\partial\tau] = 0$ if $[\partial^2 Pr^*(\tau)/(\partial\tau)^2]\,[1 - Pr^*(\tau)] - \{1 + \delta^C[1 - Pr^*(\tau)]\}[\partial Pr^*(\tau)/\partial\tau\,]^2 > 0$ for all $\tau \in [0, h]$ and $\partial Pr^*(\tau)/\partial\tau = 0$ at $\tau = 0$, then establish that $\tau \in (0, \text{h})$ for every $\tau_{-1} \in [0, h]$ and $\tau \in G(\tau_{-1})$.

First note that $\partial F(\tau_S, \tau_S)/\partial\tau = \partial u(\tau_S, l^*)/\partial\tau > 0$ at $\tau_S = 0$ and $\partial^2 F(\tau_S, \tau_S)/\partial\tau^2 < 0$ with $\partial F(\tau_S, \tau_S)/\partial\tau = \partial u(\tau_S, l^*)/\partial\tau = 0$ at $\tau_S = h$ from the assumptions on the derivatives of $u(\tau, \tau^*)$ w.r.t. τ and τ^*. Because $\partial V(\tau_S)/\partial\tau = -[\partial Pr^*(\tau_S)/\partial\tau\,]\{u(\tau_S, l^*) + \delta^C V(\tau_S) - [u(\tau_S, h^*) + (\delta^C - \delta^*)V_N + \delta^* V_C]\} = 0$ at $\tau_S = 0$ from the assumption of $\partial Pr^*(\tau)/\partial\tau = 0$ at $\tau = 0$, $F(\tau_S, \tau_S)/\partial\tau > 0$ at $\tau_S = 0$ implies that *IC* in (11) will not be satisfied at $\tau_S = 0$. Now, define $A(\tau_S) \equiv u(\tau_S, l^*) + \delta^C V(\tau_S) - [u(\tau_S, h^*) + (\delta^C - \delta^*)V_N + \delta^* V_C]$ and $B(\tau_S) \equiv \delta^C[1 - Pr^*(\tau_S)][\partial Pr^*(\tau_S)/\partial\tau]A(\tau_S)$, thus $\delta^C[1 - Pr^*(\tau_S)]\cdot[\partial V(\tau_S)/\partial\tau] = -B(\tau_S)$. Then, $\partial B(\tau_S)/\tau_S = \delta^C A(\tau_S)[[\partial^2 Pr^*(\tau)/(\partial\tau)^2]\,[1 - Pr^*(\tau)] - \{1 + \delta^C[1 - Pr^*(\tau)]\}[\partial Pr^*(\tau)/\partial\tau\,]^2] > 0$ for all $\tau_S \in [0, h]$ because $[\partial^2 Pr^*(\tau)/(\partial\tau)^2]\,[1 - Pr^*(\tau)] - \{1 + \delta^C[1 - Pr^*(\tau)]\}[\partial Pr^*(\tau)/\partial\tau\,]^2 > 0$ for all $\tau_S \in [0, h]$ by assumption and $A(\tau_S) > 0$ as shown in the proof for *Lemma 3* (*a*). This implies that there exists a unique $\tau_S \in (0, h)$ such that $\partial F(\tau_S, \tau_S)/\partial\tau + \delta^C[1 - Pr^*(\tau_S)]\cdot[\partial V(\tau_S)/\partial\tau] = 0$.

Now, I only need to prove that $\tau \in (0, \text{h})$ for every $\tau_{-1} \in [0, h]$ and $\tau \in G(\tau_{-1})$. Because $G(\tau_{-1})$ is strictly increasing in τ_{-1} as proved in *Lemma 3* (*b*), it suffices to prove that $0 \notin G(0)$ and $h \notin G(h)$. I will prove these by contradiction. First, assume that $0 = G(0)$, implying $V(0) =$

$\sum_{d=0}^{\infty}\left\{(\delta^C)^d \cdot \left[\prod_{i=0}^{d-1}\left[1-\Pr^*(\tau_i)\right]\right]\cdot F(\tau_d,\tau_{d+1})\right\}$ with $\{\tau_d = 0\}_{d=0}^{\infty}$. Consider an alternative protection sequence with $\tau_0 = 0$, $\tau_1 = \varepsilon > 0$, and $\{\tau_d =\}_{d=2}^{\infty}$, which defines a corresponding discounted expected payoff, denoted by $V_A(0)$. Then, I can show that $V_A(0) - V(0) = \{Pr^*(0)u(\varepsilon, h^*) + [1 - Pr^*(0)]u(\varepsilon, l^*) + Pr^*(0)[(\delta^C - \delta^*) V_N + \delta^* V_C]\} - \{Pr^*(0)u(0, h^*) + [1 - Pr^*(0)]u(0, l^*) + Pr^*(0)[(\delta^C - \delta^*) V_N + \delta^* V_C]\} + \delta^C[1 - Pr^*(0)][Pr^*(\varepsilon) - Pr^*(0)]\{u(0, h^*) - u(0, l^*) + [(\delta^C - \delta^*) V_N + \delta^* V_C]\} + \delta^C[Pr^*(0) - Pr^*(\varepsilon)]F(0, 0)\delta^C[1 - Pr^*(0)]/\{1 - \delta^C[1 - Pr^*(0)]\}$. Because $u(\tau, \tau^*)$ and $Pr^*(\tau)$ are differentiable, I can derive $\lim_{\varepsilon\to 0}[V_A(0) - V(0)]/(\varepsilon - 0) = \partial u(0,l^*)/\partial\tau > 0$ using $\partial^2 u(\tau,\tau^*)/\partial\tau\partial\tau^* = 0$ and $\partial Pr^*(\tau)/\partial\tau = 0$ at $\tau = 0$, which contradicts $V_A(0) \le V(0)$.

