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Abstract

This paper establishes relationships between static Nash equilibria and dynamic Markov perfect equilibria of tariff and quota retaliation games. In supermodular games where tariffs are strategic complements, the steady state of every, symmetric Markov perfect equilibrium must have lower tariffs than in the static equilibrium. If tariffs are strategic substitutes, tariffs in the dynamic game are higher than in the static equilibrium. The supermodular case is extended to quota competition. Instead of the well-known non-equivalence between tariff and quota retaliation outcomes under complete myopia, in some circumstances, free trade can be supported in the steady state of a Markov perfect equilibrium, regardless of whether policies employed are quotas or tariffs. We reach the conclusion that the effect of introducing dynamics crucially depends on whether the policy instruments employed by the countries are strategic substitutes or complements irrespective of whether they are tariffs or quotas. (144 words)

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1. Introduction

It is a well-known result of the optimal tariff literature that free trade cannot be supported as Nash equilibrium of a static game (Johnson, 1953-54): If all countries follow free trade, it is optimal for any one large country to deviate by imposing the positive optimal tariff. Moreover, in the same framework it turns out that when import quotas are used as strategic instruments, autarky obtains (see Rodriguez, 1974 and Tower, 1975). This pessimistic view of the prospects of free trade is not quite born out in practice. On the contrary, the last decades have seen an unprecedented increase in trade alongside a gradual reduction of trade restrictions with the advent of such organizations as the WTO. The institutionalization of negotiations cannot be the only reason for this success story, because some countries have even been seen to unilaterally remove import restrictions, possibly in the hope that such a move will be reciprocated (see Furusawa and Kamihigashi, 2006).

It is, therefore, natural to ask how dynamic considerations change the incentives of countries when considering trade restrictions. Introducing dynamics into a tariff retaliation game leads to a plethora of equilibria even in the relatively straight-forward case where the dynamic strategies are restricted to be Markov-perfect (see Furusawa and Kamihigashi, 2006). In a Markov-perfect equilibrium, strategies are allowed to depend only on the pay-off relevant state variables. Thereby, one rules out the possibility that players employ complex punishment strategies, which would allow us to support basically any pay off vector in some equilibrium for some discount factor. Still, even in the Markov-perfect case, it is difficult to find general results. For this reason, our paper focuses on the steady state of games where players employ Markov-perfect strategies. This slight change of perspective allows us to find surprisingly simple answers regarding the impact of dynamic considerations and straight-forward characterizations of all possible steady states.

The principal result of this paper is that *the effect of introducing dynamics crucially depends on* *whether the policy instruments employed by the countries are strategic substitutes or complements irrespective of whether they are tariffs or quotas*. If they are strategic complements, countries can expect that a reduction of their tariff will be reciprocated by their trading partners. Therefore, countries expect to be rewarded for lowering tariffs, once dynamic considerations are taken into account. We can show that with strategic complements, the steady state of an MPE always results in countries imposing lower tariffs than in the static Nash equilibrium. This result, whilst confirming the intuition of Furusawa and Kamihigashi (2006) about dynamic incentives for lowering tariffs, is still surprising because it is obtained in precisely that case, where the preferences are such that they could conceivably support retaliatory measures resulting in a trade war. Moreover, we find a limit result where free trade can be supported as an MPE. On the other hand, if tariffs are strategic substitutes, lowering one's tariff will result in the other countries increasing theirs. So taking account of dynamics will deter countries from lowering tariffs. We find that in every steady state of an MPE with strategic substitutes, countries always have higher tariffs than in the static equilibrium.

We are also able to employ our framework to the question of non-equivalence of tariffs and quotas implied by the results of Rodriguez (1974) and Tower (1975). Here, we show that once dynamic considerations are taken into account, the autarky result can be dismissed altogether. Instead, we show that an equivalence result holds: with complete patience, free trade can be supported irrespective of whether tariffs or quotas are the policy instruments.

Our approach allows us to employ general utility functions as they are characteristic of the classical international trade literature, in that we only require them to satisfy local single crossing properties. For such utility functions we are able to prove general existence of stable steady states of Markov perfect equilibria on which we predicate general policy predictions. We are thus able to compare the dynamic steady-state outcomes to the static steady-state outcomes of the Johnson-Rodriguez-Tower theories of tariff and quota retaliation, thereby going considerably beyond this literature, using general utility functions instead of specific parametric forms, and, *inter alia*, are able to take account of the effects of strategic considerations.

In section 2 we set up a static tariff retaliation game. Section 3 introduces dynamics and discusses the solution. Section 3 also deals with the properties of the dynamic steady states, and provides the intuition that underlies our conclusion of pertinence to the tariff-retaliation game. Section 4 deals with quota retaliation. Section 5 contains some concluding remarks.

2. Static Tariff Retaliation

Suppose that the world is made up of two countries, home (*h*) and foreign (*f*). Country *h* is endowed with a fixed quantity of commodity 1 and country *f* has a fixed endowment of commodity 2. Each country's preferences are given by the utility function of its country's respective representative agent, namely, $u_i = u_i(x_1^i, x_2^i)$, $i = h, f$, where x_1^i, x_2^i are the quantities of good 1 and good 2 consumed in country *i*. Both countries must abide by their respective budget constraints. And, each country can impose an *ad valorem* tariff, t_h, t_f, on its imported commodity. All tariff revenues are assumed to be returned lump-sum to the representative consumer. We focus on the case where countries are symmetric up to a relabeling of the goods. This is important for avoiding the dependence of conclusions that are based on taste differences across countries, as is the tradition in both neo-classical and Heckscher-Ohlin trade theory. This enables us to characterize steady state Markov perfect strategies.

