DYNAMIC TARIFFS WITH ASYMMETRIC INFORMATION

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ABSTRACT

Recent work in game theory has demonstrated how cooperative outcomes can be sustained when the game is played repeatedly, defectors are punished, but agents play non-cooperatively. This methodology is applied here to determine when two countries can sustain freer trade given that they determine trade policies non-cooperatively.

We focus on the role of asymmetric information. Countries have private information about the extent of their own protection, but the overall level of protection can be thought of as private information. Therefore, any agreement to eliminate or reduce tariffs is limited by the fact that countries can cheat on the agreement by using non-observable forms of protection.

Using import trigger strategies, cooperation (in the form of low tariffs) can be supported. There are periodic reversionary (high tariff) episodes which necessarily occur. They are not the result of mistakes, attempted manipulation, or misperception. Neither country cheats on the low tariff agreement, but reversions to high tariffs are triggered by the random variable.

In section V we examine a slightly different trigger strategy. Countries' strategies are based on their observations of the terms of trade. This alteration changes the results and in this case cooperation does not occur.

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I. Introduction

Recent developments in the theory of repeated games has been applied to try to better understand protection of international trade. This paper's contribution is to view protection as the outcome of a repeated game in which countries cannot perfectly observe other countries protection policies.[1] The main purpose is to argue that the lack of perfect information about protection policies is central to understanding protection of international trade.

The notion that protection is not perfectly observable can be justified on factual and theoretical grounds. Current U.S. trade legislation includes a new provision called Trade Liberalization Priorities (Super 301) which revises section 301 of the 1974 trade bill. This new provision directs the U.S. Trade Representative to identify trade practices and countries which hinder U.S. exports the most. These priority countries would then face retaliation from the U.S. if a negotiated agreement to reduce these barriers to U.S. exports could

[1] An early version of the dynamic problem by Jensen and Thursby (1980) uses the idea of approximate equilibria, a paper by Mayer (1981) focuses on different negotiation schemes to reduce tariffs, Enders (1986) examines different punishment schemes, Dixit (1987) determines when cooperation breaks down, Bagwell and Staiger (1988) have a model in which the level of protection depends on the volume of trade, Ludema (1989) determines optimal trade agreements. All of these papers assume that protection is observable. Copeland (1989) does consider imperfect observability of protection.

not be reached. Thus, it is not clear a priori, which countries or practices this applies to, and the provision for retaliatory action suggests that the offending countries and the USTR may not agree on what constitutes unfair trade practices.

A provision which failed to be included in the current trade bill took a more direct approach to the same problem. This amendment which has become known as the Gephardt Bill, proposes punishing Japan with higher U.S. tariffs if the bilateral trade deficit is above some predetermined level. The rationale behind this bill is that the Japan-U.S. trade deficit is due to hidden protection by the Japanese. The Gephardt Bill is a trigger strategy in which the punishment is higher U.S. tariffs which are triggered by certain realizations of the Japan-U.S. trade deficit. This threat of punishment would discourage Japan from using hidden protection to the extent this protection affects the trade deficit.

This proposed legislation generated a great deal of public discussion during which it became apparent that there is great disagreement over how much Japan actually protects its imports. Japanese tariffs are not especially high and have been substantially reduced in recent years. Yet many feel that Japan effectively keeps out U.S. imports with a variety of non-tariff trade barriers. Opponents of the Gephardt Bill argue that no such hidden protection exists and that the U.S. trade deficit is due to the inability of U.S. industries to compete with the Japanese. This debate suggests that U.S. policymakers do not know how much Japan protects imports, and it raises the question of how policy should be conducted in light of this fact.

Another example of how protection involves asymmetric information is the recent EEC ban of beef imports from the U.S. The Europeans claim that U.S. beef producers are using dangerous hormones and that the meat is unsafe. U.S. beef producers say that this is simply disguised protection. Who is correct? Practically speaking, we do not know and have no way of knowing what the European motivations for this policy are, and hence do not know whether the ban represents legitimate domestic policy which protects the health and safety of EEC citizens or whether it is disguised protectionism.

Theory suggests that it may be difficult to know the extent of foreign protection. For example, in simple models a 10% tariff can be replicated by a 10% consumption tax along with a 10% production subsidy. In more complicated

models it may be difficult to exactly replicate the effects of tariffs with domestic policies, but one can always use domestic policies to manipulate international trade. Therefore, any agreement to eliminate or reduce tariffs is limited by the fact that countries can cheat on the agreement by using domestic policies or other forms of protection not covered by the agreement. Ray and Marvel (1984) have shown that following the Kennedy round of tariff reductions, U.S. industries were able to replace tariffs that had been negotiated away with other forms of protection.

The theory of political economy explains non-tariff forms of protection by arguing that politicians use them in order to disguise protection from the voters. Then, inadvertently, political considerations might work to make protection less observable to foreigners. Thus, the facts and the theory suggest that viewing protection as not observable to foreigners is appropriate.