I can show that $h \notin G(h)$ in a similar way. First, assume that $h = G(h)$, implying that $V(h) = \sum_{d=0}^{\infty}\left\{(\delta^C)^d \cdot \left[\prod_{i=0}^{d-1}\left[1-\Pr^*(\tau_i)\right]\right]\cdot F(\tau_d,\tau_{d+1})\right\}$ with $\{\tau_d = h\}_{d=0}^{\infty}$. Consider an alternative protection sequence with $\tau_0 = h$, $\tau_1 = h - \varepsilon$, and $\{\tau_d = h\}_{d=2}^{\infty}$, which defines a corresponding discounted expected payoff, denoted by $V_A(h)$. Then, I can show that $V_A(h) - V(h) = \{Pr^*(h)u(h - \varepsilon, h^*) + [1 - Pr^*(h)]u(h - \varepsilon, l^*) + Pr^*(h)[(\delta^C - \delta^*) V_N + \delta^* V_C]\} - \{Pr^*(h)u(h, h^*) + [1 - Pr^*(h)]u(h, l^*) + Pr^*(h)[(\delta^C - \delta^*) V_N + \delta^* V_C]\} + \delta^C[1 - Pr^*(h)][Pr^*(h - \varepsilon) - Pr^*(h)]\{u(h, h^*) - u(h, l^*) + [(\delta^C - \delta^*) V_N + \delta^* V_C]\} + \delta^C[Pr^*(h) - Pr^*(h - \varepsilon)]F(h, h)\delta^C[1 - Pr^*(h)]/\{1 - \delta^C[1 - Pr^*(h)]\}$. Once again, I can derive $\lim_{\varepsilon\to 0}[V_A(h) - V(h)]/(\varepsilon - 0) = -\delta^C[\partial Pr^*(h)/\partial\tau][1 - Pr^*(h)]\{(1 - \delta^C)[u(h, h^*) + (\delta^C - \delta^*)V_N + \delta^* V_C] - u(h, l^*)\}/\{1 - \delta^C[1 - Pr^*(h)]\} > 0$ where the last inequality comes from $\partial Pr^*(h)/\partial\tau > 0$ and $u(h, l^*)/(1 - \delta^C) > u(h, h^*) + (\delta^C - \delta^*)V_N + \delta^* V_C$ as shown in Lemma 3 (a). This implies that $h \notin G(h)$.

***For Lemma 4 (b)*:**

To prove *Lemma 4* (*b*), I will show that H cannot strictly increase its discounted payoff by initiating an explicit tariff war in a period that that follows a cooperative period during which H set its protection level at $l' \neq l = \tau_S$, as long as the lengths of tariff war phases satisfy the sufficient condition for *ICP* and *ICP** in Lemma 1 (a). Once I prove this result, this implies that H cannot increase its discounted expected payoff by initiating explicit tariff wars along any (deviatory) protection sequence, thus *Lemma 4* (*b*).

Suppose that H sets its protection level at l in a period that follows a cooperative period during which H sets its protection level at $l' \neq l = \tau_S$, then chooses its optimal protection sequence from the next period on. Denote the discounted expected payoff from taking this potentially suboptimal action by $C(l^{/})$, then

(A5) $$C(l^{/}) = Pr^{*}(l^{/})[u(l,h^{*}) + (\delta^{C} - \delta^{*})V_{N} + \delta^{*}V_{C}] + [1 - Pr^{*}(l^{/})][u(l,l^{*}) + \delta^{C}V_{C}].$$

Now suppose that H initiates a tariff war phase by setting tariff level at h in a period that follows a cooperative period where H set its protection level $l^{/} \neq l = \tau_S$, then follows its specified strategy once the tariff war phase is over. Denote the discounted expected payoff from taking this potentially suboptimal action by $D(l^{/})$, then

(A6) $$D(l^{/}) = Pr^{*}(l^{/})[u(h,h^{*}) + (\delta^{C} - \delta^{S})V_{N} + \delta^{S}V_{C}] + [1 - Pr^{*}(l^{/})][u(h,l^{*}) + (\delta^{C} - \delta)V_{N} + \delta V_{C}].$$