Substituting $x_1^i(t_i, t_j)$ and $x_2^i(t_i, t_j)$ for country *i* we obtain the indirect utility function $U_i[t_i, t_j] \equiv u_i[x_1^i(t_i, t_j), x_2^i(t_i, t_j)]$. For this indirect utility function, $\partial U_i[t_i, t_j]/\partial t_j < 0 \;\forall t_i, t_j \in [0, \bar{t}]$ where $\bar{t}$ is the prohibitive tariff, which results in autarky. Since the optimal tariff must be positive at least in the case where the other country imposes no tariff at all, it follows that $\partial U_i[t_i, 0]/\partial t_i > 0 \;\; \forall t_i \in [0, \bar{t}]$. The best response correspondence $r_i(t_{j \neq i})$ maps $[0, \bar{t}]$ into itself. Given continuity of U in both its arguments, there exists at least one fixed point of this mapping which corresponds to a static Cournot-

Nash equilibrium (t_h^s, t_f^s) of the static tariff retaliation game. Because the best response of i for $t_j=0$, is strictly greater zero, any equilibrium is positively-valued.[1] If in addition the best-response correspondence is either monotonically decreasing or changes from monotonically increasing to monotonically decreasing only once, it follows that this equilibrium is unique.

In the case that utility functions are twice differentiable, we obtain reaction curves with the slope $\frac{dr_h^s(t_f)}{dt_f} = \frac{\partial^2 U_h / \partial t_h \partial t_f}{\partial^2 U_h / \partial t_h^2}$. The case of positively-sloped reaction curves ($\partial^2 U_i / \partial t_i \partial t_j \geq 0$), is referred to as being strategic complements, with negatively-sloped reaction curves ($\partial^2 U_i / \partial t_i \partial t_j \leq 0$) the tariffs are referred to as being strategic substitutes. Note that tariffs cannot be strategic complements everywhere: A country's optimal reaction yields a positive tariff for tariffs of the other country just below the latter's choke-off level, $\bar{t}$, and since symmetric reasoning shows that a country's optimal reaction yields a negative tariff for tariffs of the other country just beyond the choke-off level, it follows that the home and foreign tariffs are strategic substitutes exactly at the choke-off levels.

3 The Dynamic Multi-Period Model

Following Maskin and Tirole (1987), we set up an alternating move game where country h sets the tariff t_h in period $s = 1, 3, 5, ...$ and country f sets the tariff t_f in period $s = 2, 4, 6, ...$. This implies that when country f moves at $s = 2$, the tariff set at $s = 1$ by country h is exogenously given, and similar for country h at $s = 3$. The infinite horizon dynamic problem for country h is of the form,

$$\max_{t_h \in [0, \bar{t}]} \left(\sum_{s=0}^{\infty} \delta^s U_h[t_h, t_f] \right)$$

In order to establish a steady state for a model which potentially exhibits non-continuities, we only require that around the steady state tariffs either are strategic complements in which case the difference

[1] Moreover, it is trivially true that it is the best response of a country to set its tariff equal to zero when the other country sets its tariff at the prohibitive level, because in that case there is no international trade anyway: there can be no tariffs on imports or exports if there are no imports or exports.

$U(t_h, t_f) - U(t'_h, t_h)$ is nondecreasing in t_f or they are strategic substitutes in which case the difference $U(t_h, t_f) - U(t'_h, t_h)$ is nonincreasing in t_f.[2] Single-crossing property holds around the steady state.[3], [4] Basically, these conditions ensure that the best-response functions are non-decreasing (non-increasing). This ensures existence of an equilibrium point because by Tarski's theorem, any order-preserving map has a fixed point. In the case of strategic complements the condition ensures that the game is supermodular (Topkis, 1979, Milgrom and Roberts, 1990).

For solving the game we use Markov-perfect equilibrium as solution concept.[5] Unlike the history-dependent strategies that support the folk theorems for repeated games, Markov solutions allow no more dependence on past actions than is indicated by the payoff-relevant features of the game. Markov perfect equilibria of oligopoly games have been studied by Maskin and Tirole (1987) and Dana and Montrucchio (1986), both assuming differentiability of the objective functions. The latter show that multiple MPE's are supported depending on the specification of reaction functions. However, all strategy profiles in an MPE converge to some steady state. Furusawa and Kamihigashi (2006) study MPE of a tariff retaliation game in a simplified setting where the myopic best response is independent of the strategic choice of the opponent. We provide the following theorem which makes no assumptions on differentiability and does not restrict dependence of the pay-off functions on the other agent's choices:

Theorem 1: *Assuming tariffs are strategic substitutes (strategic complements) around the steady state and that the single-crossing-property holds locally, the discounted, infinite-horizon, alternating-move tariff game has a stationary equilibrium consisting of a pair of negative-(positive)-monotonic lower (upper) semi-continuous reaction functions, r_h and r_f, mapping $[0, \bar{t}\,]$ into itself.*

For the proof of Theorem 1 and its Corollary see the Appendix. Note that we do not claim that a unique stationary equilibrium exists. The main difficulty which we need to address in the proof is that

[2] Due to a result by Veinott, increasing differences, continuity and supermodularity are preserved under summation and taking the point-wise limit of the sequence, if U fulfills those properties (see Milgrom and Roberts, 1990).

[3] In the case where U is twice differentiable these conditions imply $\partial^2 U_i / \partial t_i \partial t_j \geq (\leq)\, 0$ for complements (substitutes).

[4] These conditions have an ordinal interpretation. For a weakening, see Milgrom and Shannon (1994).

[5] See Fudenberg and Tirole (1991).

even if the underlying objective functions are continuous, reaction functions need not be, due to the possible existence of multiple, separated optima. This can happen to dynamic reaction functions even if the corresponding static reaction functions are continuous. Despite these technical difficulties, it is easily shown that, whatever the initial tariff levels, increasing differences in the case of complements or decreasing differences in the case of substitutes imply that the two countries' tariffs will converge over time to some pair of steady-state tariff levels.