The basic model we use comes from Dixit (1987). He develops the standard prisoner's dilemma tariff model and shows that in an infinitely repeated game, cooperation (free trade) can be attained for some period of time provided that the gains from tariffs are not too large and that the discount factor is not too small. We extend his model in two directions. We add uncertainty in the underlying model and non-observability of protection.

We use recent work in game theory which has demonstrated how cooperative outcomes can be sustained when the game is played repeatedly, defectors are punished, but agents play non-cooperatively. Recent papers examine how a group of firms, acting non-cooperatively, can produce the monopoly level of output when they can observe other firms output levels (Rotemberg and Saloner (1986)) and when they cannot observe other firms output levels (Green and Porter (1984), Abreu, Pearce and Stacchetti (1986)).

We use the Green and Porter methodology to determine when two countries can sustain freer trade given that they determine trade policies non-cooperatively. The Green and Porter trigger strategies are simple, have a straightforward economic interpretation in our problem, and seem to correspond to practical policy measures (such as Super 301 or the Gephardt Bill).[2]

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[2]Recent work by Abreu, Pearce, and Stacchetti (1987) and Fudenberg and Maskin (1986) examine more general prisoner's dilemma games. Their results suggest that the Green-Porter strategies may not be optimal. A direction for future research is to characterize optimal protection policies when protection

In section III we analyze the effect of adding uncertainty when protection is perfectly observable. This model works much like Dixit's except that certain realizations of the random variable can trigger tariff wars. Rotemberg and Saloner (1986) take a different approach by focusing on how much cooperation can be sustained under varying demand conditions.

Protection is not observable in section IV. Here, using import trigger strategies, cooperation (in the form of low tariffs) can be supported. As in Green and Porter (1984) there are periodic reversionary (high tariff) episodes which necessarily occur. They are not the result of mistakes, attempted manipulation, or misperception. Neither country cheats on the low tariff agreement, but reversions to high tariffs are triggered by the random variable. In spite of this, countries go along with the reversionary episodes because they realize that high tariff periods are necessary to provide each country with the correct incentives to sustain the low tariff episodes. In addition, the high tariff equilibria are short-run Nash equilibria. The extent and duration of cooperation depends on the form of the trigger strategy and the actual parameter values. Thus, it is not clear whether free trade is a possibility, nor is it clear whether cooperative periods or reversionary periods are more prevalent.

In section V we examine a slightly different trigger strategy. Countries' strategies are based on their observations of the terms of trade. This alteration changes the results and in this case cooperation does not occur. This result is in sharp contrast to section IV and to the results of Green and Porter (1984) who find that in the case of an oligopoly, cooperation can be attained for periods of time. However, our result does indicate a major difference between the tariff problem and the oligopoly problem. In the oligopoly problem firms try to cheat in the same direction, namely, they all want to produce a little more, selling it at the monopoly price. This pushes the price down no matter which firm does it. When the price falls below a certain level a reversion to Cournot outputs and prices is triggered. Symmetric punishments make sense since there is no way to determine (even ex post) which firm cheated. In the tariff problem, the countries are trying to push the terms of trade in opposite directions, hence the reversion to Nash tariffs occurs if the terms of

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is not observable.

trade are too high or too low. It turns out that a country gets punished when it could not have been cheating and in this case, symmetric punishments do not induce cooperation.

These results show that whether protection is observable or not matters. When protection cannot be observed, as in Section IV, some cooperation can be achieved, but it may be quite limited. In particular, free trade might not be a possibility. Reversions to high tariffs occur, but for different reasons than when tariffs are observable. In the observable case, reversions occur because a realization of the random variable makes cheating worthwhile. In the model with non-observable protection countries never cheat, but reversions occur because the observable variable is pushed below some predetermined level by a realization of the random variable. Also, as section V makes clear, the choice of the mechanism used to induce cooperation is crucial. If the "wrong" trigger strategy is chosen then no cooperation will be achieved.

II. Model

The basic model employed is from Dixit (1987). There are two countries, home and foreign (foreign country variables are denoted by *) and two competitive industries producing goods x and y. The home country imports x, the foreign country imports y and countries can levy positive or negative tariffs, (τ, τ^*) on imports. There are four prices p_x, p_y, p_x^*, and p_y^* , and they are related by the following

$$p_x = p_x^* (1 + \tau) \qquad p_y^* = p_y (1 + \tau^*).$$

Define $\pi = p_x^*/p_y$, the international relative price or terms of trade. Notice that the home country prefers lower values of π, and the foreign country likes higher values. We ignore all intra-country income distribution issues. The justification for this is based on optimal taxation considerations. Since tariffs are far down the list of desirable policies to accomplish any redistribution of income, there is no a priori reason to think that income redistribution considerations will be important in the determination of tariffs.