I can rewrite $C(l^{/})$ and $D(l^{/})$ into

(A7) $$C(l^{/}) = u(l,l^{*}) + \delta^{C}V_{C} - Pr^{*}(l^{/})[u(l,l^{*}) - u(l,h^{*}) + (\delta^{C} - \delta^{*})(V_{C} - V_{N})]$$
$$D(l^{/}) = u(h,l^{*}) + (\delta^{C} - \delta)V_{N} + \delta V_{C} - Pr^{*}(l^{/})[u(h,l^{*}) - u(h,h^{*}) + (\delta - \delta^{S})(V_{C} - V_{N})].$$

Now, note that $C(l^{/}) - D(l^{/}) = [u(l, l^{*}) - u(h, l^{*})] + (\delta^{C} - \delta)(V_C - V_N) - Pr^{*}(l^{/})\{[u(l, l^{*}) - u(l, h^{*})] - [u(h, l^{*}) - u(h, h^{*})] + [(\delta^{C} - \delta^{*}) - (\delta - \delta^{S})](V_C - V_N)\} = 0$ from $[u(l, l^{*}) - u(l, h^{*})] = [u(h, l^{*}) - u(h, h^{*})]$ and the sufficient condition for *ICP* and *ICP** in *Lemma* 1 (*a*): $\delta^{C} - \delta = [u(h, l^{*}) - u(l, l^{*})]/(V_C - V_N)$ and $\delta^{C} + \delta^{S} = (\delta^{*} + \delta)$. Because $C(l^{/})$ is equal or possibly lower than a discounted expected payoff from choosing an optimal protection sequence of not involving an initiation of a tariff war phase, this implies that H cannot strictly increase its discounted payoff by initiating an explicit tariff war in a period that follows a cooperative period during which H sets its protection level at $l^{/} \neq l = \tau_S$.

<u>Proof for Proposition 1</u>

Recall that the unique l^{c} ($< h$) that satisfies $I(l^{c}) = 0$ in (13) is denoted by l_S^{c}. Note that l_S^{c} is equal to τ_S, the unique stationary protection level from which H does not have any incentive to deviate from, as described in *Lemma 4*. By symmetry, l_S^{c} is also such a protection level for F. If $l = l^{*} = l_S^{c}$, then *PTS* satisfying the sufficient condition for *ICP* and *ICP** is a supergame perfect equilibrium in the protection setting game between H and F from which no country has any unilateral incentive to change its specified strategy under *PTS*.

One possible concern about *Proposition 1* is whether the condition for *Lemma 4* (*a*) is a stronger condition than the one in *Proposition 1* so that it rules out the possibility to have a unique l^{c} ($< h$) that satisfies $I(l^{c}) = 0$ in (13). As discussed in Footnote 35, however, the condition for *Lemma 4* (*a*) is a weaker condition that allows possibility of multiple l^{c} ($< h$) that satisfy $I(l^{c}) = 0$ in (13) or even the possibility of nonexistence of such l^{c}.

Proof for Proposition 3

From the discussion of the signs of the last terms in (16) and (19) in the text, it is obvious that the first part of *Proposition 3* is true. Therefore, it remains to prove the second part of *Proposition 3*: "an increase in the speed of protection readjustment can decrease the lengths of tariff war phases to the degree that it is impossible to sustain any level of cooperative protection ($l^c < h$) regardless of the accuracy of imperfect private signals in detecting potential deviations." As a possible cause for countries not being able to sustain any level of cooperation, note that this second part of proposition specifically points out the reduction in the lengths of tariff war phases. This claim is made despite the fact that an increase in the speed of protection readjustment does increase the cooperative protection level attainable under symmetric *PTS* even when one ignores its effect on the lengths of tariff war phases, as shown through (16). Therefore, proving the second part of *Proposition 3* takes two step: (i) proving that countries may sustain a certain level of cooperation ($l^c < h$) even with $n \to \infty$, if one ignores corresponding reductions in the lengths of tariff war phases, thus using (16); (ii) proving that proving that countries cannot sustain any level of cooperation when $n \to \infty$, using (19) which does include the effect of corresponding reductions in the lengths of tariff war phases, regardless of the accuracy of imperfect private signals.

To prove (i), with $n \to \infty$, I rewrite (16) into

(A8) $$[\partial u(l^c, l^c)/\partial \tau][1 - Pr^*(l^c)] = \delta^C[\partial Pr^*(l^c)/\partial \tau][1 - Pr^*(l^c)][u(l^c, l^c) - u(h, h^*) + (\delta^C - \delta^*)(V_C - V_N)].$$

When $Pr^*(l^c) \to 0$ (with an improvement in the accuracy of the private signals), (A8) changes into $\partial u(l^c, l^c)/\partial \tau = \delta^C[\partial Pr^*(l^c)/\partial \tau][u(l^c, l^c) - u(h, h^*) + (\delta^C - \delta^*)(V_C - V_N)]$ for which one can easily show that there exists l^c ($< h$) that satisfies such equality as long as $\partial^2 Pr^*(l^c)/(\partial l^c)^2$ (>0) is high enough.