Corollary: *Starting from any initial tariff level tariffs converge monotonically for each country to some pair of steady-state tariffs* (t_h^*, t_f^*) *such that* $t_f^* \in r_f(t_h^*)$ *and* $t_h^* \in r_h(t_f^*)$. *There is always such a pair forming a strict steady state, in the sense that* $t_f^* = r_f^*(t_h^*)$ *and* $t_h^* = r_h(t_f^*)$, *and to which the dynamics locally converge.*

Note that from above reasoning it quickly follows that the retaliation process is order-preserving in the sense that if $t_1^0 \geq \hat{t}_1^0$ then $t_1^s \geq \hat{t}_1^s$ for all time periods *s*. This is regardless of whether the two initial points lead to the same steady state or not. Note that no continuity properties were needed to prove the existence of a steady state.

Plugging the opponent's dynamic reaction functions into the objective function of *h*, the maximization problem at time $s = 0$ assumes the form

$$\max_{t_h} W_h = \sum_{s=0}^{\infty} \delta^s U_h[t_h, r_f(t_h)] \qquad (1).$$

Assuming differentiability at the steady state, [6] the first order conditions for problem (1) require that, given t_h, t_f be chosen such that

$$\frac{\partial}{\partial t_h} U_h[t_h, t_f] + \delta \frac{\partial}{\partial t_h} U_h[r_f(t_h), t_h] + \{\delta \frac{\partial}{\partial t_f} U_f[r_f(t_h), t_h] + \delta^2 \frac{\partial}{\partial t_f} U_h[r_f(t_h), r_h[r_f(t_h)]]\} \frac{dr_f(t_h)}{dt_h} = 0 \qquad (2).$$

If at the steady state, the countries' tariffs are strict strategic substitutes, that is if reaction curves

[6] In the case where *U* is not differentiable at the steady state, we can use Gaussian curvature to determine the slope of the objective function in which case our result generalizes to non-differentiable objective functions.

are strictly monotonically decreasing (i.e. $dr_f(t_h)/dt_h<0$), the indirect intertemporal effect of increasing one's tariff is an indirect strategic gain, since such an increase will cause the other country to lower its tariff in future periods which then redounds to one's benefit (since $\partial U_h/\partial t_f<0$). If, on the other hand, the countries' tariffs are strict strategic complements ($dr_f(t_h)/dt_h>0$), increasing one's tariff results in an intertemporal loss because it expects an increase in the other country's tariff which reduces its own benefit. Only in the case, where the other country does not react does the intertemporal effect of one's tariff choice vanish. From (2) we can derive a relationship between the short run *MRS* and its dynamic counterpart:

Lemma 1: *Let $(t_h^{d^*}, t_f^{d^*})$ be the dynamic steady state. If tariffs are strategic complements in $(t_h^{d^*}, t_f^{d^*})$, the indifference contour of the short-term problem must increase, or $MRS_i^s > 0$. If tariffs are strategic substitutes, $MRS_i^s < 0$.*

Proof: Follows immediately from the observation, that in $(t_h^{d^*}, t_f^{d^*})$ equation (2) must hold for either country, each country's utility is decreasing in its opponent's tariff and $\frac{dr_i}{dt_j}$ > (<) 0 in the case of strategic complements (substitutes). ♦

The intuition behind the lemma is that in a steady state, where a country expects to win from lowering its tariff, there must be an off-setting short-run gain for it to be compatible with equilibrium.

3.1 Static versus Dynamic Equilibrium

An immediate consequence of Lemma 1 is the following proposition.

Proposition 1: *If the preferences of both countries exhibit patience ($\delta > 0$), any symmetric dynamic steady state when tariffs are strict strategic complements (substitutes) must occur in the region below (above) the myopic equilibrium, where both countries charge a lower (higher) tariff. As a consequence,* *both countries will be better off (worse off) in the dynamic steady state than in the static equilibrium.*

Proof: Let MRS^s be the slope of the indifference curve in the static game. Because in the static equilibrium, short term reaction curves intersect, it must be that in the static equilibrium, $(t_h^{s^*},\ t_f^{s^*})$, $\frac{dU_h}{dt_h} = 0$ from the best response property and, hence, $MRS^s=0$.

Suppose that tariffs are strategic complements and short term reaction curves are upward sloping in $t_h^{s^*} = t_f^{s^*}$. We have to show that in a dynamic equilibrium, for $(t_h', t_f') < (t_h^{s^*},\ t_f^{s^*})$, the indifference contour is non-decreasing. To see this, construct in Figure 1 the point $(t_h',\ t_f^0)$ on the home country's static reaction curve $r_h^s(t_f)$ through $(t_h^{s^*},\ t_f^{s^*})$. [7] Because t_h' is a best response to t_f^0, it must be that $U_h(t_h',\ t_f^0) \geq\ U_h(t_h^0, t_f^0\ )$ for some $t_h^0 < t_h'$. Now consider (t_h', t_f') located on the 45^0-line and, hence, vertically above $(t_h',\ t_f^0)$. Say the intersecting indifference contour is decreasing in (t_h', t_f'). In that case the two countries must be indifferent between (t_h^0, t_f'') and (t_h', t_f') , with $t_f'' > t_f'$. Hence, $U((t_h^0, t_f') > U(t_h',\ t_f')$. However, recalling that $U_h(t_h',\ t_f^0) \geq\ U_h(t_h^0, t_f^0\ )$ this implies that the difference $U_h(t_h',\ t_f) - \ U_h(t_h^0,\ t_f)$ is decreasing in t_f, contradicting the condition of non-decreasing differences. Similarly, it can be shown that in the region above $(t_h^{s^*},\ t_f^{s^*})$, the short term indifference contour must be non-increasing at the point of intersection with the 45^0-line.