Each country has a social welfare function, $U(\pi,\tau)$ and $U^*(\pi,\tau^*)$. These give rise to import demand functions $M(\pi,\tau)$ and $M^*(\pi,\tau^*)$. Equilibrium occurs when the balance of payments is zero,[3]

$$\pi \, M(\pi,\tau) = M^*(\pi,\tau^*).$$

This determines a function $\pi(\tau,\tau^*)$ which we assume to be continuous and differentiable.

We now adopt the view that countries select tariff policies that maximize expected social welfare over an infinite horizon, and hence view the tariff game as an infinitely repeated game. Uncertainty arises because of shocks to preferences or endowments, and is manifested by the fact that home imports have a random component. We assume

$$M_t = \theta_t \, M(\tau_t, \tau_t^*)$$

where θ_t is i.i.d. with c.d.f. F and continuous density f, $E(\theta_t) = 1$.[4] Substituting this expression for imports into the balance of payments condition π_t, M_t, and M_t^* can be written as functions of τ_t, τ_t^*, and θ_t.

Social welfare can now be expressed as

$$W(\tau_t, \tau_t^*, \theta_t) = U(\pi_t(\tau_t, \tau_t^*, \theta_t), \tau_t)$$

with a similar expression for the foreign country. The problem facing the home country is

(1)
$$\max_{\tau} \ \sum_{t=0}^{\infty} E \, \beta^t \, W(\tau_t, \tau_t^*, \theta_t)$$

where $\tau = (\tau_0, \tau_1, \tau_2, \ldots)$ and β is the discount factor.

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[3]An interesting extension would be to allow for trade imbalances. This will introduce an additional set of intertemporal considerations (see Marimon (1988)).

[4]Different assumptions about the timing and observability of θ_t will be made in different sections of the paper.

Assume that the Marshall-Lerner conditions hold and that all tariff revenues are redistributed to consumers, so that raising tariffs improves the terms of trade.

$$\frac{\partial \pi_t}{\partial \tau_t} < 0, \quad \frac{\partial \pi_t}{\partial \tau_t^*} > 0 ,$$

In addition, assume that starting from a zero tariff a country's welfare improves when it imposes a small tariff, and one country is always hurt by increases in the other country's tariff.[5] As a one-shot game, the tariff game results in a prisoner's dilemma in which charging tariffs is a Nash equilibrium, yet there are gains available if free trade can be attained.[6]

Our approach to cooperation is to assume that countries do not formally cooperate, but adopt strategies that can lead to cooperation over time (see Friedman (1971)). Such mechanisms involve strategies in which defectors from the cooperative equilibrium are punished. However, the punishments must be credible in the sense that if defection does occur the other country will actually carry out the punishment; that is, the game must be subgame perfect. One convenient way to do this is to make the punishment be a finite reversion to the one-period equilibrium strategies (see for example, Green and Porter). In our model this would mean that the punishment would involve countries adopting the one-shot Nash equilibrium tariffs for some fixed number of periods.[7] We will analyze two different models: one in which the random shock and tariffs are observable and one in which they are not.

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[5]Once autarky is reached this last statement has to be modified because further increases in tariffs have no effect.

[6]In what follows we ignore one potential Nash equilibrium, autarky. As discussed in Enders (1986) this is a weak equilibrium.

[7]These are not necessarily jointly optimal strategies in the sense that harsher punishments might be better because they would induce longer periods of cooperation or a greater degree of cooperation.

III. Observable Tariffs

In this section all tariffs and random variables are observable. We assume that both countries adopt trigger strategies (see Friedman (1971)) which require free trade if free trade occurred in the previous period.[8] Any defection from free trade is punished by a reversion to Nash equilibrium tariffs.   In this section, for analytical convenience, we assume that the Nash reversion is infinite.   More generally, one could consider finite reversions (which we do later), and other choices for the reversion equilibrium (autarky for example) to determine optimal punishments.

The timing critically affects the results.   Suppose tariffs are chosen simultaneously, then θ is revealed.   Free trade is sustained as long as it never pays a country to defect.   That is, if the one period gain from defection is less than the discounted stream of losses from having Nash tariffs forever, then free trade is chosen.   At time T the home country will choose free trade if (2) holds

$$(2) \quad \underset{\theta}{E} \left(W(\tau^0, 0, \theta_T) - W(0, 0, \theta_T) \right) < \sum_{t=T+1}^{\infty} \beta^t \underset{\theta}{E} \left(W(0, 0, \theta_t) - W(h, h^*, \theta_t) \right)$$

where τ^0 is the standard optimal tariff and h, h^* are the one-shot Nash tariffs. The left hand side gives the one period expected gain to cheating by charging the optimal tariff.   The right hand side gives the expected discounted losses that occur because from the next period on high tariffs will be charged by both countries instead of free trade.   If the LHS is smaller than the RHS then there is no incentive for the home country to cheat on a free trade agreement.   A similar condition exists for the foreign country. This condition is essentially the same as Dixit's.   Free trade can be sustained by tacit cooperation provided β is not too small.