To prove (ii), with $n \to \infty$, I rewrite (19) into

(A9) $$[\partial u(l^c, l^c)/\partial \tau][1 - Pr^*(l^c)] = \delta^C[\partial Pr^*(l^c)/\partial \tau][1 - Pr^*(l^c)]\{[u(h, l^c) - u(l^c, h^*)] - [u(h, l^c) - u(l^c, h^*)]\}.$$

Note that the equality in (A9) can be satisfied only when $l^c = h$ for any $Pr^*(l^c) < 1$.

Proof for Proposition 4

Proof for Proposition 4 is composed of two parts: (i) proving that IC and IC^* in Figure 4 are positively sloped with IC being flatter than 45 degree line and IC^* being steeper than 45 degree line; (ii) proving that a higher σ shifts IC upwards and IC^* to the left in Figure 4. To save the space, the following proof will only provide the derived values of the variables of which I need to know signs of their derivatives to prove *Proposition 4* and the resulting signs of those derivatives, without showing the corresponding derivation processes. The work showing those derivations is available upon request.

***Part (i)*:**

To prove that *IC* is positively sloped in Figure 4, I use *IC* in (22). First, I sketch the process of deriving

$$\textbf{\textit{IC}}:\quad \partial u(l,l^*)/\partial\tau = \delta^C[\partial \Pr^*(l)][1-\Pr^*(l)]\{[u(l,l^*)-u(l,h^*)]+[u^*(h^*,l)-u^*(l^*,l)]\frac{V_C-V_N}{V_C^*-V_C^*}\}$$

(22)

$$\text{with}\quad \frac{V_C-V_N}{V_C^*-V_N^*}=\frac{[u(l,l^*)-u(h,h^*)]+Pr(l^*)[u(h,l^*)-u(l,l^*)]-Pr^*(l)[u(l,l^*)-u(l,h^*)]}{[u^*(l^*,l)-u^*(h^*,h)]+Pr^*(l)[u^*(h^*,l)-u^*(l^*,l)]-Pr(l^*)[u^*(l^*,l)-u(l^*,h)]},$$

from *ICP* and ICP^* in (7) together with the sufficient condition for them to hold in *Lemma 1* (*a*). From $(\delta^C - \delta^*) = [u^*(h^*, l) - u^*(l^*, l)]/(V_C{}^* - V_N{}^*)$, $(\delta^C - \delta^*)(V_C - V_N) = [u^*(h^*, l) - u^*(l^*, l)](V_C - V_N) /(V_C{}^* - V_N{}^*)$ as shown in (22). To derive the expression for $(V_C - V_N) /(V_C{}^* - V_N{}^*)$ in (22), I starts from $(V_C - V_N) /(V_C{}^* - V_N{}^*) = [(\delta^C - \delta^*)/(\delta^C - \delta)]\{[u(h, l^*) - u(l, l^*)]/[u^*(h^*, l) - u^*(l^*, l)]\}$, implied by the sufficient condition for them to hold in *Lemma 1* (*a*). *ICP* in (7) implies that $\{u(l, l^*) - u(h, h^*) - Pr^*(l)[u(l, l^*) - u(l, h^*)]\}/\{u(h, l^*) - u(h, h^*) - Pr^*(l)[u(h, l^*) - u(h, h^*)]\} = [(1- \delta^C) + Pr^*(l)(\delta^C - \delta^*)]/[(1- \delta) + Pr^*(l)(\delta^C - \delta^*)]$ and ICP^* in (7) implies that $\{u^*(l^*, l) - u^*(h^*, l) - Pr(l^*)[u^*(l^*, l) - u^*(l^*, h)]\}/\{u^*(h^*, l) - u^*(h^*, h) - Pr(l^*)[u^*(h^*, l) - u^*(h^*, h)]\} = [(1- \delta^C) + Pr(l^*)(\delta^C - \delta)]/[(1- \delta^*) + Pr(l^*)(\delta^C - \delta)]$. From these two equalities, I can derive an expression for $[(\delta^C - \delta^*)/(\delta^C - \delta)]$, which in turn being plugged into $(V_C - V_N) /(V_C{}^* - V_N{}^*) = [(\delta^C - \delta^*)/(\delta^C - \delta)]\{[u(h, l^*) - u(l, l^*)]/[u^*(h^*, l) - u^*(l^*, l)]\}$ to generate the corresponding expression in (22). While I omit the complete derivation process to save the space, it is available upon request.

Having derived (22), now I provide the closed-form solutions (in terms of parameters of the model) for the variables in (22), from which one can derive the signs of derivatives of variables that are relevant for the analysis to follow:

$$\partial u(l,l^*)/\partial \tau = \frac{\sigma}{(1+\sigma)^2}[\sigma(\alpha_2^* - \alpha_2) - (2\sigma+1)(\beta+B)l],$$

$$u(l,l^*) - u(l,h^*) = \frac{\sigma}{2(1+\sigma)^2}[(\beta+B)(l^*+h^*) + 2(\alpha_1^* - \alpha_1)](l^* - h^*),$$

$$u^*(h^*,l) - u^*(l^*,l) = -\frac{\sigma}{2(1+\sigma)^2}[2(\alpha_1 - \alpha_1^*) - (2+\sigma)(\beta+B)(l^* - h^*)](h^* - l^*)$$