From Lemma 1, we know that in the case of strategic complements, the short term *MRS* must be positive at an equilibrium point, hence an equilibrium in the case of strategic complements can occur only in the region below $(t_h^{s^*},\ t_f^{s^*})$. It is straightforward to prove that for strategic substitutes any equilibrium point must lie in the region above $(t_h^{s^*},\ t_f^{s^*})$ ♦

From this result, dynamic considerations in a stationary *MPE* in a world where tariffs are strategic

[7] Note that the assumption that the static reaction curve is positively sloped is not necessary for our argument. The reaction curve may also be negatively sloped. If differences are non-decreasing (similar for non-increasing), it can be shown that starting with a point where *h* and *f* employ a greater tariff than their greatest best-response to equilibrium play, then there exists a monotone decreasing sequence converging at the equilibrium point (see Vives, 1990 and Topkis, 1979). Hence, at the steady state the reaction curve cannot be positively sloped with a slope exceeding one.

substitutes always result in higher tariffs than in the static equilibrium. If the world is one of strategic complements, it results in lower tariffs.

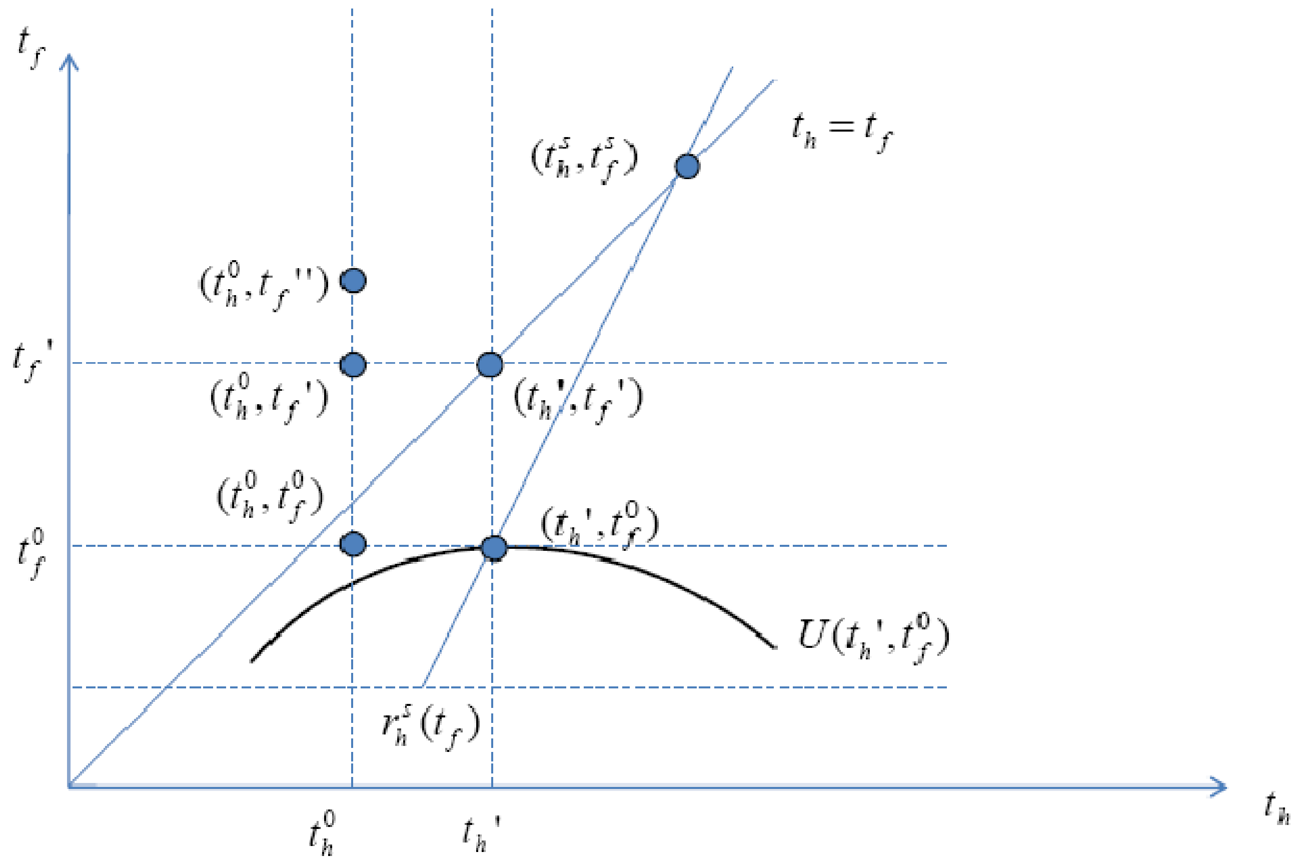

Figure 1: Proof of Proposition 1

Only in the case where intertemporal effects on the opponent's policy choices vanish can playing the myopic equilibrium strategies be a stationary MPE. This confirms results obtained by Furusawa and Kamihigashi who show that in the absence of such intertemporal effects, playing the myopic (Nash) equilibrium strategies always can be supported as a stationary MPE.

It is important to point out that only strategic complementarity (Johnson's "Scitovsky" case) captures ideas often implicit in the terms "tariff retaliation." It is only in this case that one gets the intuitive result that the long-run deleterious consequences of a tariff war induce countries to rein back the competitive impulses that prevail in the short run. This is so since it is only in the case of strategic complements that the individual long-run consequences of aggressive behavior are indeed deleterious, since it is only then that when one raises one's tariff will the other respond with a higher tariff, in the manner implicit in the term "retaliation." In the case of strategic substitutes, on the other hand, the individual long-run incentives are instead to behave aggressively, since the other country will always respond in an accommodating fashion, though of course, in the manner of the prisoner's dilemma, the joint result of this individually rational aggression is liable to be harmful to both countries.