Different timing changes the results.   Suppose that θ is revealed first, followed by the simultaneous choice of tariffs.   The left hand side of (2) changes because the value of θ is known when tariffs are chosen.   The condition for free trade to be sustained becomes

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[8]We rule out state contingent tariff agreements.

$$(3) \qquad W(\tau^0, 0, \theta_T) - W(0, 0, \theta_T) \quad < \sum_{t=T+1}^{\infty} \beta^t \quad \underset{\theta}{E} \; (W(0, 0, \theta_t) - W(h, h^*, \theta_t))$$

Interpreting θ as a temporary shock any realization of θ affects only the LHS of (3). Realizations of θ that make the LHS of (3) larger increase the likelihood that tariff reversions are triggered. For example, values of θ that make the foreign offer curve very inelastic would increase the gains from the optimal tariff and hence increase the likelihood of high tariff episodes.

This framework can be used to develop testable models of tariff wars. Specifying particular motivations for protection will yield specific versions of inequality (3). For example, one could suppose welfare depended on employment, or the terms of trade, or one could formulate a political economy version in which the function W is an outcome of a political process (see Feenstra and Lewis (1987)). Then, differentiating with respect to θ gives predictions about what triggers reversions to high tariffs. This hypothesis can then be tested by examining periods of high and low levels of protection.

IV. Non-observable Tariffs-Import Trigger Strategy

In this section we assume that countries cannot observe the tariffs of other countries, nor can they observe the random variable θ. The motivation for this is that since tariffs can be replaced exactly by the correct combination of domestic policies (an equal percentage production subsidy and consumption tax or appropriate behavior on the part of a state trading agency) protection is in a real sense not observable. To some extent the current dispute with Japan over the U.S. trade deficit is an example of this phenomenon. Much of the debate concerns the extent of actual Japanese protection with the Japanese pointing to their relatively modest tariffs and the U.S. claiming that the local Japanese price of goods imported from the U.S. are much higher than they should be based on these tariff rates.

One way to interpret what follows is that there are observable and non-observable forms of protection. Assume that the observable tariffs are zero, for example because of international treaties, so that only non-observable

protection can be used. For analytical convenience we will assume that non-observable protection takes the form of tariffs.[9]

　　We use the model developed in section II, except that countries now observe only π_t, M_t (and therefore, M_t^*) and their own tariff, with the other country's past and current tariffs and past and current θ_t not observable. Countries use the same type of strategy as before, but since they do not know directly what tariff the other country is charging their strategies have to be conditioned on observables. This problem is similar to the one solved by Green and Porter for an oligopoly. What follows draws heavily from their model.

　　Countries have trigger strategies s and s^* defined by

$$s = (s_0, s_1, \ldots) \quad , \quad s^* = (s_0^*, s_1^*, \ldots)$$
$$s_0 = \tau_0 \ , \ s_0^* = \tau_0^*.$$

τ_0 and τ_0^* can be any given initial tariffs. The strategy at time t depends only on the history of home imports up to time $t-1$[10]

$$s_t(M_0, \ldots, M_{t-1}) = \tau_t, \quad s_t^*(M_0, \ldots, M_{t-1}) = \tau_t^*$$

　　A Nash equilibrium is a pair $\bar{s}, \bar{s}^*$ for which

(4)
$$E_{\bar{s}, \bar{s}^*} \left\{ \sum_{t=0}^{\infty} \beta^t \ U(s_t(M_0, \ldots, M_{t-1}), \pi_t) \right\}$$

$$\leq E_{\bar{s}, \bar{s}^*} \left\{ \sum_{t=0}^{\infty} \beta^t \ U(\bar{s}_t(M_0, \ldots, M_{t-1}), \pi_t) \right\}$$

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[9]We assume that tariffs are not observable throughout. This would be appropriate, for example, if the non-observable protection is equal percentage production subsidies and consumption taxes. Less efficient methods of protection may have to be used but the qualitative results will be unaffected by this.

[10]Strategies do not depend on past values of tariffs and θ_t, except to the extent that these variables influence M_t.

for all possible strategies s, with a similar condition for the foreign country.

An equilibrium occurs when both countries' strategies maximize discounted expected utility, taking the other country's strategy as given. This is the usual definition of Nash equilibrium, except that the strategies are trigger strategies. In this model, both countries realize that they are in a prisoner's dilemma game. They would prefer the low tariff outcome (free trade if possible) and will set low tariffs provided that the other country is also setting low tariffs. However, the other country's tariffs cannot be directly observed, nor, since there is uncertainty, can they be inferred by observing imports or the terms of trade.