$$[u(l,l^*) - u(h,h^*)] + Pr(l^*)[u(h,l^*) - u(l,l^*)] - Pr^*(l)[u(l,l^*) - u(l,h^*)]$$

$$= [1 - Pr^*(l)]\frac{\sigma}{2(1+\sigma)^2}[(\beta+B)(l^*+h^*) + 2(\alpha_1^* - \alpha_1)](l^* - h^*)$$

$$+ [1 - Pr(l^*)]\frac{\sigma}{2(1+\sigma)^2}[\sigma(\alpha_2^* - \alpha_2) - (2\sigma+1)(\beta+B)l)](l-h),$$

$$[u^*(l^*,l) - u^*(h^*,h)] + Pr^*(l)[u^*(h^*,l) - u^*(l^*,l)] - Pr(l^*)[u^*(l^*,l) - u(l^*,h)]$$

$$= -[1 - Pr^*(l)]\frac{\sigma}{2(1+\sigma)^2}[2(\alpha_1 - \alpha_1^*) - (2+\sigma)(\beta+B)(l^*+h^*)](h^* - l^*)$$

$$+ [1 - Pr(l^*)]\frac{\sigma}{2(1+\sigma)^2}[-2(\alpha_2^* - \alpha_2) + (\beta+B)(l+h))](l-h),$$

$$\partial u^*(l^*,l)/\partial \tau^* = \frac{\sigma}{(1+\sigma)^2}[(\alpha_1 - \alpha_1^*) - (\sigma+2)(\beta+B)l^*],$$

(A10) $$u^*(l^*,l) - u^*(l^*,h) = \frac{\sigma}{2(1+\sigma)^2}[-2(\alpha_2^* - \alpha_2) + (\beta+B)(l+h))](l-h), \text{ and}$$

$$u(h,l^*) - u(l,l^*) = -\frac{\sigma}{2(1+\sigma)^2}[\sigma(\alpha_2^* - \alpha_2) - (2\sigma+1)(\beta+B)l)](l-h),$$

where $h = \sigma(\alpha_2^* - \alpha_2)/[(2\sigma+1)(\beta+B)]$, $h^* = (\alpha_1 - \alpha_1^*)/[(2+\sigma)(\beta+B)]$, and the last three equations provide closed-form solutions for the variables in IC^* defined in the same way as in (22).

Given the above expressions in (A10), it is easy to show that *IC* is positively sloped. Note that an increase in l^* will reduce the term on the right-hand side of the equality in (22) because $\partial u(l, l^*)/\partial l^* < 0$, $-\partial u^*(l^*, l)/\partial l^* < 0$, and $\partial[(V_C - V_N)/(V_C^* - V_N^*)]/\partial l^* < 0$ with the last inequality can be checked by differentiating the corresponding expression in (A10), implying a reduced incentive for H keep its protection level down. Also note that an increase in *l* will reduce the left-hand side of the equality in (22) as $\partial^2 u(l, l^*)/(\partial l)^2 < 0$ and will increase the right-hand side of the equality in (22) because $\partial\{\delta^C[\partial Pr^*(l)/\partial l][1 - Pr^*(l)]\}/\partial l > 0$, $\partial[(V_C - V_N)/(V_C^* - V_N^*)]/\partial l > 0$. Therefore, $dl/dl^*\big|_{IC} > 0$, and I can prove that $dl/dl^*\big|_{IC^*} > 0$ in a similar way.

Now, I need to prove that *IC* is sloped flatter than the 45 degree line and IC^* is sloped steeper than 45 degree line as shown in Figure 4. For $\sigma = 1$, I prove that *IC* is sloped flatter than the 45 degree line once again using *IC* in (22). First note that *IC* cannot be sloped as the 45 degree line because there exists a unique l^c (= l = l^*) that satisfies *IC* in (13), or equivalently *IC* in (22) with $\sigma = 1$, given the assumption of *Proposition 1*. For l^c (= l = l^*) > $l_{\sigma=1} = l^*_{\sigma=1}$, one can easily check that *IC* in (22) is violated because the right-hand side of the equality in (22) gets greater than the left-hand side. Note also that a decrease in l will increase the left-hand side of the equality in (22) and will decrease the right-hand side of it as shown above. Therefore, the equality in (22) can be restored for l^* (= l_c = l) > $l_{\sigma=1} = l^*_{\sigma=1}$, only by lowering l from $l = l^*$, implying that *IC* should be sloped less than 45 degree line. By symmetry, I can use the same argument for proving that IC^* is sloped steeper than 45 degree line for $\sigma = 1$.