3.2 Degree of Impatience

In this subsection, we consider the properties of the dynamic steady states when the countries exhibit either complete impatience (myopia, where $\delta = 0$), some patience ($0 < \delta < 1$), or complete patience ($\delta = 1$). As δ approaches zero and the countries become myopic, the dynamic problem approaches the static one. The same may be said of their respective first-order conditions.[8] Also, as δ approaches zero, expression (3) indicates that the marginal rates of substitution of the two countries must also approach zero at the steady state if, as required by the stability of the reaction curves, they are not to become perfectly elastic in the limit. This, of course, requires that, as δ approaches zero, the dynamic steady state reduces to the static Cournot equilibrium.

It turns out that complete patience ($\delta = 1$) is a necessary condition for free trade to be supported in the steady state of an MPE. At the state, (t_h^*, t_f^*), we can solve for the reaction curve of either country and obtain the following expression which relates the slope of the reaction curve of a country's opponent to the slope of its own *intermediate* marginal rate of substitution MRS^{IM}. This marginal rate of substitution represents the relative evaluation of tariff increases of h and f based on their consequences in the current and the next period:

[8] It is interesting, however, to observe the differences between the two cases in the expressions used to characterize the slopes of reaction functions. In the dynamic case, the slope of the home-country reaction curve is obtained as a first-order expression in terms of the foreign country's utility, whereas in the static case, it is a second-order expression in terms of the home country's own utility.

$$\frac{d\,r_f(t_h^*)}{d\,t_h} = \left(\frac{-1}{\delta}\right)\frac{\dfrac{\partial U(t_h^*,t_f^*)}{\partial t_h}+\delta\dfrac{\partial U(r_f^*,t_f^*)}{\partial t_h}}{\dfrac{\partial U(t_h^*,t_f^*)}{\partial t_f}+\delta\dfrac{\partial U(r_f^*,t_f^*)}{\partial t_f}} = \frac{1}{\delta}MRS^{IM}(t_h^*,t_f^*) \qquad (3).$$

For $\delta = 1$, expression (3) collapses to

$$\frac{d\,r_h(t_f)}{d\,t_f} = MRS_f^s(t_h^*,t_f^*) \qquad (4)$$

Thus, in an equilibrium, a country chooses its policy such that the slope of its indifference curve is equated to the slope of the other country's dynamic reaction curve $r_i(t_j)$. This is reminiscent of Stackelberg-behavior in a one-period model of oligopoly. The following proposition strengthens a similar result obtained by Furusawa/Kamihigashi (2006, Proposition 5).

Proposition 2: *Free trade can be supported as the steady state of an MPE if and only if both countries are perfectly patient ($\delta = 1$).*

Proof: At a steady state it must be $MRS^{IM} = MRS^s$. In the free-trade equilibrium, the myopic indifference curves U_h and U_f must be tangential to one another because free trade is a Pareto-optimum. Hence, $MRS_h^s = MRS_f^s = 1$.

To show the sufficiency part, suppose that $\delta=1$ and that the free-trade point (t_h^{ft}, t_f^{ft}) not a steady state. If $t_f=0$, h's best response must be to choose $t_h > 0$. Because we know that MPE-strategies converge to some steady state, after some finite length of time they must end up playing arbitrarily close to some steady state (t_h^*, t_f^*) which is Pareto-inferior to (t_h^{ft}, t_f^{ft}). [9] Because with $\delta=1$, any gain from deviating is more than made up to by the long term loss from playing an inferior steady state infinitely often, a deviation reduces both player's pay off. Hence, (t_h^{ft}, t_f^{ft}) must maximize W_h and W_f.

[9] It is immediate that with $\delta > 1/2$ only symmetric Nash equilibria can be supported as a steady state. Suppose that a steady state is asymmetric. In that case, the player with the lower pay off must benefit by choosing the strategy of the player with the higher pay off for whom it would be a best response to mimic the player with the lower pay off. Any short term loss from this change in strategy would be made up by the long run gain.

To see that $\delta = 1$ is also necessary to support free-trade as a steady state, note that from the best response property of $r_i(t_j)$ it must be that $MRS_h^d = MRS_f^d \leq 0$. Because $MRS_h^s = MRS_f^s = 1$, (2) implies that the free-trade equilibrium can only be supported if $\frac{d\, r_f}{d\, t_h} \geq 1$. Hence, the reaction function must be increasing at the steady state. By the stability condition, we can rule out $\frac{d\, r_f}{d\, t_h} > 1$. So suppose $\frac{d\, r_f}{d\, t_h} = 1$. Inserting $\delta < 1$ and $MRS^{IM}=1$ in the steady state condition (3) immediately results in a contradiction. ♦

In addition, we can rule out autarky as an outcome for $\delta > 0$. By Proposition 1, it is sufficient to focus on the case where tariffs are strategic substitutes. Suppose one country's steady-state tariff is less than $\bar{t}$. In that case, the other country would want to select a tariff below $\bar{t}$. So suppose that both levy $\bar{t}$. This can only be supported by perfectly inelastic reaction curves: otherwise the country that moves next will again depart toward trade. However, such reaction curves are not subgame perfect, because once a country deviated to a non-blocking tariff, it would be preferable for the other country to permit trade, rather than remain in autarky forever, resulting in higher pay offs for both. Hence we can conclude that

Proposition 3: *The dynamic steady state in a tariff war can never degenerate into autarky for non-myopic countries (with $\delta > 0$).*

4. Quota Retaliation

In this section we consider a dynamic game where the two countries impose quotas instead of tariffs. Indeed, Rodriguez (1974) and Tower (1975) have used the same neoclassical two-country, two-commodity international trade model to examine myopic quota games, rather than Johnson's (1953-54) myopic tariff game. They have shown that it makes little difference what combination of import or export quotas the countries employ: the equilibrium outcome is always that trade vanishes asymptotically. We therefore explicitly consider only the case of export quotas, which provides perhaps the cleanest analysis.