What is done is to adopt a trigger strategy which requires them to keep tariffs low unless there is evidence that someone is cheating on the low tariff agreement. Both countries can observe the home country's imports.[11] If either country charges higher tariffs than the low tariff agreement rates, home imports will fall. If home imports fall below some predetermined critical level then high (one-shot Nash) tariffs are used for a specified period of time. Thus, cheating can be detected, probabilistically, by observing home imports. In this way cheaters are deterred since if the cheating is detected, there will be high tariffs for some finite period of time. The punishment will actually be carried out, because the high tariffs are equilibrium tariffs in the one-shot game.

More formally, call the set of low tariffs (λ,λ^*) and the high tariffs (h,h^*). The low tariffs are endogenously determined and the high tariffs are the one-shot Nash tariffs. Countries choose the level of home imports $\hat{M}$ that triggers reversion, and the length of the reversionary period T. We also require that at the low tariff equilibrium a small change in either tariff reduces home imports: $\partial M(\lambda,\lambda^*)/\partial\lambda$ and $\partial M(\lambda,\lambda^*)/\partial\lambda^*$ are negative.[12] Equilibrium requires that the trigger imports and length of the reversionary period be the same for both countries. Period t is normal if

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[11]Presumably both countries can observe the foreign country's imports and therefore, the terms of trade. The analysis would be the same if the punishment were triggered on the foreign country's imports.

[12]A sufficient condition for this is that both offer curves are elastic at the low tariff equilibrium.

t =0, or

t-1 normal and $M_t > \hat{M}$

t-T normal and $M_{t-T} < \hat{M}$

Otherwise t is reversionary. We now can determine the tariff at any time t

$$\tau_t = \begin{cases} \lambda & t \text{ normal} \\ h & t \text{ reversionary} \end{cases} \qquad \tau_t^* = \begin{cases} \lambda^* & t \text{ normal} \\ h^* & t \text{ reversionary} \end{cases}$$

Thus, $(\lambda, \lambda^*, h, h^*, T, \hat{M})$ characterize an equilibrium. The plan of attack is to choose arbitrary T and $\hat{M}$, and use the one-shot Nash tariffs for h and h^* and solve for the λ and λ^* that will occur in normal periods. Clearly, the choice of T and $\hat{M}$ will affect the actual values of λ and λ^*, but our goal here is to characterize the equilibrium and show how cooperative trade agreements can be sustained by repetition even when protection is not observable.

Define

$$\hat{V}(\tau_t, \tau_t^*) = E \sum_{\theta_t t=0}^{\infty} \beta^t W(\tau_t, \tau_t^*, \theta_t)$$

with a similar definition for the foreign country. Let $V(r)$ $(V^*(r^*))$ be discounted expected utility when $\tau_t = r$ $(\tau_t^* = r^*)$ in normal periods, that is

$$V(r) = \hat{V}(r, \lambda^*), \quad V^*(r^*) = \hat{V}^*(\lambda, r^*)$$

Let $\gamma(r)$ be the one-period expected utility of setting the tariff equal to r given that the foreign country sets its tariff low,

$$\gamma(r) = \underset{\theta_t}{E} \ W(r,\lambda^*,\theta_t) \quad \text{and} \quad \gamma^*(r^*) = \underset{\theta_t}{E} \ W^*(\lambda,r^*,\theta_t).$$

Expected utility in reversionary periods is δ and δ^*

$$\delta = \underset{\theta_t}{E} \ W(h,h^*,\theta_t) \quad \text{and} \quad \delta^* = \underset{\theta_t}{E} \ W^*(h,h^*,\theta_t).$$

We assume that $\gamma(\lambda) > \delta$ and $\gamma^*(\lambda^*) > \delta^*$, that is, expected utility is higher with low tariffs than high tariffs for both countries. This assumption is restrictive since it assumes that no country can do better with Nash tariffs than at the low tariff equilibrium. As shown in Kennan and Riezman (1988) countries with a big enough size advantage might benefit from high tariffs.

V and V^* satisfy the equations

(5)
$$V(r) = \gamma(r) + \text{ß} \ \Pr(\theta_t M(r,\lambda^*) > \hat{M}) \ V(r)$$
$$+ \ [1 - \Pr(\theta_t M(r,\lambda^*) > \hat{M})][\sum_{t=1}^{T-1} \text{ß}^t \delta + \text{ß}^T \ V(r)]$$

(6)
$$V^*(r^*) = \gamma^*(r^*) + \text{ß} \ \Pr(\theta_t M(\lambda,r^*) > \hat{M}) \ V^*(r^*)$$
$$+ \ [1 - \Pr(\theta_t M(\lambda,r^*) > \hat{M})][\sum_{t=1}^{T-1} \text{ß}^t \delta^* + \text{ß}^T \ V^*(r^*)]$$