***Part (ii)*:**

To prove that a higher σ shifts *IC* upwards in Figure 4, I analyze how an increase in σ will affect *IC* in (22). Using (A10), I can show that $\partial^2 u(l, l^*)/\partial l \partial \sigma > 0$, $\partial[u^*(h^*, l) - u^*(l^*, l)]/\partial \sigma < 0$, and $\partial[(V_C - V_N)/(V_C^* - V_N^*)]/\partial \sigma < 0$, implying that an increase in σ will increase the right-hand side of the equality in (22) and will decrease the left-hand side of it. To satisfy *IC* in (22), therefore, an increase in σ requires an increase in l (which will decrease the left-hand side of the equality in (22) and will increase the right-hand side of it, as shown above) for any given level of l^*. This implies that a higher σ shifts *IC* upward in Figure 4. I can prove that a higher σ shifts IC^* to the left in Figure 4 in a similar way.

References

Athey, S. and Bagwell, K., 2001, Optimal Collusion with Private Information, *Rand Journal of Economics* 32(3), 428-465.

Athey, S. and K. Bagwell and C. Sanchirico, 2004, Collusion and Price Rigidity, *Review of Economic Studies* 71 (2), 317-349.

Bagwell, K. and Staiger, R., 1990, A Theory of Managed Trade, *American Economic Review* 80(4), 779-795.

Bagwell, K. and Staiger, R., 2002, The Economics of The World Trading System, MIT Press.

Bayard, T. O. and Elliot K.A., 1992, "Aggressive Unilateralism" and Section 301: Market Opening or Market Closing?, *The World Economy* 15, 685-706.

Blonigen, B. and Park, J-H., 2004, Dynamic Pricing in the Presence of Antidumping Policy: Theory and Evidence, *American Economic Review* 94 (1), 134-154

Bond, E. and Park, J-H., 2002, Gradualism in Trade Agreements with Asymmetric Countries, *Review of Economic Studies* 69 (2), 379-406.

Compte, O., 1998, Communication in Repeated Games with Imperfect Private Monitoring, Econometrica 66, 597-626.

Cotter, K. and Park, J-H., 2006, Non-concave Dynamic Programming, *Economics Letters* 90(1), 141-146.

Dixit, A., 1987, Strategic Aspects of Trade Policy, in Truman F. Bewley, ed., Advances in Economic Theory: Fifth World Congress, Cambridge University Press.

Fudenberg, D. and Tirole, J., 1991, Game Theory, MIT Press.

Green, E. and Porter, R., 1984, Noncooperative Collusion under Imperfect Price Information, *Econometrica* 52, 87-100.

Kandori, M. and Matsushima, H., 1998, Private Observation, Communication and Collusion, *Econometrica* 66, 627-652.

Kennan, John and Riezman, R., 1988, Do Big Countries Win Tariff Wars?, *International Economic Review* 29 (1), 88-85.

Matsushima, H., 1991, On the Theory of Repeated Games with Private Information: Part I: Anti-Folk Theorem without Communication, *Economics Letters* 35 (3), 253-256.

Maggi, G., 1999, The Role of Multilateral Institutions in International Trade Cooperation, *American Economic Review* 89 (1), 190-214.

McLaren, J. 1997, Size, Sunk Costs, and Judge Bowker's Objection to Free Trade, *American Economic Review* 87, 400-420.

Milgrom, P., and Segal, I., 2002, Envelope Theorems for Arbitrary Choice Sets, *Econometrica* 70 (2), 583-601.

Park, J-H., 2000, International Trade Agreements Between Countries of Asymmetric Size, *Journal of International Economics* 50, 473-95.

Park, J-H., 2002, Sustaining Freer Trade with Imperfect Private Information about Non-Tariff Barriers, mimeo.

Porter, R., 1983, Optimal Cartel Trigger Price Strategies, *Journal of Economic Theory* 29, 313-338

Riezman, R., 1991, Dynamic Tariffs with Asymmetric Information, *Journal of International Economics* 30, 267-283.

Staiger, R., 1995, International Rules and Institutions for Trade Policy, Handbook of International Economics, volume III.

Stocky, Nancy L., and Lucas, Robert E. with Prescott, Edward C., 1989, Recursive Methods in Economic Dynamics, Harvard University Press.