The case of quotas can be analyzed in analogy to the case of tariffs. For the analysis of this case we replace (t_h, t_f) with (q_h, q_f) and it is understood that a quota of 1 corresponds to free trade and a quota of 0 corresponds to autarky.

For simplicity, we consider the traditional case of well-behaved offer curves that are positively sloped and convex in the relevant range. In addition, we assume that a single-crossing property holds, i.e. that the game is supermodular. Note that despite this assumed regularity over consumption bundles, the binding nature of quotas implies that the induced preferences over quotas will not be quite so regular. In particular, there will be a non-smooth division into regions according to which quotas bind. So while static reaction curves exist, they are not described by any first-order condition in terms of quota-induced preferences, but instead, along their relevant portion, are made up of the offer curves themselves, which serve to divide the various quota regions. This follows since while the home country's utility in quotas rises in its own quota up to the point where the other country's quota binds, it falls thereafter. The kink on the foreign country's quota-ridden offer curve is where this transition occurs, and so the foreign offer curve traces out the family of kinked optima that makes up the home country's reaction curve. Given that these offer curves are positively sloped up to the static optimal-tariff outcome, we have an unambiguous case of static strategic complements. The only relevant intersection of the offer curves occurs at autarky, which is then the stable steady state of this myopic quota game.

For analyzing the dynamic game, we can restrict our attention to the case where quotas are strategic complements. This case corresponds to the earlier trade war scenario where countries reciprocate an opening of the market of the other country by increasing their own quota. Note that in equation (2), increasing one’s quota now results in an intertemporal benefit if the other country’s reaction curve is positively sloped and it uses its quota to reciprocate. Hence, the short term $MRS_i^s < 0$ in (q_h, q_f)-space. Thus, the steady state quotas satisfying (2) must be found in the area above the static equilibrium values $(q_h^{s^*},\ q_f^{s^*})$. Hence, in the case of strategic complementarities, dynamic considerations take us nearer to free trade, i.e. countries choose quotas which are greater than in the static equilibrium. All this is depicted in Figure 2.

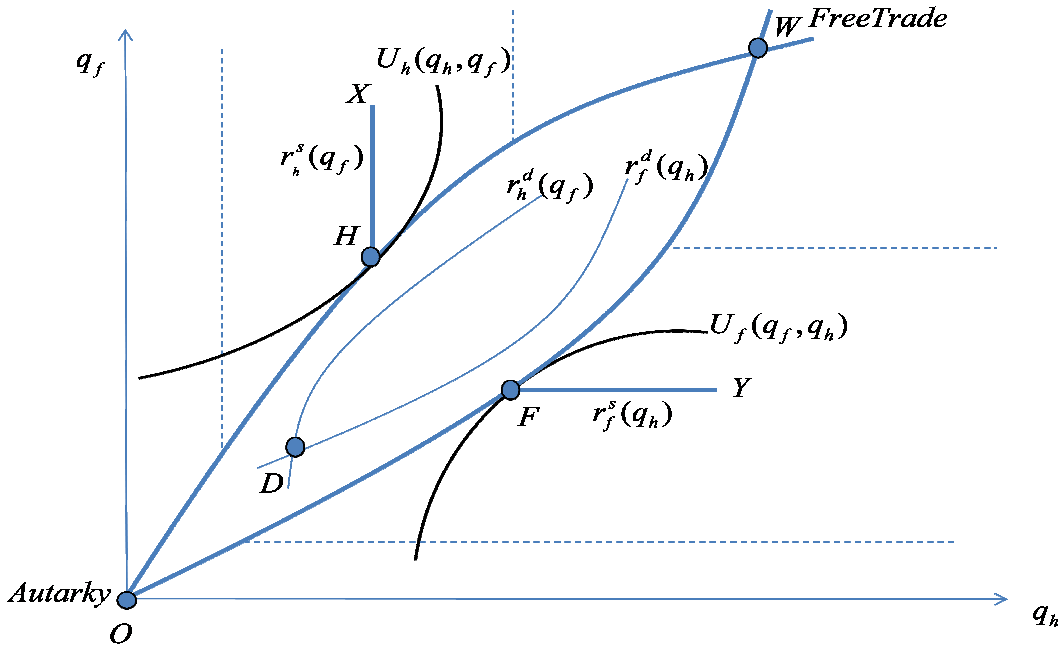

Figure 2: Dynamic Quota Retaliation

In Figure 2, autarkic equilibrium, with zero import quotas by both countries, is *O*, which is also the static Cournot equilibrium, and the one identified by Rodriguez (1974) and Tower (1975) as the one asymptotically approached in a myopic quota retaliation game. *W* is the free trade equilibrium, and, for countries that have a positive degree of patience, meaning that $\delta > 0$, *D* is the dynamic steady state of a quota retaliation game, at which the dynamic reaction curves $r_h^d(q_f)$ and $r_f^d(q_h)$ intersect. The curve *OHX*, or $r_h^s(q_f)$, is the home country's static reaction curve, and *H* is its optimal quota in the absence of any retaliation by the foreign country, with U_h tangent to the foreign offer curve *OHW* at *H*. Similarly, *OFY*, or $r_f^s(q_h)$, is the foreign country's static reaction curve, and *F* is its optimal quota in the absence of any retaliation by the home country, with U_f tangent to the foreign offer curve *OFW* at *F*.