For each country the probability of no reversion, given that the other country charges low tariffs, is a function of its tariff,

(7)
$$\Pr(\theta_t M(r,\lambda^*) > \hat{M}) \ = 1 - F(\hat{M}/ \ M(r,\lambda^*)) \equiv 1-b$$
$$\Pr(\theta_t M(\lambda,r^*) > \hat{M}) \ = 1 - F(\hat{M}/ \ M(\lambda,r^*)) \equiv 1-b^*$$

Then (5) becomes

$$(8) \qquad V(r)(1 - \text{ß}(1-b) - b\text{ß}^T) = \gamma(r) + b \sum_{t=1}^{T-1} \text{ß}^t \delta$$

With some straightforward algebraic manipulation this becomes

$$V(r) = \frac{\gamma(r) + \dfrac{b(\text{ß} - \text{ß}^T)}{1-\text{ß}} \delta}{1 - \text{ß} + b(\text{ß} - \text{ß}^T)}$$

This in turn simplifies to

$$(9) \qquad V(r) = \frac{\gamma(r) - \delta}{1 - \text{ß} + b(\text{ß} - \text{ß}^T)} + \frac{\delta}{1 - \text{ß}}$$

The interpretation of (9) is that the home country's expected utility of tariff rate r is the gain from the low tariff agreement plus the utility with high tariffs, appropriately discounted. The corresponding expression for the foreign country is

$$(10) \qquad V^*(r^*) = \frac{\gamma(r^*) - \delta^*}{1 - \text{ß} + b^*(\text{ß} - \text{ß}^T)} + \frac{\delta^*}{1 - \text{ß}}$$

If (λ, λ^*) is a Nash equilibrium, then given $\hat{M}$, h, h^*, and T

$$(11) \qquad V(r) < V(\lambda) \quad \text{for all } r,$$

and

$$(12) \qquad V(r^*) < V(\lambda^*) \text{ for all } r^*.$$

The first order conditions are

$$(13) \qquad V'(\lambda) = 0$$

$$(14) \qquad V^{*\prime}(\lambda^*) = 0.$$

Using (7), (9) and (10), (13) becomes

$$(15) \qquad [1 - \text{\ss} + (\text{\ss} - \text{\ss}^T)(F(\hat{M}/M(\lambda,\lambda^*)) \; \gamma'(\lambda)$$

$$+ \; (\gamma(\lambda) - \delta)(\text{\ss} - \text{\ss}^T)f(\hat{M}/M(\lambda,\lambda^*))(\partial M(\lambda,\lambda^*)/\partial\lambda)(\hat{M}/M(\lambda,\lambda^*)^2) = 0$$

and for the foreign country (14) becomes

$$(16) \qquad [1 - \text{\ss} + (\text{\ss} - \text{\ss}^T)(F(\hat{M}/M(\lambda,\lambda^*)) \;\; \gamma'(\lambda^*)$$

$$+ \; (\gamma^*(\lambda^*) - \delta^*)(\text{\ss} - \text{\ss}^T)f(\hat{M}/M(\lambda,\lambda^*))(\partial M(\lambda,\lambda^*)/\partial\lambda^*)(\hat{M}/M(\lambda,\lambda^*)^2) = 0$$

Equations (15) and (16) give the necessary conditions for equilibrium with trigger strategies to exist under the conditions stated above. These equations are analogous to the equilibrium conditions in Green and Porter (see their equation (6)). The first term is the marginal gain from an increase in the tariff given that the other country has low tariffs. For both countries this term is positive. The second term gives the marginal loss due to the expected change in the probability that a reversionary episode is triggered by this increase in tariffs. The components of the second term are all positive except for $\partial M(\lambda,\lambda^*)/\partial\lambda$ in (15) and $\partial M(\lambda,\lambda^*)/\partial\lambda^*$ in (16), which are negative since any increase in tariffs reduces the volume of trade. Thus, no country cheats in equilibrium since the expected one period gain from doing so is exactly offset by the discounted expected losses which occur because cheating on the low tariff agreement increases the probability that reversion to high tariffs occurs.

However, as in the Green-Porter model, reversions to the punishment phase, high tariffs, will be triggered by the random variable. Even though each country knows it is not optimal for either country to cheat, it is rational to participate in the high tariff phase because countries understand the incentives of the dynamic equilibrium which require that the punishment phase actually occur. Thus, the empirical prediction of the model is that there will be periods of low tariffs and periods of high levels of protection, i.e., trade wars. In this model, these reversions to high tariffs are not some kind of mistake or miscalculation; rather they are necessary to sustain the low tariff periods. Another interesting feature is that the actual tariff rates observed in the low

tariff phase are affected by tariff rates in the one-shot Nash game. Thus, over time, if the underlying one-shot Nash game changes so will λ and λ^*.