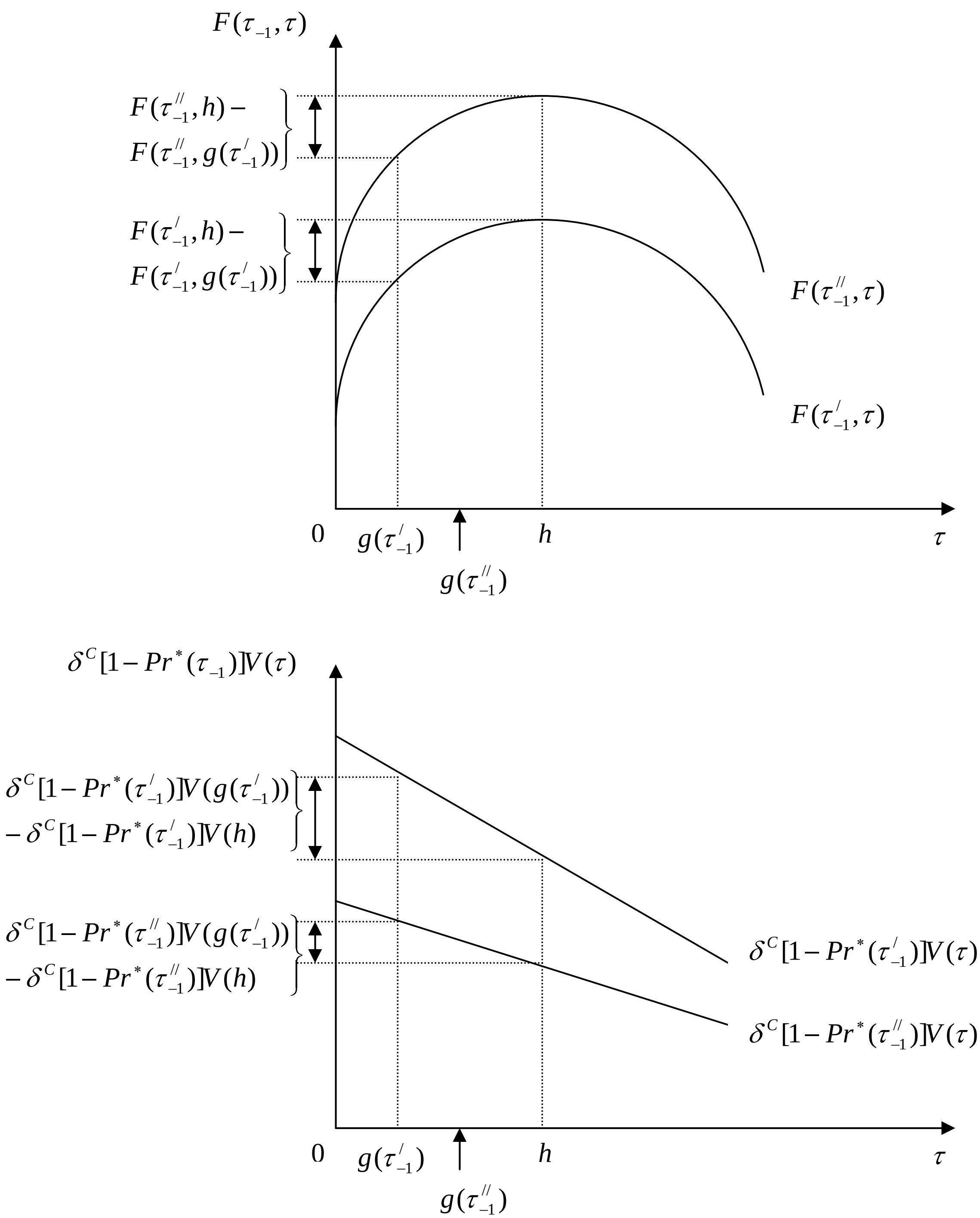

Figure 1. The Effect of A Higher τ_{-1} on the Optimal Choice of τ

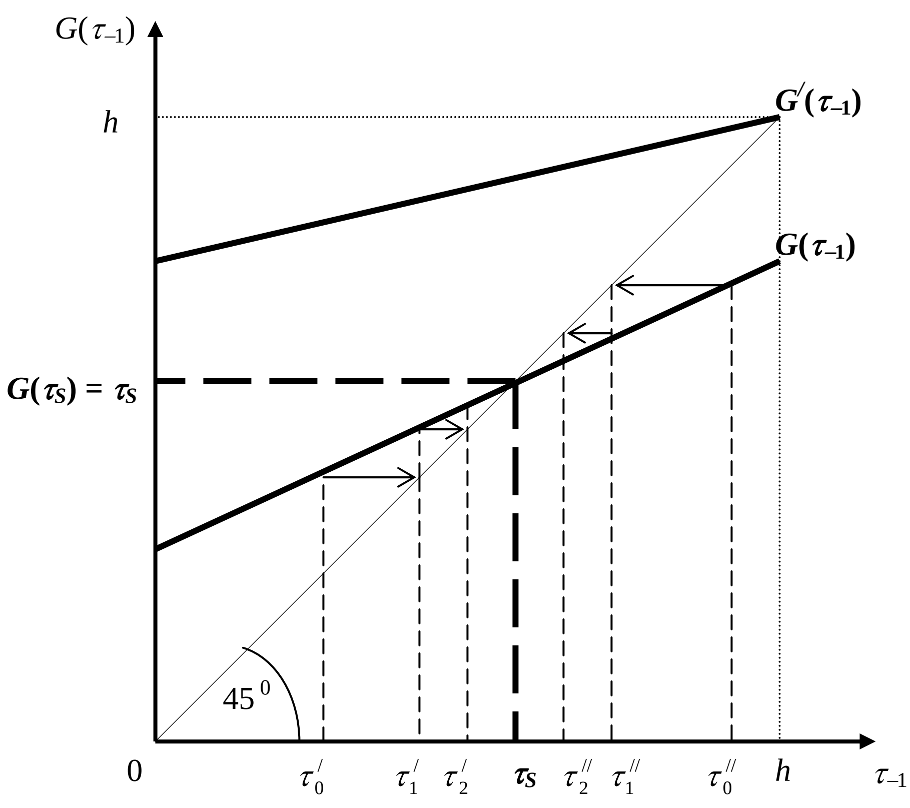

Figure 2. The Existence of a Stationary Protection Sequence at τ_S