With the help of Figure 2, it is more apparent that we have:

Proposition 4: *If preferences of both countries exhibit patience (δ>0), the dynamic steady state of the relevant super-modular game must occur in the region above the myopic equilibrium where both countries allow greater quotas than in the static equilibrium.*

The following two propositions directly correspond to Propositions 2 and 3:

Proposition 5: *In a quota-retaliation policy game, free trade can only be supported in a stable steady state of an MPE if both countries exhibit complete patience (with δ = 1).*

However,

Proposition 6*: For countries that exhibit any positive degree of patience (δ>0), autarky cannot be a dynamic steady state of a quota-retaliation policy game, except in the extreme case of complete myopia (δ=0).*

Proposition 6 yields a rather striking result: whilst in the static game, autarky is asymptotically obtained, the outcome of autarky can never arise as the steady state in a game in which dynamic considerations play a substantive role.

4. Conclusions

In this paper we seek to extend the neoclassical general equilibrium theory of tariff and quota retaliation beyond the work of Johnson, Rodriguez, and Tower. Their results pertain to either a static world or to a dynamic but completely myopic one. We introduce dynamics for non-myopic countries, and thus investigate the consequences of long-run strategic considerations in an internally consistent framework with fully rational countries. Our results pertain to the general equilibrium framework of traditional trade theory, where the full effects of policies are taken into account (see Neary (1988)). Like Johnson, Rodriguez and Tower, we assume that each economy is internally characterized by flawless perfect competition.[10] In this framework, we investigate the pure-strategy Markov perfect equilibria of an

[10] Instead of endowments of the two commodities in both countries, we could assume that each country's production structure is characterized by its respective GDP function, $g^i(p^i(1+t_i), v^i), i = h, f$, that is defined for a non-empty, compact and

alternating-move discounted infinite-horizon game, in the manner of Maskin and Tirole (1987, 1988a, 1988b). However, we avoid specific parametric forms, and instead, follow the abstract traditions of neoclassical trade theory. Thus, rather than obtaining explicit solutions to particular parametrizations, we focus on qualitative properties of long-run, observable steady-state behavior, applicable to a large class of situations. We are thus able to compare the dynamic steady-state outcomes to the static steady-state outcomes of the Johnson-Rodriguez-Tower theories of tariff and quota retaliation, thereby going considerably beyond this literature, using general utility functions instead of specific parametric forms, and, *inter alia*, succeed in ascertaining the effects of strategic considerations in such contexts.

We find that Johnson's results for tariff wars require modification, the direction of which depends on whether tariffs act as strategic complements or substitutes. We observe that the orthodox case is that of strategic substitutes, but that the intuition suggested by the notion of tariff retaliation more closely corresponds to the case of strategic complements. It is only when reaction curves are upward sloping (strategic complementarity) that an opponent raises his tariff in response to an increase in one's tariff, as suggested by the term retaliation, and it is only in this case that long-run strategic considerations lessen short-run aggression. When rather than strategic complementarity, we have strategic substitutability, then the long-run incentives are instead to become more aggressive than in the short run, since the other country will be accommodating, given that it has a downward-sloping reaction curve. In the dynamic game, the result of the countries' combined aggression harms both countries in the manner of the prisoner's dilemma.

The cooperation resulting from strategically complementary tariffs or quotas is quite consistent with the taxonomy introduced by Fudenberg and Tirole (1984). Just as with the Scitovsky case of strategic complementarity in tariffs, dynamic considerations regarding quotas promote greater cooperation than in the myopic world, and thus yield greater welfare for both countries. In the quota case, however,

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convex production set and constant returns to scale technology in the production of both commodities, where p^i is the relative price of a country's imported good, v^i is its factor endowment vector, and perfect competition prevails in both commodity and factor markets, and then the entire argument formulated here still holds.

this cooperation occurs through higher levels of action variables, rather than through lower ones, as occurs with tariffs. This is due entirely to the fact that whereas higher tariffs of one country are bad from the point of view of the other, higher quotas of one country are, instead, good for the other. In Fudenberg and Tirole's (1984) terminology, one has the "soft, strategic complement case", which calls for a "fat cat" strategy, where both countries drive up their choice variables (quotas) in order to deter competition.

Whilst our results only modify Johnson's static steady-state predictions, the non-equivalence result of Rodriguez and Tower's is overturned completely once dynamic considerations are taken into account. Whilst in their static quota-retaliation game the autarky is asymptotically obtained, autarky cannot be supported in the steady state of an MPE in the regular case where the two countries' quotas are characterized by strategic complementarity. Moreover, the non-equivalence of the outcomes between retaliation by tariffs or by quotas is predicated on complete myopia. We reach the conclusion that the effect of introducing dynamics crucially depends on whether the policy instruments employed by the countries are strategic substitutes or complements irrespective of whether they are tariffs or quotas.

Our canonical formulation of the issue – outcomes of retaliation by tariffs or by quotas – as non-myopic dynamic games in Markov perfect strategies leads in the direction of equivalence, rather than non-equivalence, especially when the countries exhibit greater patience. In addition, if countries exhibit complete patience, we obtain an equivalence result in the sense that free trade can be supported irrespective of whether tariffs or quotas are the policy instruments used by the countries.

Much remains to be learned about international trade relations and the use of instruments of foreign trade policy. Voluntary export restraints, VERs, have gained prominence over time, and it would be good to know what a dynamic VER-retaliation game produces as the steady sate outcomes. For, arising from the quantity-constraint, the VER rents are lost by the country that receives a smaller amount of imports than under free trade. Another useful line of investigation would be to consider dynamic retaliation in a world of both international trade in commodities and in factors; Neary (1993) has done this for a world in which "the home country is relatively free to choose the values of trade and international capital restrictions, whereas the foreign country responds passively without any retaliation" (p. 132). Retaliation with factor taxes and subsidies, especially on the internationally non-traded factors, if there are commodity import restrictions and other factors are internationally mobile would appear to be a promising line to pursue. If taste differences across countries are also deemed a matter of significance, the investigation needs to be of asymmetric countries rather than the symmetric ones examined here. Much work still remains to be done.