There is one aspect of the tariff problem that is different than the oligopoly problem. In the oligopoly case, the punishment phase is triggered by the price falling below some level. Even ex post there would be no way to determine which firm, if any, cheated on the agreement (firm output is only observable to the firms themselves). Thus, having all firms share equally in the punishment makes sense. The same is not true in the tariff case. Presumably the terms of trade are observable. Suppose the punishment is triggered and the terms of trade move in favor of the home country. In this case it seems very unlikely that the foreign country cheated on the low tariff agreement. Yet, the foreign country will be punished. Intuitively, it seems that there is useful information available that is not being used to detect cheating. In the next section we examine this more closely by changing the model of this section to have the punishment triggered by the terms of trade instead of home imports. As we will see the results are quite different.

V. Non-observable Tariffs-terms of trade trigger

In this section, countries use observations of the terms of trade to detect cheating on the low tariff agreement. The model is the same as section IV with the following modifications. The strategy at time t depends on the history of prices up to time t-1

$$s_t(\pi_0,\ldots,\pi_{t-1}) = \tau_t, \quad s_t^*(\pi_0,\ldots,\pi_{t-1}) = \tau_t^*$$

A Nash equilibrium is a pair $\bar{s}, \bar{s}^*$ for which

$$(4') \qquad E_{s,\bar{s}^*}\left\{ \sum_{t=0}^{\infty} \beta^t \, U(s_t(\pi_0,\ldots,\pi_{t-1}),\pi_t) \right\}$$

$$\leq E_{\bar{s},\bar{s}^*}\left\{ \sum_{t=0}^{\infty} \beta^t \, U(\bar{s}_t(\pi_0,\ldots,\pi_{t-1}),\pi_t) \right\}$$

for all possible strategies s. There is a similar condition for the foreign country.

Countries keep tariffs low if the terms of trade stays within a predetermined range. If world prices are outside that range then high (one-shot Nash) tariffs are used for a specified period of time. Thus, cheating can be detected, probabilistically, by observing prices. In this way cheaters are deterred since if the cheating is detected, there will be high tariffs for some finite period of time. As before, the punishment will actually be carried out because the high tariffs are equilibrium tariffs in the one-shot game.

As in section IV, call the set of low tariffs (λ, λ^*) and the high tariffs (h, h^*). Countries choose the price that triggers reversion on the low end π_λ, the high end π_h, and the length of the reversionary period T. Equilibrium requires that the trigger prices and length of the reversionary period be the same for both countries. Period t is normal if

$$t = 0, \text{ or}$$

$$t-1 \text{ normal and } \pi_\lambda < \pi_t < \pi_h, \text{ or}$$

$$t-T \text{ normal and either } \pi_{t-T} < \pi_\lambda \text{ or } \pi_{t-T} > \pi_h.$$

Otherwise t is reversionary. The tariffs at any time t are

$$\tau_t = \begin{cases} \lambda & t \text{ normal} \\ h & t \text{ reversionary} \end{cases} \qquad \tau_t^* = \begin{cases} \lambda^* & t \text{ normal} \\ h^* & t \text{ reversionary} \end{cases}$$

Using the same approach as section IV, V and V^* satisfy the functional equations

(5')
$$V(r) = \gamma(r) + \beta \, Pr(\pi_\lambda < \theta_t \pi(r, \lambda^*) < \pi_h) \, V(r)$$
$$+ [1 - Pr(\pi_\lambda < \theta_t \pi(r, \lambda^*) < \pi_h)][\sum_{t=1}^{T-1} \beta^t \delta + \beta^T V(r)]$$

(6') $\qquad V^*(r^*) = \gamma^*(r^*) + \text{ß Pr}(\pi_\lambda < \theta_t\pi(\lambda,r^*) < \pi_h) \; V^*(r^*)$

$$+ [1 - \text{Pr}(\pi_\lambda < \theta_t\pi(\lambda,r^*) < \pi_h)][\overset{T-1}{\underset{t=1}{\Sigma}} \; \text{ß}^t\delta^* + \text{ß}^T \, V^*(r^*)]$$

Define

(7') $\qquad \text{Pr}(\pi_\lambda < \theta_t\pi(r,\lambda^*) < \pi_h) = F(\pi_h/\pi(r,\lambda^*)) - F(\pi_\lambda/\pi(r,\lambda^*))$

$\qquad \text{Pr}(\pi_\lambda < \theta_t\pi(\lambda,r^*) < \pi_h) = F(\pi_h/\pi(\lambda,r^*)) - F(\pi_\lambda/\pi(\lambda,r^*))$

Then (5') becomes exactly the same as equation (8) before. The analysis proceeds as in section IV, except (15) and (16) become