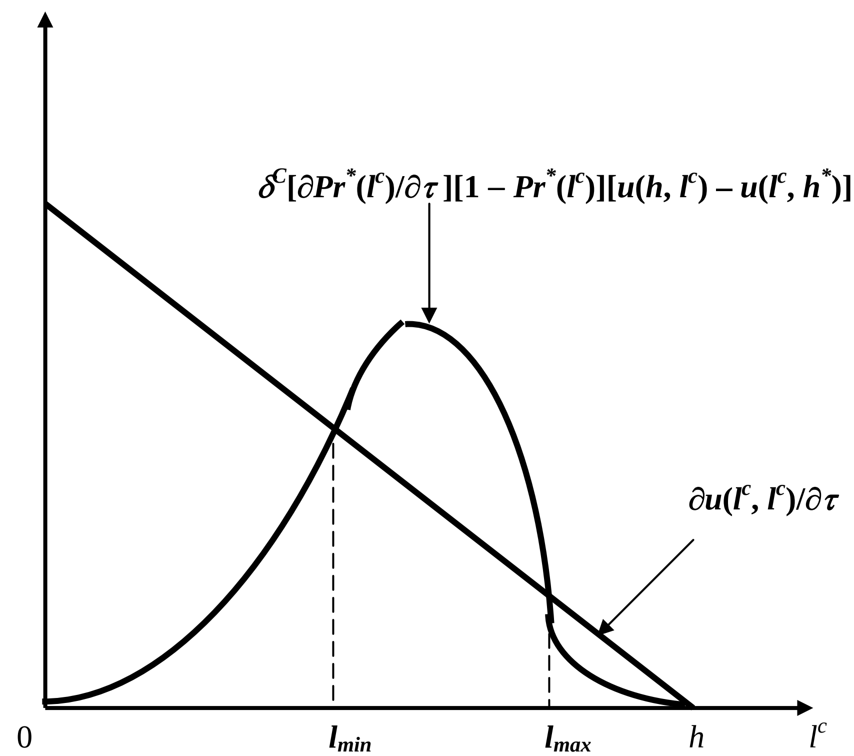

Figure 3. Multiple l^c satisfying $I(l^c) = 0$

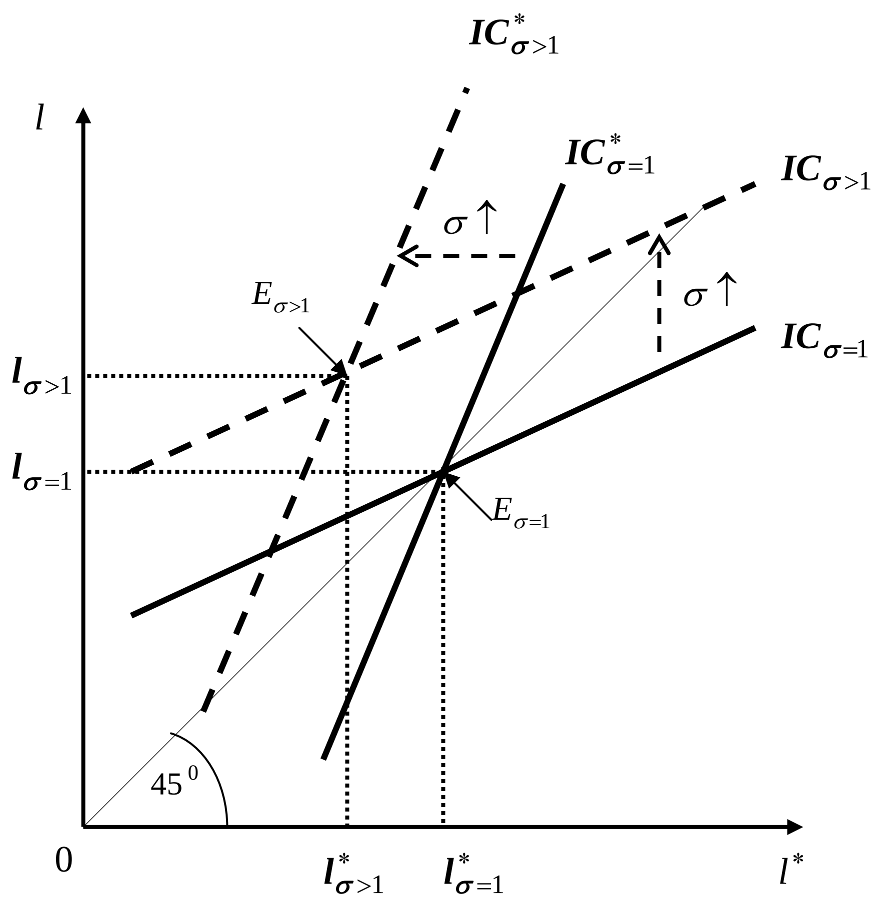

Figure 4. The Effect of Asymmetry among Countries on *IC* and *IC**