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APPENDIX

Theorem 1: *Assuming tariffs are strategic substitutes (strategic complements) around the steady state and that the single-crossing-property holds locally, the discounted, infinite-horizon, alternating-move tariff game has a stationary equilibrium consisting of a pair of negative-(positive)-monotonic lower (upper) semi-continuous reaction functions,* r_h *and* r_f*, mapping* $[0,\bar{t}\,]$ *into itself.*

Proof:[11] The space of lower semi-continuous negative-monotonic functions is a compact metric space in the topology of weak convergence (Helly's theorem, e.g. in Parthasarathy (1967)), and hence complete. This constitutes the space of candidate dynamic reaction functions. Consider the problem

$$\max_{t^s \in [0,\bar{t}\,]} \left(\sum_{s=1}^{\infty} \delta^{2s} \hat{U}_h [\, t^{s-1}, t^s \,] \right)$$

where

$$\hat{U}_h \left[t^{s-1}, t^s \right] \equiv U_h \left[t^s, \phi_f(t^{s-1}) \right] + \delta U_h \left[t^s, \phi_f(t^s) \right] .$$

Recall that countries move sequentially, each one at a time. Continuity of U_h and the assumed lower semi-continuity or ϕ_f assures $\hat{U}_h$ is upper semi-continuous, given that U_h is negative-monotonic in its second argument. One may therefore consider the contraction mapping

$$(Tf)(y) = \max_t \left(\hat{U}_h [y,t] + \delta f(t) \right) ,$$

where $M(y) \equiv (Tf)(y)$ is upper semi-continuous, given that $\hat{U}_h + \delta f$ is itself upper semi- continuous for any upper semi-continuous real-valued function f (see Ausubel and Deneckere (1993) for the appropriate generalization of Berge's maximum theorem). Thus, in the manner of Blackwell's theorem (see Stokey and Lucas (1989)), T maps from the complete metric space of upper semi-continuous functions into itself, and is a contraction with a unique fixed point, the valuation function

$$V_h(y) = \max_t \left(\hat{U}_h [y,t] + \delta V_h(t) \right).$$

The reaction functions are

$$\hat{\Phi}_h(y) \equiv \underset{t}{argmax} \left(\hat{U}_h [y,t] + \delta V_h(t) \right)$$

Say, strategic substitutability holds. Then $\hat{\Phi}_h(y)$ is a negative-monotonic correspondence, in the sense that $t \in \hat{\Phi}_h(y)$ and $y' \geq y$ implies $t' \leq t$ for all $t' \in \hat{\Phi}_h(y')$, and since $\hat{\Phi}_h(y)$ is upper hemi-continuous by the generalized Berge maximum theorem, it then follows that $\hat{\phi}_h(y) \equiv \min \{ \hat{\Phi}_h(y) \}$ is a negative-monotonic, lower semi-continuous function, that is, one with at most a countable number of

[11] Since, as remarked, similar proofs have appeared in the literature for related problems, we merely indicate the essential parts of the argument.

discontinuities and continuity from the right.

The above procedure may be considered as a map F_h taking a candidate reaction function ϕ_f of the foreign country and yielding a candidate $\hat{\phi}_h = F_h(\phi_f)$ for the home country, where the map F_h is seen to act continuously. Repeating the procedure for the other country, form the map $\Psi : (\phi_h, \phi_f) \rightarrow (F_h(\phi_f), F_f(\phi_h))$. Since the space of lower semi-continuous negative-monotonic functions is compact and convex, and Ψ maps this set continuously into itself, one may then apply Schauder's fixed point theorem (see Smart (1974)) to assure the existence of equilibrium reaction functions, r_h and r_f, where $r_h = F_h(r_f)$ and $r_f = F_f(r_h)$.[12]

Now consider the case where instruments are strategic complements in the myopic formulation of the model. If the single-crossing property holds, the game is supermodular (see Milgrom and Shannon, 1994). If the static utility function *U* satisfies supermodularity, the dynamic objective function W also does (Milgrom and Roberts, 1990, Theorem 11). For a supermodular game there exists a largest and smallest serially undominated strategies which are pure Nash (Milgrom and Roberts, 1990, Theorem 5) and $\hat{\Phi}_h(y)$ is a monotone non-decreasing correspondence (Milgrom and Roberts, 1990, Theorem 4), which follows from Topki's montonicity theorem.

Corollary: *Starting from any initial tariff level of, say, the home country, tariffs converge monotonically for each country to some pair of steady-state tariffs* (t_h^*, t_f^*) *such that* $t_f^* \in r_f(t_h^*)$ *and* $t_h^* \in r_h(t_f^*)$. *There is always such a pair forming a strict steady state, in the sense that* $t_f^* = r_f^*(t_h^*)$ *and* $t_h^* = r_h(t_f^*)$, *and to which the dynamics locally converge.*

Proof: As observed by Dana and Montrucchio (1986, discussion of Theorem 3.1), the map $r_h \circ r_f$ is non-decreasing in both cases and so the dynamics converge to a limit t_h^*, which then must be a fixed point of the composite map in the sense that $t_h^* \in r_h(t_f^*)$ for some t_f^* such that $t_f^* \in r_f(t_h^*)$. The existence of a stable strict steady state follows from Tarski's theorem (see the discussion in Fudenberg and Tirole (1991)).

[12] In the above theorem we selected the lowermost value at each of the countable number of possible discontinuities of the resulting reaction function, in order that it indeed be a single-valued function, but for the purposes of the following argument we observe that the upper value of a discontinuity may be included as an equally valid reaction, since the underlying reaction correspondence $\hat{\Phi}$ is in fact upper hemi-continuous.