(15') $\qquad [1 - \text{ß} + (\text{ß} - \text{ß}^T)(1 - F(\pi_h/\pi(\lambda,\lambda^*)) + F(\pi_\lambda/\pi(\lambda,\lambda^*)))] \; \gamma'(\lambda)$

$$+ (\gamma(\lambda) - \delta)(\text{ß} - \text{ß}^T)\frac{\partial\pi(\lambda,\lambda^*)/\partial\lambda}{\pi(\lambda,\lambda^*)^2} \quad X$$

$$[-f(\pi_h/\pi(\lambda,\lambda^*))\pi_h + f(\pi_\lambda/\pi(\lambda,\lambda^*))\pi_\lambda] = 0.$$

and for the foreign country we have

(16') $\qquad [1 - \text{ß} + (\text{ß} - \text{ß}^T)(1 - F(\pi_h/\pi(\lambda,\lambda^*)) + F(\pi_\lambda/\pi(\lambda,\lambda^*)))] \; \gamma^{*\prime}(\lambda^*)$

$$+ (\gamma^*(\lambda^*) - \delta^*)(\text{ß} - \text{ß}^T)\frac{\partial\pi(\lambda,\lambda^*)/\partial\lambda^*}{\pi(\lambda,\lambda^*)^2} \quad X$$

$$[-f(\pi_h/\pi(\lambda,\lambda^*))\pi_h + f(\pi_\lambda/\pi(\lambda,\lambda^*))\pi_\lambda] = 0.$$

Equations (15') and (16') give the necessary conditions for equilibrium with trigger strategies to exist under the conditions stated above. These equations are analogous to the equilibrium conditions (15) and (16). The first term is the marginal gain from an increase in the tariff given that the other country has low tariffs. For both countries this term is positive. The second

term gives the marginal gain or loss due to the expected change in the probability that a reversionary episode is triggered by this increase in tariffs. The second term consists of four terms: three are non-negative (by previous assumptions), but the third term which has $\partial\pi(\lambda,\lambda^*)/\partial\lambda$ in (15') and $\partial\pi(\lambda,\lambda^*)/\partial\lambda^*$ in (16') has opposite signs in the two equations. An increase in tariffs has opposite effects on the terms of trade. Suppose that $\partial\pi(\lambda,\lambda^*)/\partial\lambda < 0$ and (15') holds. Then, $\partial\pi(\lambda,\lambda^*)/\partial\lambda^* > 0$ and (16') cannot hold. Hence, it is impossible that both first order conditions (15') and (16') hold simultaneously, and hence no trigger strategy equilibrium exists.[13]

This result stands in sharp contrast to Green-Porter and to the results of section IV. In the Green-Porter model equilibrium exists because firms always cheat in the same direction. Cheating means selling more which lowers the price which in turn, increases the probability that a reversionary episode is triggered. In their model the one period gain from cheating is equated to the expected losses due to a higher probability of reversion. In the section V model each country's cheating push the relevant price in _opposite_ directions. So, for example, if the home country cheats by increasing its non-observable tariff it gets the one period gain and increases the probability of a reversion being triggered by π being too low. But, reversions are also triggered by π being to high, and the home country's cheating reduces the probability that this happens. What (15') and (16') taken together show that for one of these countries cheating has to _lower_ the probability that reversion occurs. Hence, for one country it always pays to cheat, and there can be no low tariff equilibrium.

Section IV fixes things up by having the reversion triggered when imports are too low. This works because any cheating lowers imports (given some restrictions on offer curve elasticities.) Hence, any cheating causes the probability of reversion to increase. This suggests that low tariffs could be achieved using terms of trade trigger strategies by introducing asymmetric punishments so that the home (foreign) country only gets punished when π is too low (high). Then any cheating would increase the probability of reversion.

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[13]The second terms of (15') or (16') could be zero, but if this is the case no equilibrium exists, since the first term is unambiguously positive. There are benefits, but no cost to cheating.

V. Conclusion

We have analyzed dynamic theories of tariffs when there is uncertainty and when protection is both observable and not observable. If protection is observable free trade can be sustained over time, however, there will be periodic reversions to high tariffs. This occurs because certain realizations of the random variable make cheating worthwhile. When tariffs are not observable, if countries use the correct trigger strategies, some degree of cooperation can be sustained. Periodic reversions will occur but for different reasons than in the observable case. Reversions occur because a realization of the random variable pushes the observable variable below some critical value. Even though no country cheats it is still optimal for the reversion to take place. It remains to be determined under what circumstances free trade can be maintained, but the general conclusion is that there will be periods of high and low protection levels when countries use import trigger strategies. The high tariff episodes are necessary to provide the right incentives for countries to cooperate some of the time, and are not the result of irrationality or miscalculation.

Interesting extensions would be to analyze the terms of trade trigger strategy with asymmetric punishments. In addition, other types of strategies can be analyzed. Another important direction for future research is to consider finite horizon models. It is important that these results do not depend critically on the infinite horizon assumption. A longer range goal is to provide more modeling detail to produce a model that can be tested using historical data.

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